DYNAMIC RELATIONSHIPS BETWEEN SECTORAL ELECTRICITY CONSUMPTION, ECONOMIC GROWTH AND ELECTRICITY PRICES IN

SOUTH AFRICA

By

Sunday L Ezesele

Student No. 200710108

A Dissertation Submitted to the Faculty of Commerce, Administration and Law in Fulfilment of the Requirements for the Master of Commerce (Economics) Degree.

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Supervisor: Prof I. Kaseeram Co-Supervisor: Prof .T. Contogiannis

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Thanks to the National Research Foundation for the financial assistance towards this research. Opinions expressed and conclusions drawn at, are those of the researcher.

DECLARATION

I declare that this dissertation and the work presented in it are my own and that it has been generated by me as the result of my own original research work under the supervisory guidance received and I can confirm that I have used only the resources mentioned in the references. I further certify that the dissertation is original, and has not been submitted before at this or any other university for the award of any degree at any other university purpose of obtaining a degree.

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Sunday L Ezesele Date: 16 January 2017

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ABSTRACT

The purpose of this paper is to explore the dynamic relationship between the sectoral outputs, electricity supply and electricity price in South Africa within the endogenous growth model framework. Over the past two decades or more the relationship between economic growth and electricity consumption has received much attention due to its various policy implications. However, none of the studies considered the relationship between electricity consumption and sectoral output growth, additionally no study to the best of our knowledge considered the impact of electricity prices on sectoral (or on aggregate economic) growth. In the light of this, the current study uses multiple equation VAR and Johansen (1991) methodologies to assess the long run cointegrating and short run adjustment relationships between sectoral outputs, electricity consumption, and electricity price in South Africa for the period January 1991- March 2015 using monthly data.

According to VECM results in the long run electricity supply affect the retail sector, while in the case of mining and wholesale sectors, growth in these sector puts upward pressure on electricity supply. In the long run manufacturing sector is not affected by and does not affect electricity supply. In the short run there were some unidirectional causalities, however, the crucial finding is that an abundance of electricity supply will enhance most of the sector under study.

In the long run electricity price does not affect the manufacturing, wholesale and retail sectors, it only affects the mining sector. This implies that the manufacturing, retail and wholesale sectors can absorb the price increases in the long run but the mining sector is adversely affected by such price increases. In the short run the VECM results suggest that price adversely affects the mining and wholesale sectors. While the manufacturing and retail sectoral growths tend to affect price. However, the VAR results suggest that there is a bidirectional causality between electricity price and the manufacturing and mining sector in the short run. Moreover, there is no causality between electricity price and the retail and wholesale sectors respectively. Hence in summary evidence of causality running from price to growth, at least in some sectors over the short run , for example, in a labour intensive sector like mining and in the

somewhat labour intensive wholesale and manufacturing sectors, hence electricity supply ought to be expanded in the economy to keep price down.

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LMAN	-	Log Manufacturing output
LMIN	-	Log Mining output
LWHOL	-	Log Wholesale Trade
LRET	-	Log Retail Sales
LES	-	Log Electricity Supply
LWEP	-	Log Weighted Electricity price
ADF	-	Augmented Dickey- Fuller
SIC	-	Schwarz Information Criterion
EG	-	Engle-Granger
AR	-	Autoregressive
ARDL	-	Autoregressive Distributed Lag
VAR	-	Vector Autoregressive
VECM	-	Vector Error Correction Model
DF	-	Dickey-Fuller
OLS	-	Ordinary Least Squares
AEG	-	Augmented Engle -Granger
ECM	-	Error Correction Model (Mechanism)
AIC	-	Akaike Information Criterion
SBC	-	Schwarz Bayesian Criterion
RSS_r	-	Restricted Residual Sum of Squares
RSS_{ur}	-	Unrestricted Residual Sum of Squares
SARB	-	South African Reserve Bank
SR	-	Short Run
STATS SA	-	Statistics South Africa

TFP - Total Factor Productivity

ANC - African National Congress

LR - Long Run

R&D - Research and Development

NERSA - National Energy Regulatory of South Africa

DSGE - Dynamic Stochastic General Equilibrium (models)

GDP - Gross Domestic Product

OECD - Organisation for Economic Co-operation and Developmen

TOU - Time of Use

SMEs - Small and Medium Enterprises

FMOLS - Fully Modified Ordinary Least Squares

ADF - Augmented Dickey-Fuller

PP - Phillips-Perron

CHAPTER ONE

OVERVIEW OF THE STUDY

1.0 Introduction

Over the past two decades the relationship between economic growth and electricity consumption has received much attention especially from researchers and economists due to its various policy implications The thrust of this debate is largely based on which of the two variables are independent (dependent) on one another e.g. whether electricity consumption causes economic growth or vice versa. However, numerous empirical studies have analysed the causal relationship between electricity consumption and economic growth. But unfortunately, they present inconsistent or conflicting results across countries including the methodologies used within the same countries. This work will use Vector Auto regression (VAR) and the Johansen (1991) Vector Error Corrections methodology to examine the relationship between economic growth, electricity output and electricity prices as they are regarded as cutting-hedge approaches to estimating dynamic relationships between the variables within a system.

This study will employ endogenous growth theory developed by Romer (1986) where technology and electricity supply for example could be included into a traditional Solow (1956) growth model comprising solely of capital and labour and where technology is treated as a constant.

The pioneering Kraft and Kraft (1978) study, examined the causal relationship between electricity consumption and economic growth in the United States. They found strong uni-directional causality runs from economic growth to electricity consumption. The interest raised by this finding motivated and led to a large number of further empirical studies across different countries to confirm the finding (Abosedra *et al.*, (2009); Apergis and Payne, (2010); Li *et al.*, 2008). The correlation between these two variables is necessary for deriving policies that encourage economic growth.

The literature provides four possible relationships between energy (electricity) consumption and economic growth: firstly the Growth Hypothesis suggests that there is a uni-directional causal relationship running from energy consumption to economic growth e.g. a nation that depends entirely on electricity consumption for its economic prosperity; energy conservation policies could have a serious negative effect on their growth. On the other hand if the causality finding supports the Conservation Hypothesis which states that a uni-directional causality runs from economic growth to electricity consumption, then policy initiatives to conserve energy can be implemented without any or little adverse effect on economic growth. The Feedback Hypothesis which suggests a bi-directional causality between energy consumption and economic growth implies that a high level of economic growth leads to high level of energy demand and vice versa, in other words, they are interdependent (interrelated) and maybe best described as as complementing each another (Apergis and Payne, 2009). Lastly, the Neutrality Hypothesis posits no causality between energy consumption and economic growth meaning that policy initiatives aim to conserve energy but do not affect economic growth, (Asafu-Adjaye, 2000; Paul and Bhattacharya, 2004).

Generally electricity has been characterised as one of the strong pillars that drive economic growth and also the most important infrastructural input that stimulates all economic activities. The increasing concern in this specific area has been heavily motivated by the increasing demand for energy globally. World Economies today are heavily dependent on energy and South Africa no exception. Alam (2006) stated that “energy is the indispensable force that derives all economic activities.” In addition, the increasing consumption of electricity presents a positive sign of economic prosperity of the nation. In other words, electricity demand is associated with the growth rate of GDP (IEA, 2006).

The role of electricity has been recognised as the tool that drives the increasing standard of living of the developed nations and it has contributed the technological innovations and scientific improvement of these nations. However, it has also been shown that there is a positive relationship between electricity consumption and health improvement as well as educational standard of the poor (Kanagawa, and Nakata, (2008). In the light of above important background attention need to be paid to the relationship between energy consumption and economic growth. This present study aims to examine the causality links between economic growth and energy (electricity) consumption in South Africa over the 1984 to 2012 period. This period was chosen due to the non-availability of data prior to 1984. However since electricity prices have been a major concern to households and business in recent times this study will also extend the analysis to includes energy prices as well.

1.1 Background of the research

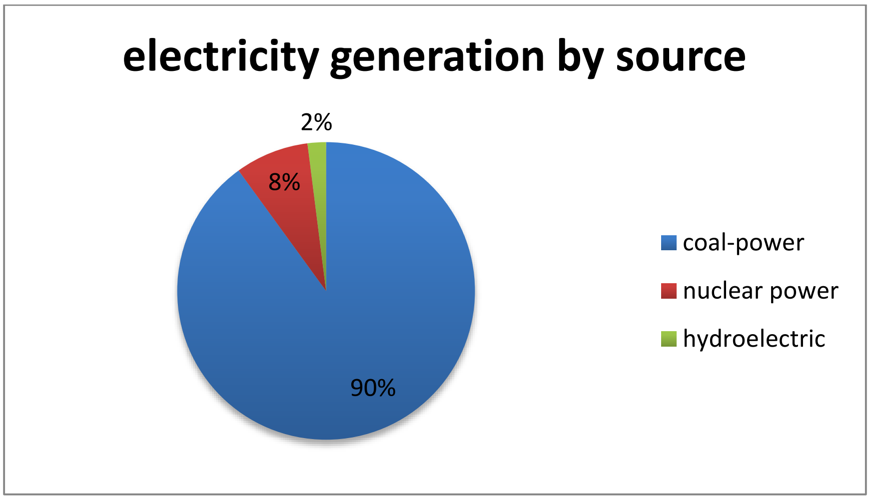
Electricity generation in South Africa was primarily aimed at supporting the turn-of-the century mining industry, as most mining operations used electrical generators up until 1909, when the Victoria-Falls power company was established and started to supply power to those mining industries. In 1923 the electricity parastatal Eskom was formed and started to supply electricity both to non-mining industries and railroad. In 1948, Eskom bought out the Victoria Falls power company and has been the major power producer in South Africa since then. After WWII, Eskom sales dramatically increased faster than the national GDP growth resulting in an expansion of Eskom's utility. From 1950 to 1982 Eskom constantly experienced average sales growth of 8 percent per annum. Despite this good record of Eskom's sales an estimated R27 billion was spent between 1983 and 1987 as government capital investment.

In 1985 Eskom was one of the enterprises that were seriously affected by foreign loans and some of its new projects were left uncompleted, while there were delays in completing others, which discouraged plans for further expansion.

Estache *et al.,* (2008) noted that Eskom supplied 95 percent of South Africa's electricity needs and 45 percent of other African countries' consumption requirements. With approximately 40000 MW generating capacity only a few mining industries and households provide power generator of their own in South Africa. Eskom directly provides electricity to 45 percent of the total end user and 55 percent is resold by redistributors, e.g., municipalities.

The overall energy sector in South Africa contributes more than 15 percent of GDP, and also employs about 250000 people. Eskom derives roughly 90 percent of total electricity from coal-fired power stations, 8 percent from a nuclear power plant and 2 percent from hydroelectric sources.

Figure 1



Source: Own calculations based on figures from statistics SA

However the country recently experienced a shortage in its reserve margins which led to a series of power outages in early 2008. Load shedding was used as the last resort solution in order to avoid nationwide blackouts. However, this intervention strategy by Eskom made it possible to bring the electricity demand a little closer to its supply.

Moreover, Eskom's (2007) power crisis review noted that numerous reasons could be stated as being responsible for the recent 2008 electricity crisis in South Africa, including: the White Paper on the energy policy of South Africa and instructions by government to stop building new Power stations; economic growth and increasing demand for electricity; skill shortages; poor systematic planning and lack of essential spare parts for maintenance of the power stations; significant decrease in reserve margins; Eskom's BEE policy was also part of the problem as some of the stations were facing shortage of stock.

With all these reasons mentioned above the position of public electricity supply in South Africa has been relatively unreliable (as seen in the high frequency of load-shedding since 2006 although it has ceased in recent times) and inefficient, resulting in a number of households and manufacturing industries turning to alternative sources including private generating power systems for their daily operations which has resulted in a rapid yearly rise in electricity prices since 2008 Moreover, many economists have asserted that supply constraints and high electricity prices are a major cause for concern for they form a structural constraint on economic growth.

A number of studies have estimated the relationship between electricity supply and aggregate economic growth in South Africa, (see, Inglesi, 2010, Amusa *et al*, 2009 and Ziramba 2008).

However none of these studies considered the impact of electricity supply constraints on sectoral growth, nor have any of them focused on the impact of electricity prices on economic growth, let alone sectoral growth. These relationships are important to assess in order to identify vulnerable subsectors within the economy so that appropriate interventions can be made, especially in respect of averting potential losses within labour intensive industries.

1.2 Statement of the problem

Electricity production is one of the major challenges facing South Africa in recent years given the fact that total electricity supply capacity since 2001 has remained constant at around 37,000 MW with an additional reserve margin of 2000MW for peak demand periods. In 2005 and 2006 demand started to exceed supply. The crisis officially began in November 2005 when many regional power outages started affecting the country’s Western Cape Province and gradually worsened during February 2006 to the extent that it required an urgent debate in the South African parliament in March 2006 (Le Roux, 2006).

This crisis eventually spread to the entire country in 2007 and heavily affected most industrialised regions and resulted in the temporary closure of the country’s major mining and industrial sectors for a few days. Previously, the electricity price in South Africa was among the lowest. However, the constant increase in electricity tariffs in recent years has positioned South African electricity prices as among the highest in the world. This raises the concern of affordability by the country’s poor households. Moreover, given the government’s commitment to make electricity available to all of its citizens, which resulted in approximately 3 million poor households being connected to the national electricity grid and their receiving up to 50 kw free basic electricity consumption in some areas during peak periods (NERSA, 2001). Given that electricity generating capacity remains unchanged and the demand for it has increase substantially. These high electricity prices pose pressing challenges to an economy that is heavily energy dependent with e.g. Small, Medium and Micro-enterprises who largely depend on electricity consumption for their daily operations cannot compete internationally. As noted above no South African study exists on the sectoral impact of electricity supply constraints and the resulting price rises.

1.3 Aims of the Study

This study will focus on investigating the impact of electricity supply and its price increases on output growth in the mining, manufacturing and service (in the form of retail and wholesale) sectors using monthly data from June 1991 to March 2015.

1.3 Research objectives

The Primary objectives of this study are as follows:

1. To find whether long run cointegrating relationships exist between electricity consumption and sub-sectoral economic growth in South Africa.
2. To estimate the impact of electricity price increases on the major economic sub-sectors of South Africa.
3. To assess the short run adjustment processes to the long run cointegrating relationship, if any.
4. To examine the nature of the Granger causality relationship between electricity consumption and sectoral economic growth.

1.5 Hypotheses to be tested

1. A long run cointegrating relationship between electricity supply, electricity prices and sectoral economic growth does indeed exist.

2. There is a significant long run impact of electricity supply constraints on sectoral economic growth.
3. There are significant short run adjustment relationships between the variables in the cointegrating relationship.
4. There is bidirectional Granger causality (Feedback Hypothesis) between electricity demand and sectoral economic growth.
5. The Neutrality Hypothesis does not govern energy consumption and sectoral output
6. The Growth Hypothesis explains the direction of causality from electricity consumption to sectoral economic growth
7. The Conservation Hypothesis (unidirectional causality) does that runs from sectoral growth GDP to electricity consumption,

1.6 Motivation of the study

The objective of any Government is to achieve sustainable economic growth and electricity consumption on which is the “indispensable force that drives all economic activities” Alam (2006). However, addressing the challenges facing South Africa’s electricity supply is critical given the fact that the economy has over the past years remained more or less constant with an average growth rate of 2.5 percent below the GEAR strategy estimated target of 4.2 percent per annum. In order to provide adequate electricity infrastructure for the purposes of meeting our growth needs, it is critical to understand the relationship between electricity consumption, electricity prices and economic growth at the sub-sectoral level because policy interventions can avert crises in the form of firm closures especially in labour intensive (mining) and strategic (manufacturing) sectors.

The other main concern is to investigate the nature of the Granger causality relationship between electricity consumption and sectoral economic growth. From the recent experience it is evident that South Africa is primarily an energy dependent nation and that any obstruction in this sector could seriously hinder economic progress.

The massive investment by the Apartheid government in the 1960s and 1970s in coal-fired power plants provided the national utility with large excess capacity in the

1980s and 1990s that helped to keep electricity prices down; unfortunately this excess capacity is now almost exhausted (Eskom 2000). The mining and manufacturing industries are the key sectors of the South African economy that dominate the export market. However, the activities of these sectors are highly energy-intensive and depend mostly on low- cost electricity, so excessive price increases can adversely affect these sectors. Moreover, in recent years the services, tourism and financial sectors, have made major contributions to GDP and an understanding of their energy requirements and how they adjust in the face of electricity shortages is critical in formulating policy.

1.7 Significance of the study

The study is important and unique in many ways. Firstly, it attempts to examine the relationship between electricity consumption, electricity price and economic growth as the primary goal. Secondly, it will also consider how the various sectors were affected by electricity constraints, especially in terms of price impacts and electricity supply constraints on sectoral output. The findings of this study will benefit policy makers especially with regard to assessing potential losses in output and employment to the mentioned subsectors in the economy due to under provision of electricity infrastructure.

1.8 Organisation of the study

The dissertation is made up of six chapters. This chapter has provided an overview of the whole research project. Chapter two gives relevant theories used to exploring determinants of economic growth and the role played by electricity. The theory in chapter two also aims to identify and shed light on conceptual literature behind the relationship between electricity use, its prices and economic (sectoral) growth and to give a historic overview of electricity and its uses in South Africa. Chapter three deals with empirical considerations regarding the impact of electricity consumption on economic growth. All pertinent existing empirical studies in South Africa and other international- related studies are reviewed in an attempt to obtain general findings on this topic and to make a substantial contributions by filling the gaps that this study may reveal.

Chapter four addresses the relevant statistical estimation ideas and methods and the econometric specification of the models to be estimated in the subsequent chapter. The chapter is divided into two sections that discuss the time series statistical estimation techniques and model specification. In the first section, the concepts of stationarity, cointegration and their designated tests are estimated; thereafter the VECM modelling approach and functionalities will be tested. The second section discusses the theoretical model to be estimated and a description of the variables selected for the study's econometric model. Chapter five lays out the empirical findings, provides interpretations of the results, and describes the various stages of the estimation procedure. The analysis starts with a preminary examination to determine the basic properties of the data used for econometric analysis and to provide a clear understanding to the researcher of the appropriate estimation method to be used. The study utilises the VECM frameworks to examine the long run interaction of growth model using monthly data. Chapter six gives the conclusions and summary of the empirical findings of the study and also provides policy recommendations as well as the study's limitations.

CHAPTER TWO

THEORETICAL FRAMEWORK

2.0 Introduction

The purpose of this chapter is to present the theories and the existing body of knowledge that is relevant to this study and assemble it all together at the end. In addition, various appropriate models will be used to determine the relationship between electricity consumption and economic growth.

Ever since the oil crisis of the 1970s, energy has been considered as an important part of the production factor and more generally the role of energy in economic production. In exogenous growth models, human capital, innovations, or knowledge was not included as parts of growth models as the endogenous model explained the growth process, and all economic growth that cannot be empirically explained by production factors such as capital (k) labour (L) land (n) and energy (e) is attributed to technological production (A). The Solow and Swan Growth model which was developed from the Harrod-Domar model of production growth and is based on the notion of economic growth rate in terms of the level of saving and productivity of capital. But later on, this new model took into consideration ‘productivity growth’ as a vital tool in a country’s economic growth, and where new capital is valued on the basis of technological improvement over a period of time. The concept of my model development and research analysis is derived from the Theory of Production and Growth based on neoclassical economists as well as on the views of ecological economists’ model and from other researchers who have worked on Economic Growth as a function of Energy Consumption. But in this research work I have reversed the relationship and consider Electricity Consumption instead of Energy Consumption.

2.1 Economic Growth

Based on the existing literature’s definition, economic growth is the rise in per capita gross domestic product (GDP). It can be described as the rate of change in the real

GDP of a nation. Economic growth refers to the quantity of goods and services produced in a nation over a certain period of time. Economic growth has been, and will continue to be the dominant discussion of the macroeconomic aims of every country's government. Though there are now many other instruments for measuring the standard of living in a nation, such as the Human Development Index and the Human Poverty Index, the gross domestic product and gross domestic product per capita are considered the best indicators of a country's economic growth.

2.2 Exogenous growth theory

Mehrara (2011). argue that, the rate of economic growth, as measured by the growth rate of output per person fully depends on the growth rate of the total factor productivity, which is influenced by the rate of technological improvement and which in turn depends on the availability and usage of energy and in particular, electricity.

Before the existence of the endogenous growth theory proposed by Romer in 1986, there were many other growth theories that explained the growth phenomenon. The Solow growth theory, also known as the exogenous growth theory, was one of them. In 1956 the neoclassical or exogenous growth theory was developed by Solow (1956) and Swan (1956) to this day remains the standard theory of choice used in Economics not only for understanding the macroeconomic structure of growth but also for other microeconomic issues regarding incentives, policies and organisations that interact with economic growth.

In exogenous growth models, the rate of growth is assumed to be determined exogenously through the savings rate as in Keynesian theorise, (Harrod-Domar model after Harrod, 1939 and Domar, 1946) or through technological progress, as in neoclassical theories Solow (1956) and Swan (1956). Most of the exogenous growth models explained growth in output (Q), through a combination of productivity (A), capital (K), and labour (L), although some models include non-renewable resources, (see Dasgupta and Heal, 1979; Solow, 1974; Stiglitz, 1974) and energy (e) as separate production factors, (Berndt and wood, 1979; Stern, 2000; Kummel, 1982).

However, the exogenous growth theory advocated that the rate of technological improvement be influenced by a scientific process that is separate from, and independent of, economic forces. This means that economists could take the long run growth rate as given, exogenous, from outside the economic system. However, they did not explain how improvements in technology came about so that these models were confirmed to have exogenous technological change. Some of the fundamental assumptions of the Solow model are the diminishing returns to Labour and Capital and constant returns to scale as well as competitive market equilibrium and constant savings rate. The surprise idea and hence the most important was the fact that it clearly explained the long run per capita growth by the rate of technological progress, that comes outside the model. In exogenous economic growth model electricity again was not included as one of the factors of production; the theory assumed that the economy was operating under a closed economic system within which goods were produced only by inputs of capital and labour.

As the time went by, the neoclassical growth theory was improved further this time by well-known economist Paul Romer in 1986. There are other important new growth theorists like Robert E. Lucas and Robert J. Barro who also made a significant contribution to modifications of the exogenous growth theory.

2.3 Endogenous growth theory

The endogenous growth theory also called new growth theory was developed as a response to the flaws of the exogenous growth theory. Romer (1986) presented endogenous growth theory in which he incorporated human capital; innovation and knowledge are generated within the economic system itself, which is, an input in the production function, (see Barro and Sala-I-Martin, 1995). The theory attempts to explain the long run growth by endogenising technological progress or productivity growth as the outcome of decisions taken by firms and individuals, (also see Jones, 2001; Galor and Weil, 2000). The key point of endogenous growth theory is that technological knowledge can be thought of as a form of capital. It is accumulated through doing Research and Development (R&D) and other knowledge creating processes. Technological knowledge has two important features. First, there are public goods because they are non-rival: the stock of this form of capital is not depleted with use. This is significant because it shows that the knowledge stock can be stored over time, even when it is being used. Second, there are positive externalities to consumers or producers of final goods who benefit from innovation and future researchers who also benefit from past ideas. There are beneficial spillovers to the economy from the research and development process so that the social benefits of innovation exceed the private benefits to the initial innovator.

These externalities create inspiration in the growth process because as firms install new capital, and this tends to be linked with process and product innovations. The motivation to devote resources to innovation came from the view of transitory monopoly profits for successful innovations.

In the framework of endogenous growth theory the growth of Y= AK thus means the relationship between capital and output where A is a constant and K is a composite of manufacturing-based capital and disembodied technological knowledge. However, growth of the output can continue indefinitely as capital is accumulated. So, in the new growth model, the economy can sustain a constant growth rate in which the diminishing returns to manufactured capital are exactly compensated by the technological advancement or growth. Savings is directed to either manufacturing capital accumulation or the expansion (increase) of knowledge. The growth rate is constantly influenced by the savings rate. A higher savings rate increases the economy’s growth rate, but not merely in terms of its equilibrium level of income. To further explain economic growth, new growth production function takes into account capital, technology and labour. But with the constant growing dependence on energy in particular electricity worldwide, electricity is now recognised to be an integral part of all studies on economic growth. It is now a vital part of the production function.

The endogenous growth theory also professes convergence of the nations by diffusion of technology, meaning a situation in which poor countries manage to improve their economic growth or catch up with developed nations through gradual adopting change or duplicating of technology by poor nations. The same view was also professed in the neoclassical growth theory. Therefore, the production function of a firm in endogenous theory is written in the following format:

$$Q = A(R)F\ (R_i,\ K_i,\ L_i) \qquad (2.0)$$

where A represents the public stock of knowledge which generated from doing research and development (R). Ri is the general or stock of results derived from the stock of expenditure on research and development. While Ki and Li are capital stock of firm i and labour stock of firm I, respectively. The symbol Ri stands for the technological widespread at time in firm i. However, any development acquired through technology will have faster beneficial spill over to the entire economy. Technological advancement shows that the developments of new innovations have exactly the same characteristic of public good because they are non-rival. On the other hand, new innovations cause old vintages of capital to be outdated. In the endogenous growth model, both capital accumulated and innovations are the most important determinants for long run growth.

In this research work, the researcher adopts the aggregate production function of new growth theory in the following format given by Darius (1997).

$$Q = F\ (A, K, L, E) \tag{2.1}$$

Where Q represents output, A is recognised as technology advancement that comprises endogenous factors. K, L and E represent capital, labour and electricity, respectively. It is understandable that A is structured-based on the investment on research technology that comprises endogenous factors that associated with electricity. However, the current global technological innovations are not independent on the availability of electricity or various energy types to power it. The modern technological types mentioned in the study include machinery, plants and related types. Notice that the above- mentioned technology and the likes would be useless without a sufficient electricity (energy) supply. Nevertheless, these exceptional works of innovation technology could discourage the incentives of the rational profit maximisation firm to invest in research technology if the purpose of developing it cannot be utilised as a result of sufficient electricity to power it. There are also other endogenous growth models that focus on the material basis of economic growth, including the role of energy and natural resources as well as biophysical limits as governed by the laws of thermodynamics, which have also been recently developed by Smulders, (1995). Froling (2011) also included energy as an input in production function of his endogenous long-wave model.

The law of thermodynamics helps provide better justification through which the Ayres and Kneese (1969) stated “no production process can be driven without energy conversion.” Although electricity is not the primary determinant of technology it is an important instrument that ensures the smooth operations of various forms of technological types. Looking from the technologically oriented perspective of electricity production, it is worth noting that these sectors require heavy capital investment which also implies that a massive amount of machinery is needed for generation, transmission and distribution of consumable electricity or for extraction of every other related energy resources. In the context of the above, the endogenous growth model as specified in equation 1 is justified on the basis that both capital and labour can only operate efficiently together with electricity (or with various energy resources) as a critical factor in the production process.

Based on the empirical results and theories, that have been generated from theoretical justification of exogenous growth theory, that make electricity as an independent variable in equation 2.1 above, therefore electricity is considered as one of the input that determinants economic growth.

Considering electricity as one of the independent variable use in the production factor, therefore the model equation can be written as follows:

$$Q = F(A, L, K, E) \tag{2.2}$$

where Q represents output, A is technological improvement, and L, K, and E represent labour, capital and electricity respectively. In this research we consider only one main energy sector in South Africa namely, electricity.

Then the equation 2 is composed into one single regression or equation and then rewrites the model as follows.

$$GDP = F(A, K, L, EC) \tag{2.3}$$

The pure interpretation of this equation implies that gross domestic product (GDP) is actually a function of capital, labour and electricity consumption and has been found in many theories in the literature of economic growth models.

2.4 Theory of production and growth

This section reviews the logical role of electricity usage in production and hence in increasing the scale of production which is necessary for economic growth. Moreover, institutional factors play a complex and critical role in combining labour, capital and electricity in production, the understanding of which is essential in getting the fuller picture.

2.4.1 Energy in production; physical theory and economic model

Reproducibility is the fundamental idea in the economics of production. Some inputs to production are non-reproducible whereas others can be produced, or manufactured, at a cost within the economic production system and are describe as reproducible. Inputs are defined as the basic factors of production that exist from the beginning of the period under consideration and cannot be directly consumed as a result of production activities, though they can be degraded and can be added to. The intermediate inputs are those manufactured during the on-going production and used up entirely in production processes. However, there are conceptual differences regarding these definitions. Mainstream economists have long believed and articulated that capital, labour and land are the only primary factors of production whereas other goods such as fuel and materials are considered to be intermediate inputs and the prices paid for all these various types of inputs are said to be an entitlement due to the owners of primary inputs for the service rendered directly or embodied in the produced intermediate inputs Stern (1999).

This definition by mainstream economists led theorists to extend the theory of growth to include primary inputs, specifically capital and land, and give partial recognition to the role of energy (electricity) in the growth process. The primary inputs included stock resources such as oil reserve and coal deposits. Moreover, the impression from standard growth theories on the role of energy seems to be an extremely difficult and complicated one in general based on analyses of the model. Capital, labour and in the longer term even natural resources, are said to be reproducible factors of production, while energy and matter are non-reproducible factors of production. Energy vectors – electricity and fuels- and raw materials such as minerals are in theory reproducible factors though with the exception of agricultural and forest products which are normally harvested from nature and can best symbolise the accumulated work of the planet in biogeochemical cycles, which in turn are powered by energy from the sun and the earth's internal heat.

2.4.2 Energy as a Factor of Production

The law of Thermodynamics, that is, the conservation of matter highlighted the immutable constraint within which the economic processes must function (Ayres and Kneese, 1969; Boulding 1966). The mass-balance principle implies that, in order to obtain a given material output, greater or equal quantities of matter must be used as inputs, with the residual a pollutant or waste product. Because of that, there are minimal material inputs necessary for any production process producing material outputs. The second law of Thermodynamics (the efficiency law) means that a minimum quantity of energy (electricity in the case of this study) is required to carry out the transformation or movement of matter or more specific physical work, in some way and all such transformation requires electricity. Carrying out transformations in finite time needs more electricity than just these minimal requirements (Baumgartner, 2004).

Stern (1997) argues that every form of production activity involves work of different sort. Therefore, all modern economic processes require electricity and there must be limits to the substitution of other factors of production for electricity so that electricity at all-time remains an important factor of production. Information or knowledge is another factor of production which might also be considered to be a non-reproducible input in the same fashion as energy is. Several studies (such as Spreng, 1993; Chen, 1994; Ruth, 1995) suggest that information is the primary concept of non-reproducible factors of production in the same way as energy is and that ecological economists should devote as much attention to information and its accumulated as knowledge as one does to energy. Energy is necessary to extract information from the environment while active use of energy cannot be made without information and most possible accumulated knowledge. Unlike energy, information and knowledge cannot be easily quantified. The fact that these latter factors of production must be incorporated into machines and into the workers and materials scheme in order to be made useful to them provides a biophysical justification for treating capital, labour, land, energy and information or knowledge (perhaps proxied by human capital or patents) as factors of production. Even though capital and labour are easier to assess than information and knowledge, their measurement is still very imperfect compared to that of energy in the specification of the model.

In recent times electricity has continuously gained more attention globally and is also regarded as one of the most significant factors affecting economic growth. Unlike in the previous decades, several studies have been carried out on how electricity affects production and economic growth. These views can be classified into two general groups, namely, the neoclassic economists perspectives and the views of ecological economists. Neoclassic economist believe that electricity has a minor role to play in economic growth and production and is only an intermediate input overshadowed by capital, workforce, and land. On the other hand, the ecological economists consider electricity as a dominant variable in the production function and inputs such as workforce and capital as intermediate ones Stern (2004).

Maleki, (2002) advocated the ecological economist's perspective outlined above to specify the following production function which includes electricity (E) as an important factor, in addition to the traditional ones.

$$Y = f(A, K, L, E) \tag{2.4}$$

However, the above empirical literature provides evidence that, there is a common relationship between the electricity consumption and economic growth and the effects of electricity price cannot be overlooked.

2.4.3 The effects of Electricity Price on National output

Given the endogenous growth equation that makes it an addition to capital and labour, electricity consumption is also considered to be among the primary inputs affecting national output. However, in the light of the huge sustained increase in the price of electricity that South Africa has experienced post 2003, this study postulates that such increases may have had a significant detrimental effect on national output. Hence equation 4 is expanded to include the effect of the electricity price (P_E) on aggregate output as follows:

$$Y = f(A, K, L, E(\mathrm{P_E}), \mathrm{P_E}) \tag{2.5}$$

Equation (5) suggests that national output is affected directly by capital, labour, electricity consumption and price of electricity via the channelling of the effect of $\mathrm{P_E}$ on electricity consumption. The total differential of equation 5 may be written as follows:

$$dy = \frac{\partial Y}{\partial K}dK + \frac{\partial Y}{\partial L}dL + \frac{\partial Y}{\partial E}dE + \frac{\partial Y}{\partial P_E}dP_E \tag{2.6}$$

It is expected that $\frac{\partial Y}{\partial K} > 0, \frac{\partial Y}{\partial L} > 0, \frac{\partial Y}{\partial E} > 0, \frac{\partial Y}{\partial P_E} < 0$, ie, a rise in capital, labour and electricity consumption, respectively results in an increase in output, while a rise in the electricity price causes a reduction in output via the rising input cost channel.

If one considers the total derivative of equation 6 with respect to $\mathrm{P_E}$ then the following obtains:

$$\frac{\mathrm{dY}}{\mathrm{dP_E}} = \frac{\mathrm{\partial Y}}{\mathrm{\partial K}}\frac{\mathrm{dK}}{\mathrm{dP_E}} + \frac{\mathrm{\partial Y}}{\mathrm{\partial L}}\frac{\mathrm{dL}}{\mathrm{dP_E}} + \frac{\mathrm{\partial Y}}{\mathrm{\partial E}}\frac{\mathrm{dE}}{\mathrm{dP_E}} + \frac{\mathrm{\partial Y}}{\mathrm{\partial P_E}} \tag{2.7}$$

Equation 2.7 reduces to:

$$\frac{dY}{dP_E} = \frac{\partial Y}{dE}\frac{dE}{dP_E} + \frac{dY}{\partial P_E} \tag{2.8}$$

Since we assume electricity price changes do not affect capital and labour, ie, $\frac{dk}{dP_E} = 0$ and $\frac{dL}{dP_E} = 0$ furthermore, equation 8 suggests that a rise in price causes production to decrease via two channels directly through the rising input costs channel ($\frac{\partial Y}{\partial P_E} < 0$) and indirectly via the demand channel, where a rise in price causes a decrease in the consumption of electricity $\left(\frac{\partial P_E}{dP_E} < 0\right)$.

Note that in chapters four and five, due to the unavailability of capital and labour data at the monthly frequency and sectoral levels, equation (2.4) is further simplified by assuming capital and labour are constants that are associated with the technology variable (A). Thus the model to be analysed later in this study may be stated as follows:

$$Y = f(A^*, E(\mathrm{P_E}), \mathrm{P_E}) \tag{2.9}$$

where A^*, represents technological factors that operate in conjunction with a constant level of capital and labour. Although this is a strong simplifying assumption, it does not interfere with the main focus of this study which is to assess the impact of electricity supply and electricity prices on sectoral output within the context of the growth, feedback and conservation hypotheses which are discussed in significant detail in the next chapter.

2.5 Conclusion

This chapter explained the relationship between electricity consumption and economic growth theory from the neoclassical and ecological perspectives. The ecological economists established that electricity is an essential input and, therefore, can be recognised as one of the dominant variables in production function, but in the long term the scarcity of electricity could impose a strong constraint on the growth of the economy. By contrast, the neoclassical economists consider electricity as an intermediate input that has only a small role in economic growth except for specialised resources, therefore, economic growth pays no attention to the role of electricity. Moreover, they consider electricity demand as being similar to the demand for every other good and service which has suitable substitutes depending on their level of importance and complexity. Improving the ability of the demand for electricity to respond to price change could benefit not only the consumers who choose to participate actively in the electricity market, but would also help these markets operate more efficiently.

CHAPTER THREE

CONCEPTUAL LITERATURE REVIEW

3.0 Introduction

In this section of the paper, the researcher aims to sketch some of the relevant literature that sheds light on the topic. The major theme reviewed is the relationship between electricity consumption and economic growth. Minor theme include control variables, such as employment, urbanisation, electricity (energy) prices, population, manufacturing, income, industry, exports, financial development, trade openness and capital.

3.1 The relationship between electricity consumption and economic growth

The relationship between electricity consumption and economic growth has been widely researched globally since it has major implications for the growth and energy strategy a country adopts. An important topic of debate which is whether electricity consumption cause economic growth or vice versa from many researchers, and the important implications thereof from the theoretical and empirical studies present different causality results in different countries and the methodologies used. The empirical literature has emphasised four possible relationships between energy consumption and economic growth (Abosedra et al., 2009; Sheng et al., 2007). This disagreement can be seen from four different empirical views. A mainstream research concludes that there is a unidirectional causality running from electricity consumption to economic growth. A second mainstream research view supports the existence of bidirectional causality between economic growth and electricity consumption. The mainstream research view, known as the “Neutrality Hypothesis” declares that there is no causality in either direction between economic growth and electricity consumption. The fourth view, known as the “Conservation Hypothesis” suggests a one-way causality running from economic growth to electricity consumption. Hence, considerable literatures exists on the causality of energy-growth nexus and has been largely explored from different competing views which can be divided into: (1) the growth hypothesis, (2) the feedback hypothesis, (3) the neutrality hypothesis and (4) the conservation hypothesis.

3.1.2 Growth hypothesis

The first view states that energy consumption plays a crucial role in economic growth. This is known as the growth hypothesis and is advanced by ecological economists, who argued that all the other inputs (technological improvement, capital and labour) could not substitute for the important role that energy plays in the production process stern (1993). This therefore implies that a country's economic growth depends largely on energy consumption, so that any decreases in energy/ electricity consumption may bring about a reduction in economic growth. Hence, energy is a limiting factor to economic growth, so that shocks to energy supply will have a negative impact on economic growth (Ozturk, 2010a; Narayan and Singh, 2007 and Odhiambo, 2009a). This relationship denotes an energy dependent economy and as such attempt to limited access to modern energy supply can limit economic growth and may result in poor economic performance, Tsani (2010). In this scenario, national and regional development access programmes should invest in innovation approaches aimed at improving access to affordable and modern energy for all populations and productive sectors, Squalli (2007). The theory assumes that a unidirectional causality runs from electricity consumption to economic growth. Therefore, a reduction in electricity consumption due to electricity conservation oriented policies may have a detrimental impact on economic growth (Sheng et al., 2007).

In order to justify the first hypothesis, Odhiambo (2009b) applied the Autoregressive Distributed Lag (ARDL) bounds test and the Granger non-Causality test to Tanzania for the period 1971 to 2006. The results of the bounds test showed a constant long run relationship between energy consumption and economic growth. However, the Granger non-Causality results revealed proof of strong unidirectional causality running from energy consumption to economic growth as well as from electricity consumption to economic growth. The justification of these results implies that Tanzania is an energy dependent nation; therefore, energy conservation policies will have strong negative repercussions on the economic growth of the country. Von

(2009) justified the first hypothesis on the basis of panel data from 158 countries for the period 1980 to 2004 using the semi-parametric partially linear panel method. The results reveal that energy consumption leads to an increase in economic growth and the effect of time trend is not important. Viahinic-Dizdarevic and Zikovic (2010) employed the Error Correction Model (ECM) to analyse the importance of energy consumption on economic growth for Croatia for the period 1993 to 2006. The results indicated the presence of unidirectional causality. The existence and direction of causality relationship between electricity consumption and economic growth was investigated by Abosedra, Dah and Ghosh (2009) for Lebanon using monthly data covering the period of 1995 to 2005, and employed the Granger causality test and the Vector Autoregressive (VAR) test. The authors found evidence to reject the presence of a long run equilibrium relationship between electricity consumption and economic growth but accepted the existence of unidirectional causality running from electricity use to economic growth when the Vector autoregression test is used.

Narayan and Prasad (2008) use the econometric methodology of bootstrapped causality test approach to analyse the existence and the direction of causality relationship between electricity consumption and economic growth for 30 OECD countries. They used time series data, for the period 1970 to 2002 for the USA, while data for Mexico, the Slovak Republic and Korea was for the period 1971 to 2002. Data for Hungary was for the period of 1965 to 2002 while data for the rest of the OECD was from 1960 to 2002. The study was the first in the literature that considered a large group of industrialised countries including the modelling approach used in estimation procedure. The general findings of the study supported the evidence in favour of electricity consumption leading to economic growth in Austria, Iceland, Italy, the Slovak Republic, the Czech Republic, Korea, Portugal and the UK. For any dependent OCED member where electricity consumption leads to increases in economic growth in that country any effect that decrease electricity use could definitely hinder economic progress as well as create high unemployment and lower per capita income. Kwakwa (2012) probed the nexus between electricity consumption and economic growth in Ghana by adding fossil fuel consumption. The results indicated that electricity consumption and fossil fuel consumption caused economic growth.

Nyamdash and Denny (2010) used the Vector Error Correlation Model (VECM) to analyse the link between electricity consumption and economic growth in Ireland for the period 1960 to 2007 using both aggregate and disaggregate data to compare the findings. In their results, the authors found that it was possible that using the aggregate data could hide some important causalities that mighty exist in the relationship between these two variables. They found unidirectional causality running from electricity use to economic growth in the aggregate framework which indicates that Ireland is an energy dependent economy while a contradictory result was found in favour of bidirectional causality relationship when a disaggregated demand was used. Yoo and Kwak (2010) studied seven South American countries, namely Argentina, Brazil, Chile, Columbia, Ecuador, Peru and Venezuela using data for the period 1975 to 2006 and employed the most popular time series approach of the Granger causality and ECM. The results show a unidirectional causality that runs from electricity consumption to economic growth in Argentina, Brazil, Chile, Columbia, and Ecuador without feedback effect. Binh (2011) found evidence of a cointegration relationship between electricity consumption and economic growth. He also confirmed evidence in Vietnam's of unidirectional causality running from electricity consumption to economic growth which supports the growth Hypothesis.

Erbykal (2008) examined the relationship between energy consumption and economic growth in Turkey using time series data for 1970 to 2008 and employed the bounds test approach. The results suggested that both oil and electricity had a positive and statistically significant effect on economic growth in the short run while in the long run, oil consumption had a positive effect on economic growth and electricity consumption had a negative effect. Kouakou (2011) was among those who considered the importance of investigating the relationship between electricity consumption and economic growth in Cote D'Ivoire using data from 1971 to 2008. GDP per capita and industry value were added to measure economic activities. However, the long run estimates confirmed that there was a unidirectional relationship running from electricity use to economic growth. Hu and Lin (2013) investigated the relationship between electricity consumption and economic growth in China's Hainan international Tourism Island of using a data set from 1988 to 2009. They used the cointegration test, Granger Causality and the Error Correction Procedure. The results shows that in primary industry, electricity consumption Granger caused the economic growth in the tertiary industry's GDP Granger caused electricity use. The electricity consumption of the primary industry and the tertiary industry Granger caused economic growth. The authors found no evidence to support the existence of cointegration relationship between the secondary industry's GDP and electricity consumption in Hainan Island of China. Onakoya, Onakoya, Salami and Odedairo (2013) in a study of the relationship between energy consumption and economic growth in Nigeria for the period of 1975 to 2010 using cointegration and ordinary least squares techniques, found that energy consumption and economic growth had a long run cointegration and that electricity use had a significant and positive relationship with economic growth. The study also suggested that expansion of electricity facilities and efficiency use of energy resources could enhance economic growth in Nigeria. Incidentally, Nigeria is a nation with number of energy resources but lacks optimal utilisation of energy resources poor electricity facilities are part of the bottleneck affecting the supply of electricity as well as having a negative impact on Nigerian economy.

Saatci and Dumrul (2013) used the annual time series data of energy consumption and economic growth from 1960 to 2008 to examine the causal link between energy consumption and GDP for the Turkish economy and employed a unit root test with structural breaks and cointegration approach. The overall finding of the study revealed that electricity consumption and economic growth had a strong positive relationship for the Turkish economy. In addition, the outcome of the findings reflected the sensitivity of the Turkish economy meaning that, energy conservation policy could negatively affect the economic growth of Turkey. Ramcharran (1990) examined the link between electricity use and economic growth in Jamaica for the period of 1970 to 1986 a time of high increases in energy prices. The results showed that Jamaica was an electricity dependent country. Moreover, the country was highly dependent on imported energy resources which could render the economy vulnerable to external economic shocks, such as, the OPEC oil price increases and the recession in the World community market. Electricity has a significant impact on the economic growth of Jamaica. The total electricity demand was close to elastic and the electricity intensity of the economy has expanded over the years. The study also warned that in future, there was a higher possibility for increases in electricity consumption mostly on the sectional level, given that the current demands for electricity consumption differed across difference sectors. For example, the residential demand for electricity was actually dependent on income elastic whereas the demand for industrial and commercial was based on price inelastic. However, the expectation of a rapid increase in electricity demand across sectional levels in the future required the expansions of electricity facilities to accommodate the high demand for electricity consumption and since Jamaica was an electricity, dependent economy an appropriate electricity price mechanism and policy had to be implemented in order to avoid any negative economic situation. Altinay and Karagol (2005) investigated the causal relationship between electricity consumption and economic growth in Turkey for the period of 1950 to 2000. The Granger causality test showed evidence of a unidirectional causal relationship running from electricity consumption to GDP growth. Acaravci and Ozturk (2012) revisited the electricity consumption and economic growth nexus by including employment as a variable for Turkey during the period of 1968 to 2006. Their report supported the pervious study done by Altinary and Karagol (2005) on the basis of a unidirectional causality running from electricity consumption to economic growth but contradicted the findings revealed by Halicioglu (2011) who also did the same test to investigate the causal relationship between electricity consumption and economic growth in Turkey and found evidence of a unidirectional causality running from economic growth to electricity consumption.

Nondo and Kahsai (2009) and Chali *et al* (2010) used the same technique of panel unit root tests, panel cointegration and panel the error correction model to analyse the causal relationship between energy consumption and economic growth for 19 Common Market for Eastern and Southern Africa (COMESA) countries for the period of 1980 to 2005. Their findings supported causation running from energy consumption to economic growth for low income COMESA countries. Yao and Zhu (2012) used regression analysis and correlative research on energy consumption and GDP for the selected period of 1990 to 2009 in China. Their findings confirmed that energy, production and consumption always maintained a positive growth and that energy consumption had a significant impact on economic growth. However, it showed an effect not only on the current energy consumption but also on the previous energy consumption meaning that past energy consumption had a significant impact on the current economic growth. The strong relationship between energy consumption and economic growth in China showed that China still faced challenges of consuming large amount of energy in order to support national economic growth. The study conducted by Pradhan (2010) for China employed time series data for the period of 1970 to 2007 applying production function and causality techniques. The result showed unidirectional causality running from economic growth to energy consumption with infrastructure and transport included as the additional variables both also presented unidirectional causality. Studies by Shiu and Lam (2004) and Yuan *et al*., (2007) for China, and Wolde-Rufael (2006) for Benin, Congo, Democratic Republic of Congo, Egypt, Gabon, Morocco, and Tunisia found unidirectional causality running from electricity consumption to economic growth; they also reported that a decrease in electricity consumption or implementation of energy conservation policies in these countries could seriously affect their economic growth.

The studies done by Hossain (2011) revealed unidirectional causality from economic growth to electricity consumption for 9 newly industrialised countries, applying the cointegration method and VEC test to examined the causal relationship between economic growth and electricity consumption. Hossaian and Saeki (2011) carried out studies on electricity consumption and economic growth for India, Nepal and Pakistan using Cointegration and the Error Correction Model (ECM). They found that economic growth caused electricity consumption. Ghosh (2002) carried out a study on the economic growth and electricity consumption nexus using annual data for 1950-51 to 1996-97 in India. However, the results showed a unidirectional Granger causality running from economic growth to electricity consumption.

Soytas and Sari (2006) stated that electricity consumption was the engine that stimulated manufacturing industry and that insufficient electricity and its conservation could reflect a serious setback to manufacturing goods. In turn, this would create an inefficient market that might shift the market away from initial buys as a result of a price hike. Ighodaro (2010) used Johansen's cointegration approach and the result confirmed that electricity consumption caused economic growth. However, electricity consumption affected economic growth. Narayan and Singh's (2006) study revealed that electricity consumption and labour positively contributed to economic growth in Fiji. After that, most econometric techniques such as Granger causality, Ordinary Least Squares, Fully Modified ordinary least squares, and ARDL were used, and all the techniques provided the same result, i.e. that electricity consumption and labour force harms economic growth. Hong (2010) investigated the long and short term relations between GDP and electricity consumption using cointegration, the Error Correction Method and Granger causality techniques. The study proved that there was a long run equilibrium relationship between electricity consumption and economic growth. Furthermore, with evidence from the Chinese economy during the period of 1953 to 2007 there is strong evidence to support the contention that the total electricity consumption and production caused economic growth in the short term. Morimoto and Hope's (2004) study claimed that current as well as past changes in electricity consumption played a key role in changing the real GDP in Sri Lanka. Akinlo (2009) carried out a study in Nigeria to investigate the relationship between economic growth and electricity consumption during the period 1980 to 2006. The result showed that there was a unidirectional Granger causality running from electricity consumption to economic growth and revealed the urgent need for upgrading both the electricity facilities and the efficiency use of the electricity in order to speed up the country's economic growth.

Chontanawat *et al* (2008) conducted an investigation into the existence of a causal relationship between energy consumption and the economic growth nexus in thirty OECD developed economies and seventy-eight non-OCED developing economies. They detected causality running from electricity energy consumption to economic growth but that it was more common in the developed OCED economies than in the developing non-OCED economies. Using Cointegration and the Vector Error Correction Model (VECM), Belloumi (2009) stated that the Tunisian per capita electricity consumption in the short run caused per capita GDP and there was bidirectional long run causal relationship exists between the variables for the period of 1971 to 2004**.** Sami (2011) extended the literature on the causal relationship between exports, electricity consumption and real income in Brazil an emerging market economy for the period 1971 to 2007 employing the bounds testing approach. The result revealed evidence of a cointegration relationship between exports, electricity consumption and real income. The study further found that in the long run exports had a positive impact on real income. This evidence supported the export-led growth hypothesis. One of the major findings of his study was that electricity consumption effected economic growth in a positive direction.

3.1.3 Feedback hypothesis

The feedback hypothesis asserts the existence of a bidirectional causal relationship between energy consumption and economic growth. This theory reflects the interdependence of energy consumption and growth, implying that energy consumption and economic growth are jointly determined and affected at the same time. Although bi-directional causality implies that energy conservation policy harms economic growth at the aggregate level, energy policy should be carefully regulated, since one-sided policy selection is harmful for economic growth Yildirim and Aslan, (2012). The feedback hypothesis reveals the existence of a two-way (bidirectional) causal relationship between electricity consumption and economic growth. The theory suggests that economic growth and electricity consumption are complementary.

Yoo and Kwak (2010) studied seven South American countries, namely Argentina, Brazil, Chile, Columbia, Ecuador, Peru and Venezuela using the data for the period 1975 to 2006 and employed the popular time series approach of Granger causality and ECM. The authors found that bidirectional causality existed between the two variables but in favour of economic growth to electricity consumption in Venezuela. Kouakou (2011) was among those who considered the importance of investigating the relationship between electricity consumption and economic growth in Cote D'Ivoire using data from 1971 to 2008. GDP per capita and industry value were added to measure economic activities. The results, using cointegration and the error correction test, revealed that there was a relationship between economic growth and electricity consumption and also found a bidirectional causality running from electricity use to economic growth and from economic growth to electricity consumption in the short run. For Algerian, Abderrahmani and Belaid (2013) examined the causal relationship between electricity consumption and economic growth by adding petroleum prices as a control variable. The results confirmed a feedback effect between electricity consumption and economic growth. Jumbe (2004) using Malawian data, examined the casual relationship between electricity consumption, agricultural and non-agricultural income used the Error Correlation Model (ECM) and Granger causality analysis. The Granger causality results showed the existence of bidirectional causality between agricultural and non-agricultural income respectively, and electricity consumption. These results were contradicted by the ECM analysis which showed a unidirectional causality running from agricultural and non-agricultural income respectively to electricity consumption. The study carried out by Hou (2009) for Beijing used time series data and applied cointegration techniques and the Error Correlation Model (ECM). The results revealed that economic development and energy consumption were cointegrated in the long run there was, 0.427% increase in the gross energy consumption with the gross value added increase by 1% of the economic growth. The author also extended the literature on causal relationship between electricity consumption and economic growth in China. The study used times series data for the period 1953 to 2006 and employed the ADF framework, cointegration and Hsiao's Granger causality. The findings suggested economic growth and electricity consumption Granger causes each other. Tang and Shahbaz (2001) provided broader analysis on the relationship between electricity consumption, economic growth, financial development, population and foreign trade in Portugal using the annual data sample from 1970 to 2009 and employed a multivariate framework. The empirical results showed that these variables were cointegrated meaning that there were stable long run relationship between electricity consumption and its determinants. The Granger causality results showed that electricity consumption, economic growth and population growth cause each other while expansion on the financial development Granger caused electricity consumption.

Hamdi and Sbia (2012) applied cointegration, the Error Correction Model (ECM) and the Granger causality approach to investigate the link between electricity consumption and economic for Bahrain during the period 1980 to 2008. The results showed that there was a cointegration relationship between them and the Granger causality test indicated a bidirectional relationship running from electricity consumption to economic growth in the long run, they also found unidirectional causality relationship between these variables in the short run. In the case of Barbados, Lorde *et al.,* (2010) examined the cointegration and causality between electricity consumption and economic growth. The findings showed evidence of cointegration and the feedback hypothesis between electricity consumption and economic growth. Shunyun and Donghua (2011) applied a different approach and different time period for China to analyses the causality between energy consumption and economic growth for the period 1985 to 2007 within a multivariate framework and using the fully modified OLS (FMOLS). The results revealed bidirectional relationship and economic growth.

These findings contradicted Pradhan's (2010) report. Lean and Shahbaz (2012) confirmed that electricity consumption had a positive impact on economic growth and bi-directional Granger causality was found between electricity consumption and economic growth in Pakistan. Furthering the investigation between electricity consumption and economic growth, Shahbaz *et al;* (2012) examined the dynamic relationship between electricity consumption, capital use and economic growth for Romania by applying cointegration and causality methods. Their findings confirmed a cointegration relationship between the series. The Granger causality analysis reported bidirectional causality between electricity consumption and economic growth while capita use Granger caused electricity consumption. The study carried out by Francis *et al* (2010) on the increasing efficiency in electricity consumption, distribution, and production of energy in the Caribbean region showed that there was a bi-directional Granger causality which ran from electricity (energy) consumption to real GDP per capita. However, the study also suggested that electricity (energy) demand in Haiti, Jamaica, and Trinidad was expected to increase till at least 2010. In contrast to the first hypothesis, Sinha (2009) applied the dynamic panel Vector Error Correlation Model (VECM) and Causality test, using the panel data from 88 countries for the period 1973 to 2003. The findings suggested that per capita GDP and per capita electricity were cointegrated. However, the results also showed a bidirectional short and long run relationship with strong convincing causality between the economic growth and the growth of electricity consumption.

Faridula *et al* (2011) confirmed the second hypothesis on the basis of using time series data from Malaysia for 1971 to 2008 using ARDL, bounds testing methods for cointegration. The results detected the presence of long run bidirectional causality for all series. The report implied that economic growth and electricity consumption caused each other both in the short run and long run. Magazzino's (2011) study used time series data for the period 1970 to 2009 in Italy employed Vector Autoregression (VAR) and the Vector Error Correlation Model (VECM). The report showed evidence of long run bidirectional relationship between electricity consumption and economic growth. Another study was conducted in Tunisia by Chebbi and Boujelbene (2009) using time series data for the period of 1971 to 2004, using the application of multivariate cointegration. The overall results of the causality analysis and the Impulse response functions rejected that electricity consumption and GDP were neutral with respect to one another suggesting rather that bidirectional causality between electricity consumption and economic growth exist in the long run meaning that Tunisia was an energy dependent nation. Ouedraogo (2010) pointed out that there was a long run bidirectional causal relationship between electricity consumption and economic growth for Burkina Faso during the period of 1968 to 2003 and commented that electricity remained the important instrument for promoting economic development. Ansgar *et al* (2010) used the panel unit root and cointegration methods to examine electricity consumption and economic growth of 25 OCED countries for the period 1981 to 2007. They found a bidirectional causal relationship between electricity consumption and economic growth.

Ghali and El-Sakka (2004) employed the Multivariate framework to examine the causal relationship between electricity use and output growth in Canada for 1961 to 1997 taking non-classical one-sector aggregate production technology where capital and labour were included with output and electricity consumption but treated as a separate input. The long run cointegration tests confirmed the existence of a relationship between output, labour, capital and electricity use. However these variables were related by two co-integrating vectors. Moreover, the short run VEC test found causality running in both directions between output growth and electricity consumption. The Variance decomposition result targeted to test the forecast error variance of output growth, found that a shock in electricity use would cause a 15% change in the future growth rates of the output. Chontanawat (2013) used panel data from 12 Asian developing countries to investigate the causal relationship between electricity consumption and economic growth. Using the cointegration test developed by Pedroni (1999) for a panel of the countries the long run relationship was estimated through performing the PFMOLS procedures for heterogeneous cointegration panels. The empirical findings indicated that there was a strong evidence of bidirectional causality in Asian developing countries. This evidence meant that there was interdependency between electricity consumption and economic growth in these countries. The general conclusion drawn from the study revealed that higher real income provided the ground and enhanced expansions of activities that were highly dependent on electricity and vice versa.

3.1.4 Neutrality hypothesis

Another view on the causality relationship between growth and energy is the neutrality hypothesis. This view according to the neoclassical economists, argues that energy does not influence economic growth (Stern and Cleveland, 2004). In other words, both energy consumption and economic growth are neutral with respect to each other, meaning that capital and labour are the primary factors of production while energy is seen as an intermediate input of production which is used up in the entire production process Tsani, (2010) and Alam et al (2012). This theory postulates that no causality between energy consumption and economic growth in either direction exists (Odhiambo, 2009a; Asafu-Adjaye, 2000; Paul and Bhattacharya, 2004). It holds that the energy sector has no impact on economic growth. The absence of causality between energy consumption and economic growth provides evidence of the validity of the neutrality hypothesis. In this scenario policies to promote energy access and higher levels of consumption will not have an influence on economic growth (Ouedraogo, 2013). Accordingly, the electricity conservation policies will not affect economic growth. It seems that the neutrality hypothesis has little support in the applied literature. Vikas (2015) disclosed that there is no long run relationship and also no causal relationship between economic growth and electricity consumption.

Yoo and Kwak (2010) studied seven South American countries, namely Argentina, Brazil, Chile, Columbia, Ecuador, Peru and Venezuela using data for the period 1975 to 2006 and employed time series approach of Granger causality and ECM. The results in the case of Peru show no proof of Granger causality effect in either direction. Abderrahmani and Belaid (2013) found evidence of the neutrality hypothesis between electricity use and petroleum prices for Algeria. Wei (2002) identified a long run cointegration between electricity (energy) consumption, energy prices, income and heavy industry in GDP in China but failed to provide any evidence of causality in either direction.

3.1.5 Conservation hypothesis

Finally, the fourth view states the unidirectional causality that runs from GDP to energy / electricity consumption, which is known as the conservation hypothesis. This theory postulates that a country's economic growth is highly associated with energy conservation because energy as any other production factor may be the limiting factor to economic growth. In other words it implies that a country is not fully dependent on electricity consumption for its economic growth, Alam et al., (2012). Therefore, in this regard energy conservation policies such as the reduction in greenhouse gas emissions measures, and demand management policies, designed to reduce energy consumption and waste can be implemented without little if any adverse effect on economic growth. This theory is supported if an increase in real GDP causes an increase in energy consumption. In the case of an energy dependent economy, energy conservation policies that could be implemented to reduce emissions may not have influence on economic growth. The conservation hypothesis indicates the existence of a one-way causal relationship running from economic growth to electricity consumption, meaning that economic growth causes the development of the electricity sector. Furthermore, the unidirectional relationship indicates that the country is less dependent on electricity, and investing in electricity sector efficiency will not have an adverse effect on economic growth (Visak, 2015). Hence, electricity conservation policies aimed at reducing electricity consumption will have a minor or zero effect on economic growth. This theory holds that economic growth is the dynamic which causes the development of energy sector and indicates an economy which is less energy dependent. According to this hypothesis energy conservation policies, such as investments in energy efficiency and demand management policies will have no adverse impact on GDP growth (Ouedraogo, 2013).

Contradicting the growth hypothesis, Mehrara (2007) examined the relationship between the per capita energy consumption and per capita GDP using panel data for 11 oil exporting countries for the period 1971 to 2002 and applied the panel cointegration technique and the Granger Causality test. The results showed evidence of unidirectional causality running from economic growth to energy consumption for all the countries. The results suggested that energy conservation policies can be implemented with little or no negative effect on economic growth for this selected group of countries. Narayan and Prasad (2008) used the econometric methodology of the bootstrapped causality test approach to analyse the existence and direction of the causality relationship between electricity consumption and economic growth for 30 OECD countries. They used the time series data, from 1970 to 2002 for USA, data for the Mexico; the Slovak Republic and Korea was for the period 1971 to 2002; data for Hungary was for the period of 1965 to 2002 while data for the other countries was from 1960 to 2002. For other 22 OCED countries which comprise of about 73 percent, the results indicated that economic growth caused electricity consumption. For the UK, South Korea, Iceland, Finland, Hungary and the Netherlands they found that real GDP caused electricity use, so for these countries, it was common that any economic factors that caused shocks would negatively decrease the level of electricity use.

Adom (2011) investigated the correlation between electricity consumption and economic growth using data from 1971 to 2008 in Ghana and employed the Granger causality test and ARDL techniques to analyse the direction of causality between the two variables. The ARDL bounds test of cointegration results showed the existence of a long run relationship between electricity consumption and real per capita GDP. Real per capita GDP could also be treated as an instrument that determines a long run relationship between electricity consumption and economic growth. The Granger causality test supported the Growth Hypothesis and showed that electricity consumption in Ghana depended on economic growth meaning that in Ghana energy conservation policy could be considered as the best option without any fear of negative economic effects in future. Adom *et al* (2012) extended Adom’s work using an electricity demand function and employed ARDL bounds testing in order to investigate the relationship between electricity consumption and economic growth. They drew the conclusion that income, industrial growth and urbanisation were the primary contributing factors to electricity consumption in Ghana. Alinsato (2009) used times series data from 1973-4 and 2005-6 to investigate whether a causal link exists between electricity consumption and economic growth in two West African countries, namely The Benin of Republic and Togo, by applying the ARDL testing approach. The study detected that there is a long run cointegration relationship between electricity use and economic growth for both countries. Nevertheless, the cointegration test and causality indicates that both countries’ economies are less electricity dependent. In addition, the economies of these two West African countries were merely dependent on the agricultural sector which contributed more than 33 percent of the overall GDP despite the fact that this sector in those two countries was dominated by traditional system of farming. The massive contribution from the agricultural sector to GDP of these two countries (Benin and Togo) required new modern technologies that could expand the productivity of the sector. Shaari, Hassain and Ismail (2012) examined the long run relationship between energy consumption and economic growth in Malaysia between the period of 1980 to 2010 and employed the Johansen cointegration and Granger causality tests. Their findings indicated the presence of a long run relationship between energy consumption and economic growth. However, the Granger causality test results revealed that oil and coal consumption did not cause economic growth and vice versa. The reports also suggested evidence of causality running from economic growth to electricity consumption. Emeka (2010) estimated the relationship between economic growth and electricity consumption for Nigeria using the annual data from 1978 to 2008. The empirical results indicated that real GDP and electricity consumption were cointegrated and there was a unidirectional Granger relationship running from real GDP to electricity use with no feedback.

Farhani and Ben Rejeb (2012) used the annual panel data for 95countries to estimate the relationship between energy consumption and economic growth for the period of 1971 to 2008 and employed panel unit tests, panel cointegration tests and the panel causality test. These ninety five countries were divided into four different income groups, namely, low income, lower-middle income, upper-middle income and high income group according to the World Bank classifications. The results of the panel cointegration test suggested that energy consumption and economic growth were cointegrated for all four income groups of those countries. Moreover, the results of the panel causality test showed that there was a long run Granger causality relationship running from GDP to energy consumption for both low and high income groups and that bidirectional Granger causality existed between energy use and economic growth for the lower-middle and upper-middle countries. However, the general findings of the study suggest that when energy consumption stimulus to economic growth is positive, the benefits of energy consumption are much greater than the externality cost of the energy use. In other words, if an increase in GDP causes increases in energy consumption positively, then the externality cost of energy use could contain or (set back) economic growth. So, a conservation policy could be necessary. Akinwale, Jesuleye and Siyanbola (2013) tested the causal relationship between electricity consumption and economic growth for Nigeria using the annual times series data from 1970 to 2005. The study employed the Vector Auto Regressive (VAR) and the Error Correction Mode (ECM). The results showed that there was a long run relationship between economic growth and electricity consumption and that, there was also evidence suggesting the existence of Granger causality running from economic growth to electricity consumption without any feedback effect. Hu and Lin (2013) investigated the relationship between electricity consumption and economic growth China's Hainan international Tourism Island using a data set from 1988 to 2009. They made use of the cointegration test, the Granger Causality and the Error Correction Procedure. The study also included three major types of industry, namely, the primary industry, the secondary industry and the tertiary industry and the GDP in Hainan Island for the period 1990 to 2009. One of the findings of the paper showed that there was a unidirectional Granger Causality running from economic growth to electricity use.

Onuonga (2012) investigated the causal relationship between energy consumption and economic growth in Kenyan. He made use of cointegration and error correction procedures using data for 1971 to 2005 and found out that there existed a long run relationship between electricity (energy) consumption and economic growth with unidirectional causality running from economic growth to electricity consumption in the Kenyan economy. This implies that expansion in economic activities directly promoted electricity consumption through economic- dependent electricity sectors and sustained electricity consumption in the process also stimulated an expansion of economic activity. However, the finding was in contradiction to that the Akinlo (2008) report. Hatemi and Irandoust (2005) found evidence of unidirectional causality running from economic growth to electricity consumption by investigating the causal relationship between electricity consumption and economic growth for Sweden. Aqeel and Butt (2001) estimated the causal link between energy consumption and economic growth for Pakistan using the time series data from 1955-6 and 1995-6. Both cointegration techniques and the Granger causality test were used to determine the direction of the causality link between GDP and electricity use. The empirical results inferred that it was economic growth that caused the overall energy consumption. However, electricity consumption in particular was indicated as the main engine that stimulated economic growth without feedback. Pao (2009) examined the Granger Causality between electricity consumption and economic growth for Taiwan from 1980 to 2007 by applying the Cointegration and Error Correction Models. The findings revealed that electricity consumption and economic growth were cointegrated and that there was a unidirectional short run and long run Granger causality running from economic growth to electricity consumption without feedback effect. The authors concluded that the Taiwan economy was independent of electricity consumption and based on this finding energy policies targeted to conserve electricity use could have no strong damaging repercussions for the Taiwan economy.

Ghaderi, Azedah and Mohammadzadeh (2006) studied the relationship between electricity consumption and value added in Iran for the period of 1980 to 2001. Causality tests showed that electricity consumption in Iran did not have much impact on value added among most industries and for that matter on economic growth. Esso (2010) analysed the long run relationship between electricity consumption and economic growth for 7 sub-Sahara African countries for 1970 to 2007 employing bounds testing approach to cointegration. The results suggested evidence of a unidirectional relationship between GDP and electricity consumption for all the countries except for Cote D'Ivoire where the results of Granger causality showed a one way causality relationship between energy consumption and the real GDP. Narayan, Smyth and Prasad (2005) applied the same methodology used by Jumbe (2004) to Australia data. The results showed that economic growth affected electricity consumption and employment only in the short run.

The Marathe and Mozumder (2007) study applied Granger causality analysis to an examination of the causality direction between GDP and electricity consumption in Bangladesh. The results showed that GDP affected electricity consumption and no causality was found running from electricity consumption to GDP. Aitor and Alonso (2007) applied the Toda Yamamoto 1995 method to examine for both linear and non-linear causal relationships between electricity consumption and economic growth for Spain using the data set for 1971 to 2005. The study reported a unidirectional linear causal relationship between the variables with causality running from economic growth to electricity consumption. The authors failed to provide any evidence in support of a non-linear Granger causal relationship between the series in either direction. Wolde-Rufael (2006) studied the causality between electricity consumption and economic growth in 17 African countries including Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe. He drew the conclusion that there was no causal relationship between electricity consumption and economic growth and these countries were not entirely dependent on electricity consumption for their economic growth and that energy conservation policies could be implemented with little or no adverse effect on economic growth. Sami (2011) for Japan used times series data from 1960 to 2007 and applied bounds testing and the VECM procedure to perform the analysis of the relationship between electricity consumption, export and real income per capita. The study confirmed the presence of a cointegration relationship between the electricity consumption, export and economic growth with causality running from real GDP per capital to electricity consumption per capita both in the short run and in the long run, thus supporting the conservation hypothesis.

For Pakistan, Ahmad and Jamil's (2010) studies used annual data for 1960 to 2008. They found a unidirectional causality running from economic growth to electricity consumption. Soytas and Sari's (2003) study confirmed unidirectional causality running from economic growth to electricity consumption for both Italy and South Korea. Wietze and Van's (2007) analysed unidirectional causality running from GDP to electricity consumption in Turkey. Dirck (2008) applied a cointegration model to investigate the causal relationship between electricity consumption and economic growth for Great Britain, Ireland, the Netherlands, Spain and Portugal. The results showed a unidirectional causality running from economic growth to electricity consumption. Narayan, Narayan and Popp (2010) examined the causal relationship between electricity consumption and economic growth using cointegration methods; they found that unidirectional causality ran from economic growth to electricity consumption for the panel data of the Middle East. Mallick (2007) used time series data covering the period of 1970-71 to 2004-5 in India and the employed Granger causality approach and variance decomposition analysis of the Vector Autoregression (VAR) test. The results of the Granger causality test showed that increases in economic growth led to higher demand for electricity consumption as a whole, whereas, the results of the variance decomposition suggested that there could be a high possibility of bidirectional causality between electricity consumption and economic growth in the future. Causal connection between electricity consumption and economic growth was studied for Singapore and South Korea by Glasure and Lee (1997) using the Vector Autoregression (VAR) Model and found a unidirectional Granger causality running from electricity consumption to economic growth for Singapore but failed to document a direction of causality in either way for South Korea. Nelson, Mukras and Siringi (2013) concluded in the case of Kenya that there was a cointegration between electricity consumption, petroleum and manufacturing growth using data for 1970 to 2010. They also found evidence of Granger causality running from electricity consumption and petroleum use to manufacturing sectors both in the short and long run period. The study also established bidirectional causality between manufacturing and electricity consumption in the short run as well as in the long term. Nevertheless, they found no evidence of causality running from the manufacturing sector to petroleum consumption as there were very few manufacturing industries that depended only on the use of petroleum given its cost and its unpredictable change of prices.

3.1.6 Mixed results

Akinlo (2008) investigated the causality between electricity consumption and economic growth for eleven sub-Saharan African countries, namely, Cameroon, Cote D'Ivoire, Congo, Gambia, Ghana, Kenya, Nigeria, Senegal, Sudan, Togo and Zimbabwe using time series data from 1980 to 2003. The study applied the Autoregressive Distributed Lag (ARDL) bounds test and Granger Causality test within the context of the VECM framework. The result of the ARDL showed that energy consumption was cointegrated with economic growth in seven of the sub-Saharan African countries viz., Cameroon, Cote D'Ivoire, Gambia, Ghana, Senegal, Sudan and Zimbabwe. The report also suggested that electricity consumption has a significant positive long run impact on economic growth in Ghana, Senegal and Sudan, whereas, the Granger causality test based on the VECM approach suggested a bidirectional link between energy use and economic growth for Gambia, Ghana and Senegal. However, in the case of Sudan and Zimbabwe, the Granger causality test showed that economic growth caused electricity consumption. While for Cameroon and Cote D'Ivoire, the Granger causality test revealed no causality relationship between electricity consumption and economic growth. In the case of Congo and Nigeria the Granger causality test within the VAR framework suggested a unidirectional causality running from economic growth to electricity consumption. However, No causality was found in either direction for Kenya and Togo, supporting the neutrality hypothesis. Chen, Kuo and Chen (2007) investigated the relationship between GDP and electricity use in 10 newly industrialised and developing Asian countries using both single and panel data techniques from 1971 to 2001. The results obtained from the single data set showed that the causality directions in 10 developing Asian countries were mixed. For instance, for Hong Kong and Korea, they found that there was a long run causal relationship running from real GDP to electricity use, with no feedback. On the contrary, the results for Indonesia indicated a unidirectional long run causality running from electricity consumption to economic growth. While in the case of India, Singapore, Taiwan and Thailand there was no substantial evidence to prove that there was long run causality between real GDP and electricity consumption. On the other hand, the results of the panel causality test presented bidirectional long run causality relation between electricity use and economic growth as well as unidirectional short run causality running from economic growth to electricity consumption with reverse relationship. Furthermore, the finding was almost the same with the previous studies done by Yoo (2005) for Korea and Jumbe (2004) in Malawi.

Squall (2007) investigated the existence and direction of causal relationship between the electricity consumption and economic growth for OPEC members using time series data for the period of 1980 to 2003 and employing the bounds testing method and the Granger causality test. The empirical results showed the existence of a long run relationship between per capita electricity consumption and real per capita GDP for all the OPEC members. The evidence also suggested that the economic growth of the five OPEC countries dependent on electricity use among them were Indonesia, Iran, Nigeria, Qatar and Venezuela, with a degree of complementarity between electricity use and economic growth for Iran and Qatar. Based on this report, energy policies targeted at conserving energy use could negatively affect the economic growth of these countries. While for Algeria, Iraq and Libya, the study found evidence in support of unidirectional causality running from economic growth to electricity consumption meaning that the economic growth of these countries was independent of electricity use. However, the findings also pointed out that energy conservation policy would have little or no effect on economic growth in most advanced economies of the Gulf, namely, Kuwait, Saudi Arabia and the UAE. Yu and Choi’s (1985) study pointed out that causality relation ran from energy use to gross national product in the Philippines and unidirectional causality from gross national product to energy consumption for South Korea. However, in the case of USA, UK and Poland they found no causality relationship between gross national product and energy consumption. Erol and Yu (1987) conducted a study of the 6 industrialised developed countries. The results showed a bidirectional causality relationship between electricity (energy) consumption and economic growth for Japan but from energy use to gross national product for Canada. For Germany and Italy they found causality running from gross national product to energy consumption but for England and France no causality was found in either direction.

Bildirici, *et al.,* (2012) used the Autoregressive Distributed Lag (ARDL) method to analyse the relationship between electricity consumption and economic growth in a selection of developed and developing countries. Their findings revealed evidence to support the first hypothesis for the USA, China, Canada and Brazil. With regard to these countries the empirical results found unidirectional causality running from electricity consumption to real GDP implying that electricity consumption acts as a stimulus to economic growth. Based on this report, these countries were energy dependent economies, meaning that energy conservation policies could negatively affect their economic growth. Furthermore, electricity consumption increased their income level. Therefore, energy policies targeted at improving the energy infrastructure and increasing the energy supply were the relevant options for these countries. In the case of South Africa, Turkey, Japan, UK, France and Italy, on the contrary, a unidirectional causality relationship running from economic growth to energy use was found supporting the conservation hypothesis, meaning that an increase in economic growth caused an increase in energy consumption. Therefore, policies aimed at conserving energy consumption may have little or no negative effect on the economic growth of these countries. In other words, these countries were less energy dependent economies. Another contribution to the literature on the relationship between electricity consumption and economic growth is by Khan, Ahmed Jam and Shahbaz (2012). They incorporated trade openness, capital and labour in production function using the annual data of Kazakhstan over the period of 1991 to 2011. The study employed ARDL bounds testing for cointegration and the VECM Granger causality test to analyse the long run causality relationship between these variables. The results confirmed the presence of a long run relationship among the variables. The empirical findings showed that electricity consumption contributed significantly to the economic growth and that trade openness stimulates economic growth; on the other hand, capital and labour promotes economic growth. The causality reports found that electricity consumption Granger caused economic growth with the feedback effect present between trade openness and economic growth. For Angola, Solarin and Shahbaz (2013) ran cointegration and causality analysis on the causal relationship between electricity consumption and economic growth by incorporating urbanisation as a control variable. The study utilised data from the period of 1971 to 2009. The empirical evidence indicated the existence of long run relationship among the variables while on the other side, the causality results illustrated bidirectional causality between electricity consumption and economic growth. The study also observed feedback effect between urbanisation and economic growth, and between electricity consumption and urbanisation. The authors also documented that the three estimators used in the study indicated that Angola's electricity consumption positively contributed to economic growth.

In the case of the United Arab Emirates, Sbia and Shahbaz (2013) extended analysis of the causal relationship between electricity consumption and economic growth by adding urbanisation and financial development as deterministic variables. The study covered the sample period of 1975 to 2011. Bounds testing, the VECM and Granger causality approach were used to detect the direction of causality relationship between the variables. The results established that there was a long run cointegration relationship between the variables. However, they found an inverted u-shaped relationship between economic growth and electricity consumption. Initially, economic growth increased electricity consumption and decreased it after a threshold level of income per capita and financial development contributed significantly to electricity consumption. The study also affirmed that urbanisation and electricity consumption face the same inverted u-shaped relationship. The causality test revealed bidirectional causality between electricity use and economic growth and the feedback hypothesis was supported by financial development and electricity consumption. They also found that financial development Granger caused economic growth while they observed an interdependent relationship in the case of economic growth and urbanisation and found that bidirectional causality existed between urbanisation and electricity consumption as well as between urbanisation and financial development. The study reported unidirectional causality running from electricity consumption to economic growth in the short run and bidirectional causality in the long run. Lee and Chang (2007) applied the Vector Autoregressive Method (VAR) to explore the relationship between electricity consumption per capita and real GDP per capita in 20 developed countries and 18 developing countries. The results provided evidence to support bidirectional causality between real GDP per capita and electricity consumption per capita for developed countries and unidirectional causality in developing countries. In addition, the authors asserted that generally electricity consumption had a significant positive role in stimulating economic activities.

Zachariadis (2007) carried out a study on G-7 countries from the period of 1960 to 2004 using different econometric methods to explore the relationship between electricity (energy) consumption and economic growth. The methods were the Granger causality, the Vector Autoregression (VAR), the Error Correction Model, and Autoregressive distributional lag (ARDL). The results showed the same in all methods for the USA but varied among other countries. The study also highlighted that sample size is crucial determining the similar results**.** Hossain (2013) for three South Asian Association for Regional Cooperation (SAARC) countries, (Bangladesh, India and Pakistan) used time series data for the period 1976 to 2009 and applied different econometric techniques to examine the dynamic long run and short run causal relationship between electricity consumption, economic growth, export values and remittance receipts. The empirical results provided evidence to support the presence of cointegration relationships for all the variables. The individual Granger causality test indicated that the short run causality runs from export values and remittances to economic growth in Bangladesh, there is long run causality running from economic growth to export values in India and there is a unidirectional short run causality running from economic growth to electricity consumption in Pakistan. Furthermore, the panel Granger test showed a bidirectional short run causal relationship between economic growth and export values but failed to document any evidence of long run panel causal relationship between the variables. This result implies that there was an interdependence relationship between exports and economic growth. In other words, higher economic growth led to expansion in the commercial and industrial sectors and the reverse was also true. The study also found that in the long run, there was higher elasticity of economic growth with respect to electricity consumption and remittances than in the short run elasticity. This means that as time went on, the increase in electricity consumption and higher remittance together caused expansion in economic activities. Bohm (2008) applied the VECM framework to investigate the causal relationship between electricity consumption and economic growth. The results showed a one-way causality relationship running from electricity consumption to GDP growth in Belgium, Greece, Italy and the Netherlands. On the other hand, the study also found unidirectional causality running from economic growth to electricity consumption in Ireland, Portugal, and Spain. Likewise, in the case of Germany, the authors found that electricity consumption and economic growth Granger cause each other.

However, the importance of the causal direction between the said variables for policy makers stems from implementing energy policy conservation, V. R. G. et al., (2010). Therefore, it is important for policy makers to have a clear understanding of the causal relationship between electricity consumption and economic growth. For instance, if it is found that there is a unidirectional causality from economic growth to electricity consumption, it indicates that the country can adopt energy conservation policies to reduce energy consumption without harming the growth process. On the other hand, if it is found that the causality direction runs from electricity consumption, it implies that the country is energy-dependent and hence, cannot adopt conservative energy policies, since this would be to the detrimental of economic growth Narayan and Smith, (2008). Since the direction of causality has significant policy implications for the government for designing and implementing electricity consumption policies, it is important to ascertain empirically the existence and the direction of the causal link between electricity consumption and economic growth.

3.2 Review of the South African literature

This section of the study considers the relevant literature on the South African economy. Given the global environmental implications of energy consumption and the need for energy conservation policies, a number of studies in South African have investigated the causality between energy use and economic growth during the past. The majority of these studies examine energy/GDP causality based on time series techniques for example; Inglesi (2010) investigated aggregate electricity demand using the Engle-Granger cointegration technique and Error correlation model, on South African data over the period 1980 to 2005. The result showed that the long run dynamic impacts of income and price were significant and both were assumed to be inelastic with estimates of 0.42 and -0.55 respectively. The short run result revealed that electricity consumption was influenced by the GDP and the population size of the country. Inglesi and Pouris (2010) studied electricity demand in South Africa by applying the Engle-Granger technique for the period of 1980 to 2007. Their results showed that income and electricity price were the major determinants of South Africa's electricity consumption in the long run but in the short run electricity consumption was influenced by population growth and economic growth. They also found evidence suggesting that price of electricity was highly significant with an estimated price elasticity of -0.56 reflecting that prices had a significant effect on electricity demand.

Inglesi –Lotz and Blignaut (2011) analysed electricity consumption in South Africa using a factor decomposition method. Using data extending over the period of 1993 to 2006, their results showed that the massive increase in electricity consumption during this period was a result of the rapid economic growth that had taken place over the previous two decades. Change in output was the dominating force that drove the increase in electricity consumption during that period. However, the effect of transformation from the Apartheid government to the inception of the African National Congress (ANC) led government understandable, given that South Africa had undergone major political, social and economic changes during the period which have contributed to the increase in economic activity. The structural change in the economy resulted in the high electricity consumption contrary to that, the efficiency effect was noted as the only factor contributing to a reduction in electricity consumption. Amusa *et al* (2009) examined the aggregate electricity demand in South Africa during the period of 1960 to 2007 using the bounds testing approach to cointegration. They found that income was the most important determinant of long run aggregate electricity demand with electricity prices having an insignificant effect on the aggregate electricity demand.

Ziramba (2008) in his impressive study found a long- run relationship between residential electricity consumption and real gross domestic product. The study also confirmed an estimated income elasticity of 0.31, a result was within the range of the previous study done by Inglesi (2010). Ziramba (2009) analysed the disaggregated energy consumption and industrial output in South Africa using the annual data from 1980 to 2005 and applying the Toda-Yamamoto test for Granger Causality and the Autoregressive Distributed Lag (ARDL) method developed by Pesaran *et al* (2001). The bounds testing result showed evidence of a long run relationship between electricity (energy) consumption, employment and industrial production. On the other hand, the Toda-Yamamoto and Granger- Causality revealed a bi-directional causality between industrial output and oil consumption. This finding confirms the neutrality hypothesis which signified that oil consumption and industrial production are interdependent.

Additionally, the electricity pricing policy is supposed to attain a suitable balance between equity, economic growth and environmental goals. An appropriate pricing system is necessary to provide affordable electricity prices for households and low cost electricity for industrial consumers. So far in the South African context there have been very few relevant empirical studies in this area. Therefore, there is a need for further research. For instance, the previous studies on electricity consumption and economic growth relationships focussed mainly on electricity prices, industrial sectors, employment and income but they did not consider trade sectors at all. Yet, which comprised between 13 and 14 percent of GDP. Therefore, the current research intends to fill the gap by including the private sector employment in the analysis.

3.3 Review of the historical electricity supply in South Africa

South Africa is the largest economy on the African content, and it follows that it is also the largest producer and consumer of electricity. Since Eskom is a dominant investor in electricity power generation in South Africa- it has the capacity to produce electricity at a cheaper rate than any new entrant into the industry. However, Eskom was previously considered among one of the world's cheapest electricity producers, Kohler (2008). As noted earlier in the background to the research reported in this dissertation, electricity generation in South Africa was primarily aimed at supporting the turn-of-the 20 century mining industry, as most mining operations used electrical generators up until 1909. In 1923 the electricity parastatal Eskom was formed and started to supply electricity both to non-mining industries and the railroad. Since then, Eskom sales have increased dramatically- indeed, faster than GDP growth- which has led to the expansion of Eskom's utility. From 1950 to 1982 Eskom constantly experienced average sales growth of 8 percent per annum. Despite a good record of Eskom's sales an estimated R27 billion was spent between 1983 and 1987 as government capital investment.

However, In 1985 Eskom was among one of the enterprises that were seriously affected by foreign loans and some of its new projects were left uncompleted, while there were delays in completing others and this surprised shock discouraged plans for further expansion. Yet the country previously had sufficient electricity reserve margins during the Apartheid government era. Unfortunately, the reserve margins were recently exhausted. For example, from 2002 to 2004, and to 2006 South Africa's electricity reserve margins dramatically decreased from 25% to 20% and 16%, respectively. This was attributed to robust economic growth and the associated demand for electricity (Odhiambo, 2009a). Also, the implementation of the free basic electricity policy in 2007 to previously disadvantaged communities might partially have contributed to the 50% increase in electricity demand in the country between 1994 and 2007. The electric power consumption per capita continuously increased from 3644.44kwh in 1980 to 4298.12kwh in 1985, then 4431.48kwh in 1990 to a slight decline of 4403.68kwh in 1995 and to 4618.36kwh in 1999 and 4680.68kwh in 2000. Between 2005, and 2008, there was a continuous annual consumption increase from 4703.97kwh to 4796.97kwh, 5108.41kwh, and 4934.39kwh respectively.

Although consumption partially decreased in 2009 to 4665.86kwh in 2012 it went back upto 4803 kwh. These scenarios served as a warning signal about crisis within the sector. In October 2004, the government finally agreed to finance the electricity capacity expansion project but it was too late to prevent the crisis (Maroga, 2009).
In 2007-2008, the entire South African economy was affected by the electricity crisis. According to Eskom's (2007) power crisis review, numerous factors can be said to have been responsible for the recent electricity crisis in South Africa, including: the White Paper on the energy policy of South Africa and instructions by government to stop building new Power stations; economic growth and increasing demand for electricity; skills shortages; poor systematic planning and lack of essential spare parts for maintenance of power stations; significant decrease in reserve margins; and Eskom's BEE policy as some of the stations were facing shortage of stock. Eskom accused government of creating the gap between the electricity supply and demand delaying its decision to approve funds for the building of a new power station given the urgent nature and substantial efforts needed in order to convince both private sector and government of the importance of the project. However, the government at the time rejected the proposed strategy in favour of allowing independent power producers into the market.

Pouris, (2008) argued that weak research on energy as a whole and in particular on electricity is one of the reasons that accounts for Eskom's uncomfortable situation. The majority of the literature involving electricity consumption and economic growth mostly focusses on South American, Asian and European countries, with only a few studies taking account of African countries. In South Africa, there are only few studies that specifically concentrate on this topic. However, these studies include price of electricity as the third variable because of the significant role it plays in determining "Price Elasticity of demand", in the overall economy, thus, giving insights into the consumption behaviour of price increase.

Price Elasticity of demand is defined as the ratio of the percentage change in the quantity demanded of a good or service to the percentage change in price, ceteris paribus. Consumers are generally responsive to an electricity price change, and reduce consumption as the price increases, Niemeyer (2001). Furthermore, South Africa's contributions global research publications in energy research constitutes only 0.45%

of which is a very small share compared to 6.04% for medicine, 5.07% for plant science and 3,05% for ecology. Moreover, South Africa performs poorly when compared to other countries like Australia, Canada, Malaysia and New Zealand. However, the general implication of the poor academic research in this field is that weak policy and incompetent decisions are likely to be made.

Since the end of Apartheid and the inception of the ANC- led government in 1994, the South African economy has sustained itself with the electricity infrastructure established during the apartheid regime without investing in additional capacities to support the fast growing demand for electricity in the economy, (NERSA, 2009). This situation has placed a serious constraint on the growth prospects of the country. Moreover, the importance of expanding electricity capacity has drawn attention from different sectors in the country and has become an urgent matter. A study conducted by the World Bank warned that electricity demand in South Africa required an urgent investment level that could be in line with the increasing demand, (World Bank, 2008). A number of studies both from developed and developing countries have concentrated their investigations on energy demand and electricity, for example, (Amarawickram and Hunt, 2008: Atakhanova, and Howie, 2007; Dergiades, and Tsoulfidis, 2008 and Narayan *et al*., 2007). The demand for any good or service is determined by its own price, the income of the consumers and the price of the substitutes. Most these studies tended to focus on income, output and electricity prices as the main causal factors affecting electricity demand.

In 2008, Eskom began a five year plan for its capital investment programmes to increase the energy capacity of the country and thus to increase the long term electricity supply. The new Eskom projects included four new power stations (Kusile, 4800 mw; Medupi, 4800mw; Ingula, 1332mw; Sere Windfarm, 100mw) that will support the existing electricity supply of the country. These projects are financed by foreign loans, for example, the Medupi project was financed by a loan of $3, 75 billion from the World Bank. At the end of 2006, Eskom began the Medupi project, which is considered to be largest investment in a single power station in African continent. Presently the power station employs 8000 workers and it is expected to contribute 0.35% of GDP.

However, the massive investment in electricity infrastructure has forced Eskom to increase electricity tariffs to fund its projects. If economic growth and electricity consumption are interlinked then high electricity tariffs are likely to affect the economy adversely. The South African- economy was built on the back of low cost electricity that spread to, and stimulated the various sectors of the economy. Therefore, the recent Eskom requests- (e.g. the government-sanctioned 8% annual tariff increase for the next five (5) years) could cripple businesses and lead to job losses and higher food prices thereby adversely affecting the growth rate of South Africa's economy. Since 2008, the cost of one unit of electricity has dramatically increased from 19 cents to 60.66 cents on average (Newsletter 2013). The aforementioned 8% increase would take the price of electricity from 61 cents a kilowatt hour in 2012/2013 to 128 cents a kWh in 2017/18, which is more than double the current rate. Worldwide, the electricity production companies are booming because the electricity utilities are being pressured by fast growing demand globally, and governments are providing substantial incentives to attract foreign investors into their countries to invest in the development of the energy sector, (Ramokgopa, 2008).

3.4 The impact of electricity constraints on major economic sub-sectors

This section of the literature review focusses on the effects of electricity constraints on major economic sub-sectors, in particular the manufacturing and mining sectors.

Electricity consumption and its connection to economic growth have been studied by various scholars both in developed and developing countries. This section of the study focusses on the impacts of electricity constraints on the various sub-sections of the economy. In terms of business obstacles, electricity takes first place. The study done by Ghaderi *et al.* (2006), for Iran investigated the electricity demand function of the industrial sector. A similar analysis of the industrial sector was also conducted for Russia by Egorova and Volchkova (2004) who found that electricity prices were a determining factor for electricity consumption. Other significant factors such as industrial output also proved to be more significant in the analysis of the study. Other papers which perfectly fit into this category are the ones by Adenikinju (2005) and Lee and Anas (1992). Relying on firm-level data they show that a large percentage of

Nigerian industries regard power shedding and voltage fluctuations as a stumbling block to their business operation.

Electricity constraints take first place in terms of business obstacles in many sectors of the economies, especially in developing countries. Power failures or voltage fluctuations occur numerous times per week without prior notification and each lasting lasts for not less than two hours, thereby causing damages and adding additional operational cost to many manufacturing plants, resulting for some in restart lost output and damage to equipment. The results further suggest that manufacturing firms in Nigeria spend on average 9 percent of their variable costs on infrastructure with electric power accounting for half of that figure. To avoid these costs, private firms provide their own electricity, but this also increases setup costs for manufacturing firms. Small firms in this case appear to experience as much as 25 percent share of restarting capital costs than large enterprise. This result seems to be true for Escribano, Guasch and Pena (2008), who state that in most Sub-Sahara African countries (SSA) countries 30-60 percent of the adverse effects on firm productivity results from deficient infrastructure. Of this amount, for half of the countries, the electricity sector constitutes 40-80 percent of the infrastructure impact.

Special attention has also been paid to the South African economy by Inglesi-Lotz and Blignaut (2011), who investigated the price elasticity of demand for electricity by sector in South Africa for the period 1993 to 2006. Their estimated results from panel data show that the industrial sector was the only one with statistically significant price elasticity over the period of study, though the relationship between electricity consumption and electricity price differed across sectors. Furthermore, the results suggested that out of the five sectors studied, economic output was a positive contributing factor to only two; industrial and commercial sectors, while for the other three sectors (agriculture, transport and mining) output proved insignificant based on their electricity usage.

In India electricity infrastructure and the manufacturing sector have been considered especially important for the development of the country. Hulten, Bennathan and Srinivasan (2005) examined the Indian manufacturing sector from 1972 to 1993. In their study, the authors excluded the role of network externalities on productivity. They used electricity-generating capacity as a measure of electricity infrastructure.

The results show that increasing the capacity at one point in an existing system may have effects on the overall network, either by extending critical association or removing constraints. Their approach in this study seems to focus more on total factor productivity instead of real output and was inspired by the previous work of, Hulten and Schwab (1991). Studies were also carried out on industrial electricity consumption by Dilaver and Hunt (2010) who examined the relationship between industries' electricity consumption, industrial value added and electricity prices in the Turkish industrial sector for the period 1960 to 2008. They concluded that output and electricity prices are the main determining factor for electricity consumption with price elasticity of -0.16 and income elasticity of 0.15. Dethier, Horn and Straub (2008) investigated the Business Climate Survey Data to analysis enterprise performance in developing countries. Their study covers 55 enterprise surveys, of telecommunication, electricity and transportation. However, electricity seems to remain the most serious infrastructure bottleneck, particularly in the poorest countries, as evidence by the fact that electricity constraints reduce severely as GDP per capita increases. This finding seems to be in line with Guatemala, Honduras and Nicaragua and five Eastern European countries but not in China, where technological infrastructure constraints seems to be more important.

Furthermore, this result seems to contradict the finding revealed subsequently by Dollar, Hallward-Driemeier and Mengistae (2005) on the basis that electricity losses have a significant negative effect on productivity in Bangladesh, China, India and Parkistan. Fedderke and Bogetic (2009) examined the impact of electricity infrastructure, as measured by gigawatt per hours of generated electricity in South Africa. They distinguished between the direct (labour productivity growth) and indirect (total factor productivity) effects, based on value added productivity functions. These authors used aggregate data and three-digit manufacturing sector data with observations from 19970 to 1993. We reported only the result for manufacturing sector due to our special interest in the particular sector. The result, based on instrumental-variable analysis, shows that the elasticity of labour productivity in relation to electricity infrastructure is higher than in the non-instrumental case, the elasticity of electricity generation is 0.06 and statistically significant, that is, a 10 percent increase in electricity generation improves labour productivity by 0.6 percent. Though this effect seems to be relatively small, in the other consideration, i.e. total factor productivity growth, the elasticity is equal to 0.04, which means in South Africa electricity infrastructure does not have significant influence on productivity growth. In Uganda, Reinikka, and Svensson (2002) suggest that private investment, employment and probability to export are negatively related to electricity interruption except for those manufacturing firms that own generators. In another study based on the impact of electricity crises on the consumption behaviour of small and medium enterprise in Cape Town South Africa using the monthly data, Von Ketelhodt and Wocke (2008) found that SMEs in South Africa appear to be more vulnerable to electricity crisis shocks. In fact SMEs reportedly loss of trade or productivity due to carrying the cost of overheads while not trading. About 89 percent of SMEs are heavily dependent on a stable electricity supply while 69 percent felt that they were severely affected by power shedding. This would seem to be in line with Adenikinju (2005) who argues that cost share is higher for small firms in most developing countries based on evidence from Nigeria.

3.5 Conclusion

The relationship between electricity consumption and economic growth is very important for any nation or society to develop and to measure global change. However, in this study the literature review showed mixed results from one study to another not only for the developing countries of the world but also for the developed countries as well. Of course the African region cannot be excluded from these results. These mixed results may be due to differences of time frame or the different econometric- techniques used in different studies and in different countries or even in the same country. It is the belief of the researcher that most of these fundamental works are very relevant to this work as their findings help to illuminate our understanding of the variables the researcher intends to test.

CHAPTER FOUR

THEORETICAL MODEL, METHODOLOGY AND MODEL SPECIFICATION

4.0 Introduction

This study aims to explore the links between economic growth, electricity price, electricity use and sectoral electricity consumption in South Africa, as outlined in chapter one. This section of this report includes the data sources and the research methodology followed in conducting the research. Having established in the previous chapter that there is some evidence of a relationship between electricity consumption and economic growth in South Africa, this study intends to empirically test the link and causality between these variables by analysing monthly and quarterly time series data using the Eviews 8 statistical software packages.

After this brief introduction, this chapter presents relevant statistical techniques and econometric specifications of the models to be estimated in the next chapter. The rest of the chapter is organised as follows: section 4.1, focusses on the theoretical model, which is the relationship between economic growth, electricity price and electricity consumption. Section 4.2 gives definition of the variables and data sources. However, after presenting the variables that will be used in this study, it is now necessary to describe the model that is employed to estimate their long and short run relationships. Section 4.3 discusses the methodology that is employed to test the possible relationship between, electricity consumption and electricity price as well as sectoral electricity consumption which is the other additional macroeconomic variable in the model. Section 4.4 concludes the model specification and diagnostic test, 4.5 gives a summary of the chapter.

4.1 Theoretical Model

As noted earlier in chapter two consumers of electricity are like consumers of every other commodity, they will increase their demand up to the point where the marginal benefit they derive from the electricity is equal to the price they have to pay**.** This approach highlighted the effect of electricity cost on the production function which indeed demonstrates the potential role of electricity in economic growth. However, the increase in electricity prices will negatively affect the national product as well as the output and facilities of the industries where electricity is used as an intermediate input in production.

4.1.1 Theoretical Framework

It was discussed in chapter two that in the endogenous growth equation (Y=f(K,L,E)) in addition to capital and labour, electricity consumption is also considered to be among the primary inputs affecting national output. However, as also noted in chapter two due to the persistent increase in the price of electricity that South Africa has experienced post 2003, this study postulates that such increases may have had a significant detrimental effect on national output and by extension on sectoral output as well. Hence equation 4, below, is expanded to include the effect of the electricity price (P_E) on aggregate output as follow:

$$Y = f(A, K, L, ES(\mathrm{P_E}), \mathrm{P_E}) \qquad (4.0)$$

As mentioned in chapter two, it is expected that $\frac{\partial Y}{\partial K} > 0, \frac{\partial Y}{\partial L} > 0, \frac{\partial Y}{\partial ES} > 0, \frac{\partial Y}{\partial P_E} < 0$, ie, a rise in capital (K), labour (L) and electricity supply (ES), respectively results in an increase in output, while a rise in the electricity price (P_E) causes a reduction in output via the rising input cost channel, Additionally, electricity supply is a function of price and is denoted as ES (P_E). However since capital and labour at the sectoral level are unavailable at the monthly frequency, the study made further simplifying assumptions to equation (4) for estimation purposes, where capital and labour were treated as constants and subsumed into the technology term (A). Thus, the multiplicative Cobb-Douglas model to be estimated in this study is reduced from

$$GDP = AK^{\beta 1}L^{\beta 2}ES^{\beta_3}\, P_E^{\beta_4}e^{ui} \qquad (4.1)$$

to:

$$Sectoral\ \ GDP = A^{*}ES^{\beta_3}\ P_E^{\beta_4}e^{ui} \tag{4.2}$$

where, A^{*}, *inter alia* also accommodates the sectoral capital and labour. Equation 4.2 is now log linearised as follows:

$$\text{LSectoral GD}P_t = \beta_0 + \beta_3\text{L}ES_t + \beta_4\text{L}P_{Et} + u_t \qquad 4.3$$

where, $\text{L}A^{*} = \beta_0$, while *LSectoral GDP* will in turn represent, mining, manufacturing, wholesale and retail outputs, respectively. Note that 'L' which prefixes the variables denotes the natural log of the variable under consideration. In other words, all variables employed in this analysis are transformed into natural logs.

4.2 Definition of the variables and data sources

In this study, the researcher employs the use of electricity supplied, electricity price, and sectoral electricity consumption (that is, Manufacturing and Mining output, Wholesale and Retail Trade) to analyse they relationship. The inspiration behind the choices to estimate these variables came from the global demand for electricity and its important impacts to provides positive effect to the various sectors of the economic based on that the study discussed the most relevant theories that support electricity as an instrument of growth see chapters two and three, respectively. According to Romar (1986), justification of production function, he incorporated human capital; innovation and knowledge are generated within the economic system itself, which is, an input in the production function but with the constant growing dependence on energy and in particular electricity, worldwide, energy is now recognised as being an integral part of the production function which is derived from accumulated work of knowledge. Stern, (1997a) argues that every form of production activity involves work of different types meaning that all modern economic processes must require electricity and there must be limits to the substitution of other factors of production for electricity so that electricity at all times remains an important factor of production based on theories and most of the empirically literature, that provides favourable evidence to support electricity as an engine to economic growth.

The data for this study was collected through secondary sources. More importantly all series were transformed into natural logarithm to generate stationarity in the variance and covariance (Chang *et al*, 2001; Fatai *et a*l 2004). This study covers the sample period from 1991/06- 2015/03. The period of analysis is chosen due to the limitations on the availability of the time series data for almost all the sectoral electricity consumption sectors.

4.2.1 Electricity Supply

Data for electricity consumption is taken from the electricity component of CPI index from statistics South Africa electricity consumption (EC), monthly released electricity Generated and available for distribution (in millions of kwh).

4.2.2 Electricity Price

The electricity price used in this study is taken from the Eskom database. Electricity price obtained is the weighted average price of electricity measured in cents per kilowatt hour (kwh) in South African rand, which includes all three periods of used, described by Eskom Miniflex time of use (TOU): as peak, standard and off-peak.

4.2.2.1 Miniflex time of use

Table 4.1: Calculation of weighted average of electricity price is given by:

Price of difference seasons	Time	Weighted Average
Peak	7am– 10am	5/24
Standard	10am-12pm	8/24
Off Peak	12pm-7am	11/24

Weighted electricity price = 5/24(peak) + 8/24(standard) + 11/24(off peak)). Note that in order to achieve the study objective monthly weighted average electricity price data are used. The following steps were carried out. First the study attempted to obtained the daily weighted average electricity price by calculating the hourly use due to the price of electricity differing between the three times of use stipulated by Eskom Miniflex. Thereafter, this was converted into weeks so as to obtain the weekly weighted average price of electricity before transforming it into monthly weighted average electricity price.

Monthly data between 1991/06 and 2015/03 was employed.

4.2.3 Manufacturing output

The manufacturing sector is included in this research are obtained from the South Africa ReserveBank (SARB). The variable is provided under the code KBP7085N. This series is captured in the total volume of manufacturing output between 1991/06 and 2015/03 and deflated by the GDP deflator (2010=100). Manufacturing output is the main drivers of economic growth as most global trade is based on goods not services. This sector has so far demonstrated high potential not only in terms of export earnings and job creations but also possibly for a country to trade services for most of its goods.

4.2.4 Mining output

This variable denotes the physical volume of total mining output including gold. This variable is available on the Statistics South Africa web page and is deflated by the GDP deflator (2010=100). Over the past decades, mining has been described as the driving force behind South Africa’s economy although it is presently on a downward trend from its peak some decades ago (from 21% contribution to GDP in 1970 to just 6 % in 2011). The mining industry nevertheless continues to make a valuable contribution to South Africa’s economy, most notably in terms of foreign exchange earnings, employment and other economic activities.

4.2.5 Wholesale Trade

The wholesale trade included in this study is collected from South Africa ReserveBank (SARB) under the trade code KBP7087T which is the monthly series between 1991Q3 and 2015Q1. Wholesale trade is a form of trade in which goods are purchased and stored in large quantities and sold in batches of a designated quantity, to resellers and professional users. The series is in index form based on an index of 2012=100.

4.2.6 Retail Trade

The retail trade data is obtained from South Africa ReserveBank (SARB) code KBP 7087T of the statistics page, the data is between 1991Q3 to 2015Q1 in a monthly time series. This variable is classified as the re-sale (sales without transformation) of new and used goods to the general public, for personal or household consumption or utilisation and is based on an index of 2012=100. This sector generates a large part of total employment and private final consumption expenditure, which represents around 60% of total GDP of OECD member countries. Most of the studies have shown that this variable is a very useful indicator of short-term development for the whole economy.

4.3 Methodology

In an attempt to estimate the long and short cointegration relationships between sectoral GDP growth, electricity supply and its prices, as well as two control variables (employment and capital), I followed six steps, starting with the unit root tests. That was to test whether the time series are stationary or non-stationary by using the most popular tests, such as the Augmented Dickey-Fuller (1979), and Phillips and Perron (1988) tests with logged time series and first difference. Thereafter, l used VAR-model estimation for short run analysis of the variables and especially to test for the direction of causality between sectoral growth and electricity supply. However, if the series were integrated of the order one I(1), a Johansen cointegration test was employed. If the times series of the three variables exhibited cointegration, then the long run cointegration Vector Error correction (VEC) model was estimated.

4.3.1 Times series

Time series generated data is different from cross-sectional data, as it is observable over time on a particular variable. Time series observations are not independent of time. Current observations of the variable depend on past observations. This shows time trends over time (Wooldridge, 2013) since the main goal of a time series analysis is to understand seasonal changes and / or trend over time. Therefore we use time series data to investigate how change over time affects the current period. Therefore, this study started by testing the concept of stationarity.

4.3.1.1 Stationarity and non-stationary time series

Basically, a stationary process is one that looks the same at any given time period. According to Gujarati (2004), a times series without any systematic change in its mean and variance and which does not have periodic variations is said to be weakly stationary. Therefore in a basic data process, where the current value of Y depends on its preceding value Y_{t-1} and a white noise error term (random shock) μ_t that is normally distributed with zero mean and variance σ^2 gives as

$$Y_t = \rho Y_{t-1} + \mu_t \tag{4.6}$$

Equation (4.1) exists when conditions of weak stationarity are as follows:

Mean: $$E(Y_t) = \mu \tag{4.7}$$

Variance: $$\text{var}\ (Y_t) = E(Y_t - \mu)^2 = \sigma^2 \tag{4.8}$$

Autocovariance: $$\gamma k = E[(Y_t - \mu)(Y_{t+k} - \mu)] \tag{4.9}$$

Here $E(Y_t)$ and var (Y_t) are constant and finite and $(Y_t,\ Y_{t+k})$ are constant for all periods of t and $k \neq 0$. Most statistical methods have confirmed that a time series can be transformed to become stationary by differencing (d) times and it is thus said to be integrated of order (d). Although a stationary series is more preferable for statistical analysis, it is also common to encounter a non-stationary time series. A time series is said to be nonstationary if it has non constant mean, variance and auto covariance over time. If a non-stationary time series has to be differenced d times to become stationary, then it said to be integrated of order d for example I(d). Many studies have shown that models with non-stationary time series tend to produce spurious regressions, thereby rendering the usual test statistics (t, F, DW and R^2) unreliable (Granger and Newbold, 1974 and Harris and Sollis, 2003). According to Engle and Granger 1987), a non-stationary time series is also characterised by a variance that is time-dependent and proceeds to infinity as time approaches infinity. Basically, if the series under estimation in a model is found to be non-stationary, standard estimation techniques cannot be applied. Two examples of a non-stationary time series are the random walk model, (which can be separated into two types; a random walk without drift and a random walk with drift) and the deterministic trend process.

To explain the concepts of a random walk without drift, consider equation (4.10).

$$Y_t = Y_{t-1} + u_t \tag{4.10}$$

According to this equation (4.10) the current value of Y depends on its past value Y_{t-1} and a white noise error term (random shock) u_t with zero mean and variance σ^2. Where the initial value of Y is assumed to be Y_0, by successive substitution in equation (4.10), it can be shown that:

$$Y_t = Y_0 + \sum u_t \tag{4.11}$$

Therefore,

$$E(Y_t) = E(Y_0) + E(\sum u_t) = Y_0 \qquad (4.12)$$

$$\mathrm{Var}(Y_t) = t\sigma^2 \qquad (4.13)$$

A the equation above shows, the mean of Y is equal to its initial or starting value, which is constant, but as time goes by, the variance of Y increases indefinitely, thus violating a condition of stationarity and thereby making it a non-stationary stochastic process. Equation (4.14) considers random walk with drift.

$$Y_t = \delta + Y_{t-1} + u_t \qquad (4.14$$

where δ is the drift parameter and u_t is the white noise error term. In this type of random walk process, it can be observed in equations (4.15) and (4.16) that both the mean and the variance increase overtime, causing Y to drift outside from its initial value and thus again violate the conditions of stationarity.

$$E(Y_t) = Y_0 + \delta_t \qquad (4.15)$$

$$\mathrm{var}(Y_t) = t\sigma^2 \qquad (4.16)$$

A deterministic trend process can be show as follows:

$$Y_t = \delta + \beta t + u_t \qquad (4.17)$$

Under the deterministic trend model, u_t is the white noise error term and the mean value fluctuate while the variance remains constant. According to Gujarati (2004; 2011), non-stationary time series possesses certain characteristic that allow one to study it only for the period over which data is available. Therefore, it is difficult to explain behaviour of the series in other time periods, thus, rendering it useless for forecasting purposes. With all the underlying reasons mentioned above it is necessary to test for stationarity before any empirical estimation is done, in order to understand the underlying data generating process for application of the appropriate methodology.

4.3.1.2 Stationarity Testing

The following are the three main approaches by which the stationarity of a time series can be estimated, namely, (1) graphical analysis, (2) correlogram and (3) unit root analysis. This study considers both graphical and unit root analysis testing in our chapter five to test for stationarity.

4.3.1.3 Graphical analysis

Testing stationarity by means of plotting a time series and its correlogram before following the recognised methods of testing for stationarity is highly much advisable and considered to be a requirement for any stationarity test as it provides an intuitive feel for the nature of the given variables.

4.3.1.4 Unit Root tests

Unit root testing according to the literature is the most widely used formal approach to investigating the nature of time series. Dickey and Fuller (1979, 1981), proposed this method which involves testing for statistically significant differences of the parameter on Y_{t-1} from equation (4.10). Examining the unit root tests involves running a random walk regression such as the one in equation (4.6) for all the time series variables specified in a given econometric model. The purpose of the unit root test is to confirm whether ρ is equal to one, that is, that there is a unit root.

Having verified stationary conditions of the core variables in this study, in line with many other studies, including those of Wolde-Rufael (2006) and Hou (2009), this study employ the augmented Dickey-Fuller (ADF) test to examine the presence of unit roots in sectoral output, which are, Manufacturing (LMAN), mining output (LMIN), wholesale (LWHOL), retail trade (LRET), electricity supply (LES) and electricity price (LWEP). The test will be used to check the stationarity of the variables before conducting the test for cointegration, since confirming the order of integration is a requirement for almost all time series analysis.

4.3.2 Augmented Dickey- Fuller Tests (ADF)

The augmented Dickey-Fuller (ADF) is a modified version of the simple Dickey-Fuller (DF) for unit root test. This new version was created due to the problem associated with the error term being unlikely to be white noise. This newly modified version includes additional lags of the independent variable to remove the autocorrelation problem and the lag length on the additional terms is determined by using the Schwarz Information Criterion (SIC). These tests are conducted in three steps: firstly, it will test the model without a constant (equation 4.18), Secondly, with a constant (equation 4. 19), and thirdly, with a constant and linear time trend (equation 4.20), in order to determine the degree of integration of the data series. The following three methods are all possible use in ADF test analysis

$$\Delta y_t = \varphi y_{t-1} + \sum_{j=1}^{\rho} \beta_i \Delta y_{t-1} + \Phi L\mathcal{D} + \mu_t \qquad (4.18)$$

$$\Delta y_t = \alpha_o + \varphi y_{t-1} + \sum_{j=1}^{\rho} \beta_i \Delta y_{t-i} + \Phi L\mathcal{D} + \mu_t \qquad (4.19\,)$$

$$\Delta y_t = \alpha_o + \varphi y_{t-1} + \alpha_2 t + \sum_{j=1}^{\rho} \beta_i \Delta y_{t-i} + \Phi L\mathcal{D} + \mu_t \qquad (4.20)$$

4.3.2.1 Hypothesis testing

The above three equations stated that the null hypothesis of a unit root will be rejected if the ADF statistic value is greater than the critical value in absolute terms and then concluded that y_t is a stationary process. In addition the study used the Phillips-Peron tests for the purposes of confirming the results of the ADF test.

4.3.3 Cointegration

The next step after testing for the stationarity status of the individual series is that of testing for cointegration of a linear combination of the series that are being modelled for meaningful long run economic relationships. However, there are various possible problems to be experienced with the use of trended or I(1) times series due to the estimation of spurious regression which arises when all the non-stationary series in the estimation model have the same stochastic trend in common, hence the regression reflects the common trends even if there are no meaningful economic relationships between the variables, (Gujarati, 2004). However, if there exists valid long run economic relationships between the variables then the cointegration tests will indicate the presence of such relationships. The cointegration technique was first developed by Granger (1981) and further expanded by Engle and Granger (1987), with the purpose of providing clear understanding to the scholar in estimating nonstationary series since it is possible that two or more variables may not necessary move together in the early stage but if they have a long run equilibrium or relationship, they will gradually move towards each other over time and their gap or difference will finally disappear, thus, forming a stationary variable (Thomas, 1997). In such situation the spurious regression problem is now eliminated. According to the Asteriou and Hall (2007), method let say that Y_t and X_t are two individually I(1) variable. That is, they contain a stochastic trend, if there is a common relationship between Y_t and X_t, that is.

$$Y_t = \beta_1 + \beta_2 X_t + u_t \qquad (4.21)$$

And the residuals are:

$$\hat{u}_t = Y_t - \hat{\beta}_1 - \hat{\beta}_2 X_t \qquad (4.22)$$

Engle and Granger (1987) define a cointegration relationship as being when the variable Y_t and X_t are $I(d, b)$ where $d \geq b \geq 0$, denoted as Y_t, $X_t \sim CI\ (d, b)$, if Y_t and X_t are I(d) and there exists a vector (β_1, β_2), which gives a mutual relationship between Y_t and X_t, at extend that $\beta_1 Y_t + \beta_2 X_t \sim I(d - b)$. The coefficient vector (β_1, β_2), is referred to as a cointegration vector, and if $\hat{u}_t \sim$ I(0), i.e., stationary, then Y_t and X_t are cointegrated.

Based on the empirical literature, lack of cointegration between time series variables has implications for the method that can be used to test the hypothesised model. For example, in a situation where all series under consideration are stationary, I(0), then a simple vector autoregressive mode (VAR) in level can be employed. In a situation where variables are non-stationary and also no cointegration, the VAR method can also still be applied to test for short run relationships between the variables. In order to achieve this the variables are differenced make to them stationary before running the estimation. Once there is establishment of cointegration between the variables then a vector error correction model (VECM) can now be employed to capture the short run adjustments between variables. But suppose there is I(0) and I(1) variables then the literature proposes that one uses autoregressive distributed lag (ARDL) technique. In most term the majority of economic variables are I(1) and that allows for the Johansen (1991) VAR/VECM method. There are three main popular techniques used in the estimation of cointegration and all will be discussed below.

4.3.3.1 Testing for Cointegration

After establishing that the time series are stationary and the lag selection, it is important to determine whether there exist long run relationships between the series, which means testing the cointegration. Kennedy (2008) suggested that there are three methods applicable to estimate cointegration, namely, the single equation, vector autoregressive, and error correction mechanisms. The single equation method is the special case which account both for autoregressive distributed lag, the Engle-Granger and augmented Engle-Granger, the dynamic ordinary least squares, the fully-modified ordinary least squares, the cointegration regression Durbin-Watson, and canonical cointegration regressions tests, merely for testing the unit roots in the cointegration regression residuals. While the Johansen (1991) vector autoregressive method account for the number of cointegration relation as well as to estimates the matrix of cointegration vectors (Johnston and DiNardo (1997). the error correction mechanism determines the coefficient of the error correction term which is known as the Granger representation theorem.

In our next chapter, the fully-modified ordinary least squares, dynamic ordinary least squares, Johansen and the autoregressive distributed lag bounds testing method will be carried out. According to Enders (2010), there are three most well-known and hence most important methods used to test for cointegration. These are the Engle-Granger (1987), the Johansen (1988) and the Stock Watson (1988) methodologies.

4.3.3.2 The Engle-Granger (EG) and Augmented Engle-Granger (AEG) Tests

The ultimate goal of the Engle-Granger test is to confirm whether the series under investigation are cointegrated through examining the residuals. If the residuals are stationary, then we conclude that the series are cointegrated. This process involves checking the order of integration first of each variable through unit root test ing, specifically the DF and ADF tests. After confirming that the variables are integrated of the same order, the hypothesised long run relationship (provided in equation (4.24) for instance) can now be estimated via OLS and again the estimated errors are retained and tested for stationarity.

Equations (4.24) and (4.25) demonstrate the DF and ADF test for the estimated residuals

$$Y_t = \beta_1 + \beta_2 X_t + e_t \tag{4.23}$$

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + v_t \tag{4.24}$$

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + \sum_{i=1}^{n}\delta_i\,\Delta + w_t \qquad (4.25)$$

where Δ is the first difference operator, e_t represents the residual of the cointegration regression, and v_t and w_t are the random error terms. Based on the DF, ADF and PP tests, the hypothesis testing in the EG and AEG tests is conducted in the same format. The null and alternative hypotheses are provided as follow:

H_0: $a = 0$ (i.e., no cointegration)

H_1: $a < 0$ (i.e., cointegration exists)

These hypotheses are tested by joining the test statistic on the regression coefficient a, to a particular set of critical values based on the number of explanatory variables in the cointegration regression computed by Engle and Granger (1987). If e_t is found to be $I(0)$ then H_0 is rejected in favour of H_1, thus Y_t and X_t are cointegrated.

4.3.3.3 The Johansen method for cointegration

Johansen (1988) and Johansen and Juselius (1990) suggested a maximum likelihood estimation procedure to simultaneously estimate a system of equations that have two or more variables where each variable can potentially serve as an endogenous (dependent) variable in its own right and if such cointegration vector(s) is (are) deemed to exist together with their own error correction mechanism ECM(s). This approach is an improvement on the traditional Engle-Granger model which estimates a single regression (vector) with its accompanying ECM. In other words, regardless of the choice of endogenous variables one can test for the possibility of having more than one cointegration vector in a higher dimensional system. The Johansen maximum likelihood procedure for the cointegration is estimated as a VAR system with multiple equations (vectors) relating endogenous variables to lags of all other variables in the system. The trace statistic and Maximum Eigenvalue test statistic are used to determine the number of cointegration vectors in the system, usually at the 5% significance level. If there is no cointegration it means that there is no long run relationship between variables, meaning that only short run relationships may be estimated via VAR modelling of I(0) variables. In order to check the cointegration, we first have to check the result of the cointegration test. The result includes the rank, eigenvalue, trace statistic and critical value. These test statistics are given by:

$$\lambda_{trace}\,(r) = -T \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right) \tag{4.26}$$

$$\lambda_{max}\,(r, r+1) = -T \ln\left(1 - \hat{\lambda}_{r+1}\right) \tag{4.27}$$

where λ is the estimated value for the ith ordered eigenvalue from the long run coefficient matrix and T is the number of usable observations. The null hypothesis is that the number of cointegrating relationship is equal to r which is provided in the “maximum rank” with the alternative being that there are more than r cointegration relationships. The further the eigenvalues are from zero, the more negative is $\ln(1 - \hat{\lambda}_i)$ and $\ln(1 - \hat{\lambda}_{r+1})$ and the larger the λ_{trace} and λ_{max} statistics, respectively. The null hypothesis is rejected if the trace statistic is greater than the critical value. That is H0: r = 0. Is rejects and H0: r = 1.when a test is not rejected. Thus, method shows the unique nature of the maximum likelihood estimation described by r cointegration vectors. (Babatunde and Adefabi, 2005;10).

So far the Johansen methodology has received more recognition than other techniques regarding cointegration testing methods. Gonzalo (1994) mentioned that the Johansen maximum likelihood is more reliable especially when the errors are not normally distributed. On the other hand, the Johansen procedure has been criticised due to the large sample test and its results can be sensitive given the number of lags used in the estimation system, and again there is the possibility of having autocorrelation problems. When there is a cointegration relationship in the Johansen test, it implies that there is long-run association between the variable, therefore we propose the VECM (Vector Error Correction Model) or else we use VAR in difference.

To explain mathematically how the Johansen methodology works, let us say for example that we have four endogenous I(1) variables Y_t, X_t, $\mathbb{Z}_t$, and Λ_t which produce the matrix nation for $Z_t = (Y_t, X_t, \mathbb{Z}_t, \Lambda_t)$ as follows:

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \mathrm{A}_3\, \mathrm{Z}_{t-3} + \ldots + A_k Z_{t-k} + \mathrm{u}_t \qquad (4.28)$$

where Z_t is a $k \times 1$ vector for endogenous variables, A_i is a $k \times k$ matrix parameter and u_t is a vector of independently and identically distributed innovations with zero mean.

The vector error correction model generated for Z_t is displayed as:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta \mathrm{Z}_{t-2} + \Gamma_3 \Delta \mathrm{Z}_{t-3} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mathrm{u}_t \quad (4.29)$$

where $\Gamma_i = -(I - A_1 - A_2 - \mathrm{A}_3 \ldots - A_k)$ $(i = 1,2,3,\ldots,k-1)$ and $\Pi = -(I - A_1 - A_2 - \mathrm{A}_3 \ldots - A_k)$.

This mode justification includes information both on the short run and long run adjustments change in Z_t. the Γ_i represents $4 + 4$ coefficient matrix shown by the short run dynamic effects and the Π is the long run multiplier that contains information concerning long run relationships. Though we can further derive $\Pi = \alpha\beta'$ where a contains the speed of adjustment to equilibrium coefficients and β' is a matrix of the long run coefficients, the term $\beta' Z_{t-k}$ is embedded in our equation (4.29) showing a $k - 1$cointegration relationship which reflects that Z_t converges back to its long run equilibrium (Harris, 1995).

According to Asteriou and Hall (2007) and Harris (1995) if Π has a full rank that is $r = n$ linear independent columns, $Y_t, X_t, \mathbb{Z}_t$ and,Λ_t are $I(0)$. If Π has a reduced rank (for instance $r \leq (n-1)$ linearly independent columns), there are $r \leq (n-1)$ cointegrating relationships. Finally, if the rank Π is zero, which means that there are no linearly independent columns, then it implies that there are no cointegrating relationships. In most case, Π has a reduced rank and when there are multiple cointegration vectors, there exists a cointegration vector for each subset of $n - r + 1$ variables and the cointegrating vectors become difficult to interpret. To further illustrate how this method works, let say that $r = 3$, the ΠZ_{t-1} component of equation (4.29) which captures the long run (cointegration) and short run adjustment relationships as:

$$\Pi Z_{t-1} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ X_{t-1} \\ \Lambda_{t-1} \end{bmatrix} \qquad (4.30)$$

Thus,

$$= \begin{bmatrix} \alpha_{11}\varepsilon_{1_t} & \alpha_{12}\varepsilon_{2_t} & \alpha_{13}\varepsilon_{3_t} \\ \alpha_{21}\varepsilon_{1_t} & \alpha_{22}\varepsilon_{2_t} & \alpha_{23}\varepsilon_{3_t} \\ \alpha_{31}\varepsilon_{1_t} & \alpha_{32}\varepsilon_{2_t} & \alpha_{33}\varepsilon_{3_t} \end{bmatrix} \qquad (4.31)$$

where $\varepsilon_{1_t} = (\beta_{11}Y + \beta_{12}X + \beta_{13}\Lambda)_{t-1}$ and $(\varepsilon_{2_t} = \beta_{21}Y + \beta_{22}X + \beta_{23}\Lambda)_{t-1}$ and $\varepsilon_{3_t} = (\beta_{31}Y + \beta_{32}X + \beta_{33}\Lambda)_{t-1}$ are the three cointegrating vectors and their speed of adjustment in case of disequilibrium are provided by α_{11}, α_{12}, α_{13}, $\alpha_{21,}$ $\alpha_{22,}\alpha_{23,}$ $\alpha_{31,}$ α_{32} and α_{33}. Nevertheless, this most used method also has its own weakness on the basis that the parameter estimates in one equation can be affected by misspecifications in other equations.

4.3.3.4 Vector Autoregressive (V AR) Models

In econometrics analysis, VAR methodology has gained more popularity due to its ability to accommodate simultaneous-equation models. Sims (1980) states that in a situation where there is simultaneity among variables (for instance, variables in a particular model are explained by the variables they are used to determines), there must not be any distinction between the endogenous and exogenous variables. Therefore all variables are considered and treated as endogenous and each equation must demonstrate the same number of regressors, providing justification of the VAR techniques (Gujarati, 2004). The VAR method, as noted in our above sub-section, is mainly used when all variables are stationary. But in a situation where some variables generate non-stationary, it means that those with non-stationary must be differenced and converted to stationary variables before they can be used in a VAR model (Koop, 2013). On the other hand, Sims (1980) criticised the idea of differencing non-stationary variables since the primary goal of VAR analysis is to examine the interrelationships among variables in a system and not the parameter estimates. He further raised the point that differencing non-stationary data could cause loss of co-movement information within the data.

The VAR model was estimated but In order to determine the number of lags both models Akaike’s Information Criterion (AIC) and the Schwarz’s Bayesian Criterion (SBC) test were used. However, this method is used for analysing the relationships between the variables and to find out the extent at which these variables affect one another on the basis of current and past economic values in the short-run periods.

In accordance with the VAR estimation techniques, the model can be written as follows:

$$\mathrm{y_t} = \mu + A_1 Y_{t-1} - - - + A_P Y_{t-P} + \varepsilon_t \tag{4.32}$$

Where Y is an $nx1$ vector of variables that are integrated of order one [1 (1)], μ is a vector of constant, ε_t is an $nx1$ vector and $A1, A2 \ldots . A_P$ are PxP matrices of estimable parameters. According to Johansen and Juselius (1990) the model incorporates a vector of nonstochastic variables such as (Dt) orthogonal to the constant term such as dummy variables. Thus, the model can be given as:

$$\mathrm{y_t} = \mu + A_1 Y_{t-1} - - - + A_P Y_{t-P} + \phi D_t + \varepsilon_t \tag{4.33}$$

In most cases, economic times series are non-stationary processes and therefore, the above VAR model discussed is in its first differenced and, can be illustrated as follows:

$$\Delta \mathrm{Y_t} = \mu + \Pi Y_{t-1} + \sum_{\mathrm{i=0}}^{\mathrm{p-1}} \varphi_{\mathrm{1j}} \, \Delta Y_{t-1} + \Phi \mathrm{LD} + \varepsilon_t \tag{4.34}$$

where

$$\Pi = \sum_{\mathrm{i=1}}^{\mathrm{p}} A_{t-1]}$$

$$\Gamma = \sum_{\mathrm{j=i+1}}^{\mathrm{p}} A_j$$

Γ and Π represent short run adjustment and long run relationship between the variables respectively. The rank of Π demonstrates the number of linear combinations of the Y_t variables that are stationary.

4.3.3.5 Vector Error Correction model (VECM)

The VECM method is applied if there are cointegrated relationships between variables in difference, but if the variables are not cointegrated or proved to have no long run relationship, the testing procedure will stop here and one will not go for the construction of an error correction model. VECM is a special method for the vector autoregressive that has cointegration data. The standart model for VECM is as follows:

$$\Delta \mathrm{X}_t = \Pi \mathrm{X}_{t-1} + \sum_{i=1}^{p} \pi_i \, \Delta \mathrm{X}_{t-1} + \varepsilon_t \tag{4.35}$$

where X_t is a $k \times 1$ vector for endogenous variables, Π is a $k \times k$ long run multiplier matrix and π_i are $k \times k$ coefficient matrices showing the short run dynamic effects. p is the VAR lag length and ε_t is a vector of independently and identically distributed innovations with zero mean. $\Pi \mathrm{X}_{t-1}$ is the vector error correction mechanism that captures the long run relationship between variables and the short run adjustments consistent with the long run relationship. Equation 4.36, is a traditional VAR in first differences that is when all elements of π are equal to zero. In the VECM method we obtain three important feature or structures. Firstly, we can generate the short-run coefficient matrices which include the parameters of short run adjustment of each variable with itself and to the other variables at its own lag time in the model. Secondly, we obtain the long run cointegration matrix which shows the long run equilibrium relationship between the variables in the model. Lastly, to obtain the matrix of the speed of adjustment terms which is an error correction in case of any deviation from the long run equilibrium will be corrected gradually through short run adjustment.

According to Gujarati (2004), if a vector (X_t) of two or more variables are cointegrated, then the long term or equilibrium relationship that exists between these variables can be expressed as ECM. This means tests for the error correction model if and only if the variables are cointegrated. For the purpose of this study the ECM is therefore given by:

$$\Delta \mathrm{L}YMA_t = b_{10} + \alpha_1 \varepsilon_{t-1} + \sum_{\mathrm{i=1}}^{\mathrm{n}} \lambda_{1i}\, \Delta \mathrm{L}YMA_{t-1} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \varphi_{1\mathrm{j}}\, \Delta \mathrm{L}ES_{t-1} + \sum_{\mathrm{K=1}}^{\mathrm{n}} \delta_{1k}\, \Delta \mathrm{In}WEP_{t-1} + \phi \mathrm{LD} + u_{1t} \quad (4.36)$$

$$\Delta \mathrm{LYMI}_t = b_{20} + \alpha_2 \varepsilon_{t-1} + \sum_{\mathrm{i=1}}^{\mathrm{n}} \lambda_{2i}\, \Delta \mathrm{LY}MI_{t-1} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \varphi_{2\mathrm{j}}\, \Delta \mathrm{L}ES_{t-1} + \sum_{\mathrm{K=1}}^{\mathrm{n}} \delta_{2k}\, \Delta \mathrm{LW}EP_{t-1} + \Phi \mathrm{LD} + u_{2t} \quad (4.37)$$

$$\Delta \mathrm{LYWHO}_t = b_{30} + \alpha_3 \varepsilon_{t-1} + \sum_{\mathrm{i=1}}^{\mathrm{n}} \lambda_{3i}\, \Delta \mathrm{LY}WHO_{t-1} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \varphi_{3\mathrm{j}}\, \Delta \mathrm{L}ES_{t-1} + \sum_{\mathrm{K=1}}^{\mathrm{n}} \delta_{3k}\, \Delta \mathrm{LW}EP_{t-1} + \Phi \mathrm{LD} + u_{3t} \quad (4.38)$$

$$\Delta \mathrm{LYRET}_t = b_{40} + \alpha_4 \varepsilon_{t-1} + \sum_{\mathrm{i=1}}^{\mathrm{n}} \lambda_{4i}\, \Delta \mathrm{L}RET_{t-1} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \varphi_{4\mathrm{j}}\, \Delta \mathrm{L}ES_{t-1} + \sum_{\mathrm{K=1}}^{\mathrm{n}} \delta_{4k}\, \Delta \mathrm{LW}EP_{t-1} + \Phi \mathrm{LD} + u_{4t} \tag{4.39}$$

where

Sectoral output is represented by Manufacturing (LY$MAN_{t)}$ Manufacturing and Mining output (LYMIN$_t$), Wholesale (LYWHO$_t$) and Retail Trade (LYRET_t)

L ES_t Is the Electricity supply

LW EP_t Is Electricity Price

Note that all variables have been transformed into natural log form, hence all possess the Lprefix (expect for LD which stands for load shedding dummy). Note further that the LY prefix denotes that the sectoral output variables in question are a share of GDP.

where Δ in the equations is the first difference operation, and n is the lag order. U_t is the white-noise error term and LD captures the load shedding effects on the respective variables that is the Dummy variable that =1 in 2007 and 2008, otherwise zero

If cointegration has been detected between series, it means that there is a long run relationship between the variables and thus a Vector Error Correction model (VECM) can be estimated to assess the short run properties of the cointegrated series. In a situation where there is no cointegration, VECM will no longer be required so VAR in levels (if variables are I(0)) or in difference (if variables are I(1)) will be applied to test the significance of the model.

Accordingly, in VECM estimation, the cointegrated rank indicates the number of cointegrated vectors. E.g. a rank of two implies that two linearly independent combinations of the non-stationary series will be stationary. The negative and significant coefficient (α_1) of the ECM (i.e. ε_{t-1} in equation 4.36) shows that any short-term fluctuations between the independent variable and the dependent variable will give rise to a stable long run relationship between the variables (Karrar, 2009). If, for instance coefficient of the (ε_{t-1}) are significant it implies bidirectional causality among the variables.

In a situation where the coefficient failed to fulfil the property of being negative and significant, we can conclude that no stable long-term relationship exists between the variables (Karrar, 2009). Furthermore, Gujarati (2004) indicated that the magnitude of the error term coefficient provides the clear extend at which the speed of adjustment converge overtime when there is shock in system.

4.3.3.6 Hypothesis testing

The hypothesis to be tested is whether a long run cointegration relationship between electricity consumption, electricity prices and economic growth does indeed exist. The sectoral demand for electricity had to adjust rapidly to price changes. The null hypothesis of no cointegration $(\mathrm{H}_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0)$ will be tested against the alternative hypothesis $(\mathrm{H}_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0)$. The rejection of the H_0 hypothesis by the F-statistic leads to the acceptance of the H_1 hypothesis which implies a long run equilibrium relationship between the variables exists. Additionally, acceptance of H_1 will enable us to quantify the nature of the long run cointegration relationships between the mentioned variables thereby shedding more light on the validity of the hypothesis mentioned in various equations.

4.3.4.1 Granger Causality Test

The Granger Causality Test is used to observer the direction of causality between the variables. This can be done irrespective of whether or not the time series of one variable is useful in predicting another variable. For instance if a change in the X_t variable resulted in a change in the Y_t variable, then we can say that ‘X_t granger causes Y_t. The granger causality test for X_t and Y_t estimation in VAR model is given as:

$$Y_t = a_1 + \sum_{i=1}^{n} \beta_i X_{t-i} + \sum_{j=1}^{m} \phi_j Y_{t-j} + e_{1t} \qquad (4.40)$$

$$X_t = a_2 + \sum_{i=1}^{n} \theta_i X_{t-i} + \sum_{j=1}^{m} \varrho_j Y_{t-j} + e_{2t} \qquad (4.41)$$

where εY_t and εX_t are uncorrelated white-noise error terms. The first step in estimation the Granger causality test, like in our equation (4.40) is to regress Y on all lagged values of Y without the lagged X variables (for example. restricted regression):

$$Y_t = a_1 + \sum_{j=1}^{m} \phi_j Y_{t-j} + e_{1t} \qquad (4.42)$$

After equation (4.42) has been estimated its restricted residual sum of squares (RSSr) is then retained. The next step is to estimate equation (4.40) and retain its unrestricted residual sum of squares (RSSur). Once all these are done then the next step is to check the significance of coefficients through testing hypothesis with the null hypothesis supporting that$\sum_{i=1}^{n} \beta_i = 0$, meaning that X_t does not granger causeY_t. The test for this hypothesis is done through the use of F test statistics, and is provided in the following format:

$$F = \frac{(RSS_r - RSS_{ur})/m}{RSS_{ur}/(n-k)} \qquad (4.43)$$

The results for the following hypothesis can be provided through Eviews 8. If the computed F value > than the critical F value at the specified level of significance, the null hypothesis is rejected on the basis that X_tGranger causesY_t. It is possible that the estimation of equation (4.42) and (4.43) would leads to different causality results. Firstly, if the lagged values of X are statistically significant and the lagged values of

Y are not statistically significant, there is unidirectional causality running from X_t and Y_t. Alternatively, there is unidirectional causality from Y_t to X_t when the lagged terms of Y in equation (4.43) are statistically significant and the lagged of X in our equation (4.42) are not statistically significant. On the other hand of a bi-directional causality between the two variables is established when both X and Y terms are statistically significant in both equations. Lastly, if both X and Y are not statistically different from zero in both equations, then Y_t and X_t are not related to one another.

4.5 Conclusion

This chapter began by defining the theoretical Cobb-Douglas model linking sectoral output, to electricity prices and electricity together with the two control variables of capital and labour. This was followed by a definition of variables used to assess the theoretical model, as well as their sources. Thereafter the concepts of stationarity and cointegration were discussed, together with their respective testing procedures. Then the Johansen VAR/VECM model was described in great detail followed by the VAR model and the VAR based granger causality approach. The I(1) cointegrated variables will be modelled using the Johansen VAR/ VECM techniques.

CHAPTER FIVE

ESTIMATION AND INTERPRETATION OF RESULTS

5.0 Introduction

Followed the empirical estimation procedures used in the analysis of the data, this chapter presents the results and interpretation of the relevant data analysis. As outlined earlier in our previous chapters, the primary objective of this empirical study is to provide clear understanding of the influence electricity has on economic growth. To do these tests, single and multiple estimation methods are employed and the rest of the paper is organised as follows:

Section 5.1 considers the properties of basic descriptive statistical and graphical findings to conclude the properties of the natural log transformation indicators for economic growth (manufacturing, mining output, wholesale and retail trade), electricity consumption and weighted electricity price. Section 5.2 deals with determining the order of integration, which is done via a test of a unit root, Augmented Dickey-Fuller (ADF) test was carried out.

Section 5.3 presents the results of the vector autoregressive (VAR) and vector error correction model (VECM) analysis, which is to test the existence of a long run relationship between sectoral economic growth, electricity consumption, electricity price, using the Johansen cointegration procedure. Then the VECM estimated, provide guard line to obtain the short run dynamics of the long run relationship and derived short-run elasticity coefficients of the mentioned variables. The researcher also utilised the Granger causality approach to identify the causal linkages among the variables using the VAR framework. Section 5.4 provides the conclusion to the chapter.

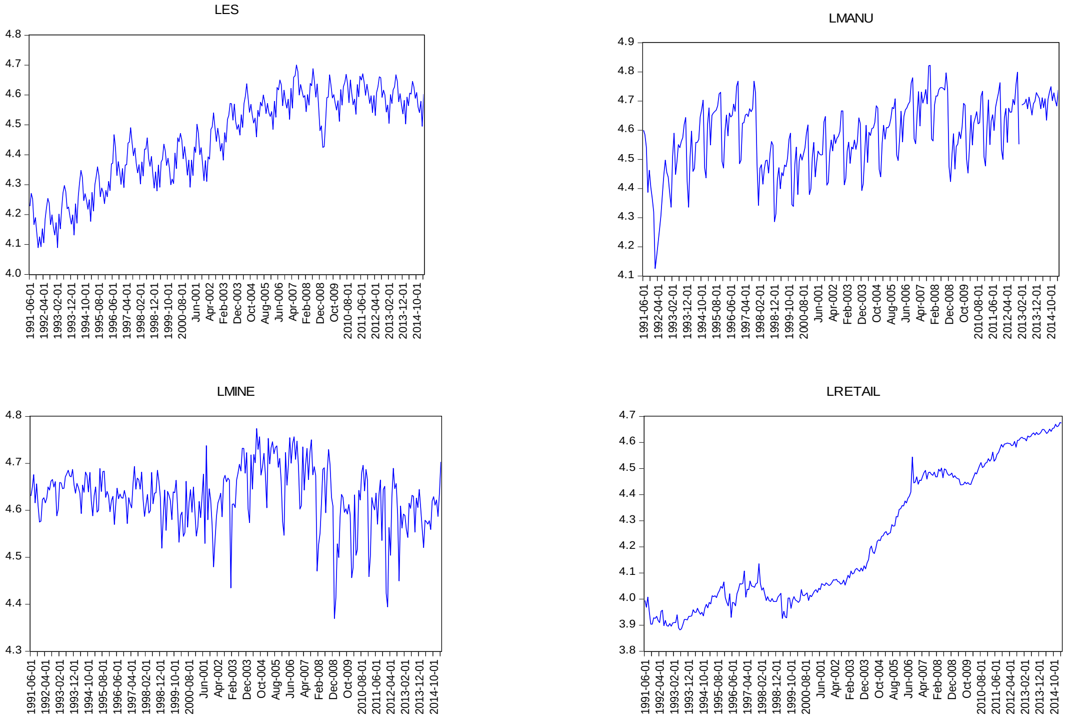
5.1 Descriptive data

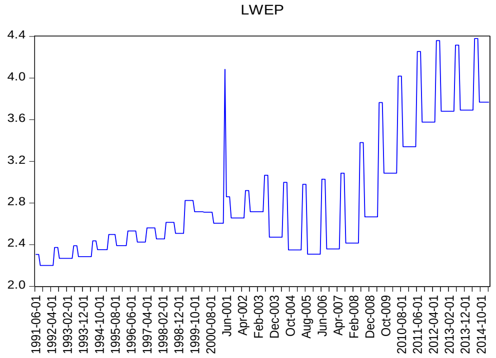
In econometrics it is necessary to carry out a preliminary checking of the data series under investigation so as to understand the features of the data in a study before doing the econometrics analysis.

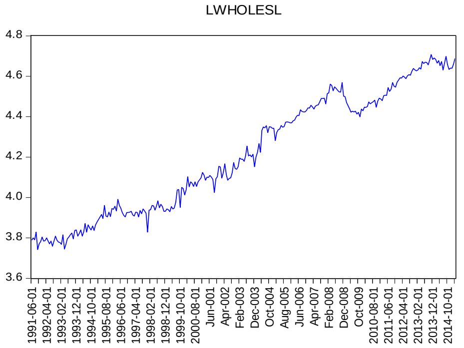
5.1.1 Graphical Analysis of Data

Before performing the necessary inspection of time series data used in this research, graphical plots of each variable were constructed. Figure 5.1 shows monthly time series plots for each of the variables in level form. The outcome of figure 5.1 leads us to concludes that all the variables are likely to be non-stationary, demonstrated by an upward trend which displays stable trends from 1991 to 2015. Regarding figure 5.1, the researcher observed that the variables turn to be stationary when they are plotted in first differences (see figure A1 of appendix A), and therefore, the series are most likely to exhibit the time-independent and mean-reverting tendencies inherent in stationary time series. However, in order to satisfy the researcher's objectives, formal stationarity tests are conducted in section 5.2 of this chapter.

Figure 5.1: Graphic plot of the variables in levels







Source: generated by the researcher

5.2 Unit root and stationary tests

Before determining whether the variables granger cause each other as well as the direction of causality, we first perform stationarity test. The stationarity property of the data and the order of integration were carried out. The study use the Augmented Dickey- Fuller to test for the presence of the unit root in the series. According to the empirical study it is necessary to know the stationarity position of the data before testing the cointegration to confirm that variable are integrated of order one and not more than in order to avoid spurious cointegration results. The variables are tested with both “intercept” as stated in equation (2) and intercept and trend as in equation (3).

Table: 5.1: Unit Root Test: Monthly

Variables	Test type	Level Test statistic	Critical statistic	Restriction	1st Difference Test- statistic	Critical statistic	Integration
LMAN	ADF	1.19 * (13)	-2.57	None	-4.68* (12)	-2.57	(1)
LMIN	ADF	-1.81* (13)	-3.45	Constant	-6.53* (12)	-3.45	(1)
LWHO	ADF	-2.80 * (2)	-3.99	Constant, Liner Trend	-16.97* (1)	-3.99	(1)
LRET	ADF	-2.50* (1)	-3.99	Constant, Liner Trend	-16.00** (1)	-3.42	(1)
LES	ADF	2.12* (12)	-2.57	None	-4.72* (11)	- 2.57	(1)
LWEP	ADF	-0.98*(14)	-3.99	Constant, Liner Trend	-4.51** (13)	-3.42	(1)

*Notes: *and ** indicate statistical significance at 1% and 5%, respectively. The bracketed lag length for the ADF tests are automatically determined by the Schwarz Information criterion (SIC).*

Tables 5.1 shows the traditional unit root test results for monthly time series using the ADF test result for the monthly series data. The null hypothesis which states that the variables under consideration have a unit root is rejected in favour of the alternative hypothesis of no unit root if the t-value obtained is greater than the critical values of the ADF statistics in absolute terms. So far, there is evidence to believe that they become stationary in their first difference according to the results obtained, all the variables can be said to be integrated of order one or I(1). Based on the unit root test results obtained, it is clear that none of the time series variables included in the model is I(2) order otherwise known as integrated of order two. Therefore, we proceed to estimates the model using VECM statistical method since the findings suggest that there is a possibility of one or more cointegration vectors in the model.

5.3 VAR and VECM Estimation Processes

This section of the research work takes account of the vector autoregressive (VAR) and vector error correction model (VECM) analysis procedures. More importantly, the interpretations of the estimated results are also reported.

5.3.1 Stability of the VECM

The study applied the Autoregressive (AR) roots tests as a standard method to examine the stability of the VAR (2) procedure and found that one of the roots lie close to one. Therefore, the traditional stability condition obtains as provided in table A2 and figure A2, of Appendix A. According to Johnston and DiNardo (1997) if an individual root has a modulus less than one, all the endogenous variables in a system will be I (0) and as a result the variables in the system requires no differencing. Since this finding coupled with the fact that almost all the variables in the study's multivariate model are I(1), shows that it is more appropriate to use the VECM approach to check if there exists a long run interaction among the series. For this reason, the Johansen test for cointegration is more suitable.

5.3.2 VECM Estimation Procedure

Having confirmed that all the series are integrated of the same order, this allows us to set up the cointegration regression and test for cointegration. In our study, we check the cointegration using the VECM cointegration test. This test is a superior test for checking cointegration. This test is based on maximum likelihood estimation and two statistics: Maximum eigenvalues and a trace statistics. But before we proceed to test cointegration it is important first to confirm the optimal lag length.

5.3.2.1 The lag length Selection

Following the establishment of the existence of cointegration, the lag length is determine based on the first difference variables from the unrestricted models using the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC). Both the AIC and SBC test results are presented in Table B1, Appendix B. Accordingly, the Johansen cointegration test starts with choosing the optimal lags length to test for cointegration, in the case of this study the optimal lag length is at 4, except for the mining and manufacturing that is at lag 5. It is actually recommended that with monthly and quarterly data the maximum lag selection number for VAR or VECM should be within 4 and 5, based on the AIC and SBC criteria that the models with the lowest critical values should be selected and it is absolutely not allowed to fix the lag. Basically, the unrestricted VAR estimation is based on a reducing down and re-estimating of the model for one lag less until zero (Asteriou and Hall, 2007). In order to proceed further, the test for mutual long run equilibrium relationship between electricity consumption, electricity price and sectoral economic growth by performing bivariate unrestricted cointegration tests with a constant and with a deterministic trend.

5.3.2.2 Deterministic Components

This step is used to determining whether the estimation can include an intercept and trend in the model. According to Asteriou and Hall (2007) and Harris (1995):

- Case 1: No intercept or trend in the cointegration equation or VAR. This rarely occurs in practice since the intercept is needed in order to account for adjustment in the unit of measurement of the variables in the model.

- Case 2: Intercept but no trend in the VAR model. In this case, the intercept is restricted to the long run model.
- Case 3: Intercept in the cointegrating vector with no trend in the cointegrating vector and VAR. It shows that the intercept in the cointegrating equation is cancelled out by the intercept in the VAR, leaving only an intercept in the short run.
- Case 4: Intercept in both the cointegrating equation and the VAR model, a linear trend in the cointegrating equation but not in the VAR model. Therefore, no time trend exists in the short-run.
- Case 5: Intercept and quadratic trend in the cointegrating equation, and an intercept and linear trend in the VAR model. This case is also not an implausible option as it is problematic to intercept from an economic viewpoint.

Table 5.2, below displays the summary of the five assumptions that are applicable in estimating cointegrating relationships among the variables in the study's model.

Table 5.2: Summary of Cointegration Assumptions

Data Trend:	**Case1:** **None**	**Case 2:** **None**	**Case 3:** **Linear**	**Case 4:** **Linear**	**Case 5:** **Quadratic**
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

The above Table 5.2 shows the five different assumptions that can be made with regard to the possible cointegrating relations that might exist among the variables in the system. Note, table 5.4 displays the possible summary of the cointegration assumption. The original copies for each monthly cointegration assumption are in Table C 9, C10, C11 and C12 of Appendix C. However, since in practice case 1 and case 5 are assumed to be implausible for microeconomic time series data and rarely used, we then focus on the remaining cases 2, 3 and 4 in the model. The results show evidence of the existence of a long run equilibrium relationship among all variables in the estimation model. When there is intercept and no trend, such as in case 2, the trace and maximum eigenvalue tests statistic tend to agree with each other, so case 2 says there will be one cointegrating relationship and, the same as in the case 3 and 4, one cointegrating relationship was suggested by both trace and maximum eigenvalue tests, which shows strong evidence of only one cointegrating vector. Thus, the study proceeded to estimate the Johansen cointegration test of the variables based on case 2, 3 and 4.

5.3.2.3 Cointegration Tests Results

In section 5.2 of the study, the unit root tests suggested that all the variables are stationary at first difference. Empirically theories contend that econometrics analysis with non-stationary variables make no sense unless their shared linear combination results in a stationary series. In the case of this study, all the estimated variables satisfied this condition. Therefore, we moved on to test for the long run cointegration relationships among the stationary variable considered in the study.

Table 5.3: summarised results for monthly cointegration

Endogenous Variables	H_0:Rank=R	Trace Statistic	0.05 Critical Value	Max-Eigen/value Statistic	0.05 Critical Value
LMAN, LES, LEP	r = 0*	101.09	35.01	90.10	24.25
	r < 1***	10.98 ***	18.39***	8.62***	17.14***
	r < 2*	2.36	3.84	2.36	3.84
LMIN,LES, LEP	r = 0*	93.87	29.79	85.97	21.13
	r < 1***	7.89***	15.49***	5.15***	14.26***

	r < 2*	2.73	3.84	2.73	3.84
LWHOL, LES, LEP	r = 0*	81.76	29.79	76.17	21.13
	r < 1***	5.58***	15.49***	5.17***	14.26***
	r < 2*	0.41	3.84	0.41	3.84
LRET, LES, LEP	r = 0*	42.41	29.79	34.03	21.13
	r < 1***	8.37***	15.49***	8.12***	14.26***
	r < 2*	0.25	3.84	0.25	3.84

Both Trace and Max-eigenvalue indicates 1cointegration at the 0.05 level

**denotes rejection of the hypothesis at the 0.05 level*

***MacKinnon-Haug-Michelis (1999) P-values*

Sources: Estimation results

Table 5.3 above provides the results for cointegration analysis and from all indications it is shown that there is substantial evidence in support of a cointegration relationship between the variables (LMAN, LMIN, LWHOL, LRET,) when electricity supply (LES) and electricity price (LWEP) are treated as determinants variables to sectoral growth. To determine the number of cointegration vectors two tests statistics were used the Maximum eigenvalues (λmax) and trace statistics ($\lambda trace$) are captured. For k-endogenous variables with each having a single unit root, there is more probability to find from zero to k-1 linearly independent cointegrating relations. The trace test ($\lambda trace$) test suggest that the null hypothesis of r cointegration vectors against the alternative hypothesis of k cointegration vectors, where k is the number of endogenous variables, for r=0, 1, 2…, k-1. The maximum eigen-values test, on the other hand, tests the null hypothesis of r cointegrating vectors against the alternative of r +1 cointegrating vectors.

In our results, both trace and eigenvalue tests statistics rejected the null hypothesis of no cointegrating vectors at the 5% level of significance. The trace test shows that the null hypothesis of r=0 cointegrating relation is rejected and the alternative r> 0 cointegrating equations is accepted. This means that there is one cointegrating equation since the null hypothesis of r≤ 1 could not be rejected. The maximum Eigen/likelihood ratio test also supports the same results. It confirms that the null hypothesis of r=0 cointegrating relation is rejected in favour of the alternative r=1. The outcome of these results from both tests determines that the rank of the cointegration is unity. This means that among the variables there is, at least, one long run relationships.

5.3.2.4 VECM Analysis and Results

The findings from our empirical results of non-stationarity and cointegration in the time series make it impossible to use a standard VAR-model. We, therefore, proceed to estimate the VECM. The Vector Error Correction model is a specially designed approach within the VAR framework for variables that are stationary in the first difference. This subsection reports both the long run cointegrating vector – involving sectoral output, electricity supply and weighted electricity prices – and the short run adjustment equation for sectoral output relative to the mentioned variables as well as the error correction mechanism which captures the readjustment of the system due to deviations from the long run equilibrium. In chapter four the VAR/VECM was discussed under the following generic equation (see equation 4.30 of the previous chapter) which is repeated here for convenience:

$$\Delta Z_t = \boldsymbol{u_0} + \boldsymbol{\Pi X_{t-1}} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma_{iY} \Delta Z_{t-i}} + \boldsymbol{\varepsilon_t} \qquad (5.0)$$

Where Z_t represents the variable vector comprising sectoral output, electricity supply and weighted electricity price. It was established earlier in this chapter that the rank of matrix $\boldsymbol{\Pi}$ is one (ie., r=1, implying there exists just one long run cointegrating vector), hence the matrix can be written as $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$, with $\boldsymbol{\beta}$ containing the r cointegrating vectors and $\boldsymbol{\alpha}$ describing the speed of adjustment to the long run equilibrium. Additionally $\boldsymbol{\Gamma_i}$ are k x k coefficient matrices capturing the short run dynamic effects. However since the study used a pth VAR model and in VECM form it is differenced to result in a p-1 order VECM model and $\boldsymbol{\Gamma_{iY}}$ becomes a p-1, k x k coefficient matrix capturing just the p-1 order lags. Additionally, $\boldsymbol{\mu_0}$ captures the vector of constants. Moreover $\boldsymbol{\Pi Z_{t-1}}$ can be expanded as follows:

$$\mathbf{\Pi} Z_{t-1} = \begin{bmatrix}\alpha_{11}\\ \alpha_{12}\\ \alpha_{13}\end{bmatrix} [1 \quad \beta_{11} \quad \beta_{12} \quad \beta_{13}] \begin{pmatrix} LSectoral\ Output \\ 1 \\ LElectricty\ Supply \\ LWeighted\ Electricity\ Price \end{pmatrix}_{t-1} \qquad (5.1)$$

Note that *L* denotes the natural log throughout this chapter. The variables entering the long run cointegrating regression include: LSectoral output which is in turn represented by mining, manufacturing, retail and wholesale output, LElectricity Supply (LES) and LWeighted Electricity Price (LWEP) while the $[1 \quad \beta_{11} \quad \beta_{12} \quad \beta_{13}]$ term in equation (5.1) represents the cointegrating vector which captures the long run relationship in the form of deviations of sectoral output from its long run equilibrium relationship with the other variables. Notice that the 1 in the variable vector represents the constant variable in the cointegrating vector and the corresponding constant term β_{11} appears in the coefficient vector. Moreover, note that the cointegrating vector is conditional (numeraire) on the LSectoral output variable; hence it is seen as a dependent variable where in the corresponding coefficient vector the first coefficient is denoted by 1, thus signifying the presence of the numeraire.

The variable vector which is lagged one period can be seen as an error correction mechanism and is represented as follows:

$$ECM = \varepsilon_{t-1} = (LSectoral\ Output - \beta_{11} - \beta_{12}LES + \beta_{13}LWEP)_{t-1} \qquad (5.2)$$

.

Equation (5.2) captures deviations of output from its long run relationship with the other variables in the cointegrating vector. Furthermore, the $\boldsymbol{\alpha_{ij}}$ coefficients in equation (5.2) are the short run adjustment coefficients. For example, if sectoral output over-shoots its long run relationship with the other variables in the previous period then $\boldsymbol{\alpha_{11} < 0}$ captures the readjustment of output downwards in order to restore equilibrium in the next period, while LES (LWEP) which shares a positive (negative) relationship with sectoral output in the next period will have to adjust upwards (downwards) in order to restore equilibrium, i.e., $\boldsymbol{\alpha_{12} > 0}$, while the variable that shares a negative long run relationship with output will adjust in a negative direction, i.e., $\boldsymbol{\alpha_{13} < 0}$

As mentioned above, equation (5.2) captures the long run cointegrating vector in error correction format, however if it is rewritten in its normal regression format the relationship takes the following form:

$$(LSectoral\ Output = \beta_{11} + \beta_{12}LES - \beta_{13}LWEP + \varepsilon_t)_{t-1}$$

Notice the long run coefficients take on the opposite signs in this equation relative to the ECM equation.

5.3.2.5 VECM Result

The VECM original results for the variables are presented in Table B1 to B8, Appendix B. The VECM results for each variable can be written in similar format to equation 4.43 from chapter four; the estimated parameters appear with negative signs due to the ECM rendition of the equation. However, the two coefficients should be interpreted as positive elasticties.

5.3.2.6. Estimating of Long Run Relationships Between monthly variables

The purpose of this section is to test for the three hypotheses, via the two unidirectional and the bidirectional causalities between electricity and sectoral output with the price of electricity appearing as a control variable.

5.3.3.7 Long Run Cointegrating Vector: Manufacturing Dependent Variables

In order to test the long run relationship between manufacturing output (LMAN) and electricity supply (LES) and electricity prices (LWEP) the following long run cointegrating relationship was obtained (refer to Appendix B, Table B1 for the original printout).

$$\boldsymbol{LMAN_t = 0.34^{***} - 0.01LWEP_t + 0.27^{*}LES_t} \qquad (\mathbf{5.1})$$

t-statistic 5.22 0.24 1.68

Note that equation 5.1 was estimated using a fifth order VAR (P=5) model. In other words, 5 lags were included in the VAR and 4 lags in the VECM model, as one lag was lost due to it being in a differenced form. Note further the assumption of intercept (no trend in the cointegrating vector was used and no intercept in the VAR model). The full results are reported in Appendix B Table B1.

Equation 5.1 suggests that in the long run the weighted price of electricity has no impact on manufacturing output. However, electricity supply has a statistically significant long run relationship at the 10% level with manufacturing output. The coefficient can be interpreted as a one percent rise in electricity supply when manufacturing output increases by 0.27 percent. Note that equation 5.1 can be converted into the following error correction mechanism:

$$\boldsymbol{ECM_{t-1} = LMAN_{t-1} - 3.40 + 0.01LWEP_{t-1} - 0.27LES_{t-1}} \qquad (\mathbf{5.2})$$

Note that the ECM captures the disequilibrium that resulted in the previous period, which was then incorporated into the short run analysis.

5.3.3.8 Short run Analysis: VECM Result

In regard to the short run relationship between the above variables, following result was obtained:

$$\boldsymbol{DLMAN_t = -0.48^{***}DLMAN_{t-2} - 0.16^{**}\ DLMAN_{t-3} - 0.13^{**}DLMAN_{t-4} + 0.05^{**}DWEP_{t-3} + 0.55^{**}DLES_{t-3} + 0.59^{***}DLES_{t-4}} \qquad (\mathbf{5.3})$$

The results clearly show that the change in manufacturing output in this period is affected by the pervious lags of itself as well as the lags of electricity price and electricity supply. Note that previous (lags, 2, 3 and 4) increases in manufacturing output causes current output to adjust downwards, perhaps due to build-up in inventories. A change in the price of electricity three periods ago causes manufacturing output to rise in this period, perhaps in anticipation of a future rise in prices. This adjustment appears to be quite puzzling. Further, notice that a rise in electricity supply three to four periods ago causes manufacturing output to rise in this period. Note that its converse is also true that a fall in electricity supply in the mentioned periods will cause a fall in manufacturing output in this period. Hence a constant predictable supply of electricity is critical for stable manufacturing output.

The adjustment to the long run cointegration relationship is statistically significant and possesses the correct sign. The coefficient suggests that when manufacturing oversteps its long run relationship with the other variables, in the cointegration vector, in the previous period then in this period has to adjust downwards by about 20% hence it will take about 5 months to restore equilibrium.

From the above analysis one can conclude that both in the long and short run there is a significant influence of electricity supply on manufacturing output in the positive direction. Electricity price has a puzzling short run effect on manufacturing output. In the above results it is clear that causality runs from electricity supply to manufacturing output.

5.3.3.9 Electricity Supply: Dependent Variable

The study made electricity supply a dependent variable in the long run cointegration relationship. In other words the study conditioned the model on the electricity supply variable and the following long run cointegrating vector was obtained (see Appendix B table B5 for the original results):

$$\boldsymbol{LES_t = 0.49 - 0.16^{***}\, LWEP_t - 0.08LMAN_t} \qquad (\boldsymbol{5.4})$$

$$\text{t-statistic} \qquad \boldsymbol{-9.55} \qquad \boldsymbol{-1.28}$$

Note that the equation 5.4 was estimated using a fifth order VAR (p=5) model. In other words, 5 lags were included in the VAR and 4 lags in the VECM model for one lag lost due to it being in a differenced form. Note further that the assumption of intercept and trend was used in the cointegrating vector and intercept in the VAR model. The full results are reported in Appendix B table B5.

The long cointegrating vector shows that there is a statistically significant relationship between electricity supply and weighted electricity price, thus indicating that over the long run there is a demand type relationship. However notice that manufacturing output has no impact on electricity supply, thus there was no need to pursue the short run relationships. In view of the overall results one may conclude that in the South African context there is a unidirectional causality running from electricity supply to manufacturing output.

5.3.3.10 Long Run Cointegrating Vector: Mining Dependent Variable

The results presented below shows the long run relationship between mining output (LMIN) and electricity supply (LES) and electricity price (LWEP) in a similar format to equation 5.1. The original long run results are presented in Appendix B Table B2.

$$\boldsymbol{LMIN = 5.15 + 0.006Trend - 0.09^{***}LWEP_t + 0.08LES_t} \qquad (\mathbf{5.5})$$

T-statistic $\mathbf{1.6}$ $\mathbf{3.7}$ $\mathbf{0.48}$

The above results in equation 5.5 was estimated using an eleventh order VAR (p=11) model. That is, 12 lags were included in the VAR and VECM model for one lag lost due to it being in a difference form. Note, that the assumption of intercept and trend in the cointegration vector was used and no trend in the VAR model.

With reference to equation 5.5, the estimated slope coefficients for weighted electricity price is statistically significant at the 1% level. The magnitude 0.09 for weighted electricity price suggests that in the long run a 1 percent rise in the electricity price will cause a 0.09 percent fall in the mining output per month. As anticipated, the electricity supply coefficient exhibits a positive relationship with mining output, but this impact is not statistically significant. Therefore the study attempts to explore the short run dynamic of equation 5.5 into the following error correction mechanism (ECM):

$$\boldsymbol{ECM_{t-1} = LMIN_{t-1} - 5.14 - 0.006Trend + 0.09LWEP_{t-1} - 0.08LES_{t-1}}$$

(5.6)

The ECM captures the disequilibrium that look place in the previous period, and was then incorporated into the short run analysis.

5.3.3.11 Short run Analysis: VECM Result

Based on the short run relationship between the mentioned variables, following result was obtained:

$$\begin{aligned} DLM\mathrm{IN}_t = {} & -0.004 - 0.170^{*}(LM\mathrm{IN}_{t-1} - 5.14 - 0.006Trend + 0.09LWEP_{t-1} \\ & - 0.08LES_{t-1}) - 0.51^{***}LMIN_{t-1} - 0.41^{***}DLMIN_{t-2} \\ & - 0.31^{***}DLMIN_{t-3} - 0.40^{***}DLMIN_{t-4} - 0.33^{***}DLMIN_{t-5} \\ & - 21^{*}DLMIN_{t-6} - 0.24^{**}DLMIN_{t-7} - 0.26^{**}DLMIN_{t-10} \\ & - 0.27^{***}DLMIN_{t-11} + 0.04^{***}DLWEP_{t-3} - 0.04^{*}DLWEP_{t-6} \\ & - 0.07^{**}DLWEP_{t-7} - 0.06^{**}DLWEP_{t-8} - 0.04^{**}DLWEP_{t-10} \\ & + 0.2^{*}DLES_{t-2} + 0.37^{**}DLES_{t-5} \end{aligned} \tag{5.7}$$

The short run dynamics of the cointegration equation are given by α adjustment coefficient of -0.17 which is statistically at the 10% level, as indicates in the equation 5.7. The result suggests that if mining output overshoots its long run equilibrium by 1% in the previous period then in the current period the adjustment of mining output is downward by 0.17% to restore the long run equilibrium. With reference to Table 2 Appendix B, notice that the short run adjustment coefficients of weighted prices and electricity supply are statistically insignificant.

With regard to the Tau coefficient notice that the past lags of a change in mining output (1,2,3,4,5,6,7,10 and 11) have a significant negative adjustment impact on current changes in mining production with the net effect (summing all the relevant coefficients) being a 23.73% downward adjustment to a 1% past increase. In economic terms past over- production leads to current downward adjustments.

There is also a net short run downward impact of weighted price of electricity (lags 3, 6, 7 and 8) on current period mining output of about 0.17% to a 1% past increase in price. Consistent with economic theory past price rises causes an increase in production costs which then forces short run downward adjustments in output.

Concerning the short run change in electricity supply it has a net positive effect on current period mining adjustment of 0.57% to a past increase of 1%. This finding is also consistent with economic theory that recent past electricity supply increases causes current mining output to rise, thus indicating, at least in the short run that electricity leads to a rise in mining output.

5.3.3.12 Electricity supply: Dependent Variable

Note here the study used electricity supply as a dependent variable in the long run cointegration relationship and thereby obtained the following results (see Appendix B, Table B6).

$$\boldsymbol{LES_t = 0.12 - 0.32LWEP - 0.15LMIN_t} \qquad (\mathbf{5.8})$$

Equation 5.8 was estimated using a fifth order VAR (P=5) model. That is, 5 lags were included in the VAR and 4 lags in the VECM framework for one lag lost because of it being in a differenced form. The assumption of intercept and trend in cointegration vector was used and no trend in the VAR model (refer to Appendix B, Table B6).

The results are puzzling and are contrary to economic theory.

5.3.3.13 Long Run Cointegration Vector: Wholesale Dependent Variable

To determine the long run relationship between wholesale trade (LWHOL) and electricity price (LWEP) and electricity supply (LES) the following long run cointegration relationship was obtained. The full details of the original result are in Appendix B, Table B3.

$$\boldsymbol{LWHO_t = 0.91 - 0.14LWEP_t + 1.01LES_t} \qquad (\mathbf{5.9})$$

The above equation 5.9 is constructed using an eleventh order VAR, that is (P=11) which included 11 lags in the VAR and 10 lags in the VECM framework for one lag lost as a result of being in a differenced form. However, the assumption of intercept (no trend) in the cointegration vector was used and VAR. The results are available in table 3 of Appendix B as well.

The long run cointegration results in equation 5.9 shows that the coefficients of electricity price and electricity supply both exhibit a positive relationship with wholesale trade; however these impacts are not statistically significant. Based on this finding there was no need to continuing the short run relationship.

5.3.3.14 Electricity Supply: Dependent Variable

In this case electricity supply was used as a dependent variable in the long run cointegration relationship and the following long run cointegration results was achieved (refer to Appendix B, Table B7 for original results).

$$\boldsymbol{LES_t = 0.21 - 0.10^{***}LWEP_t - 0.61LWHO_t} \qquad (\mathbf{5.10})$$

$$\boldsymbol{t - statistic \qquad - \qquad 4.85 \qquad - 15.45}$$

The long run results obtained in equation 5.10 its clearly shows that the coefficient of the weighted price of electricity is highly significant, in other words the outcome of this coefficient states that in the long run electricity price plays an important role in determining electricity supply on the South African economy. Furthermore, note that the coefficient of the wholesale trade is statistically insignificant, as reflected in the fact that in the long run wholesale trade has no major influence on electricity supply, and therefore there is no need to further the short run relationship. Based on these results the study therefore concluded that for the South African context there is a neutrality hypothesis between the wholesale trade sector and electricity consumption.

Note, that equation 5.10 was estimated using a fifth order VAR (p=5) of which 5 lags were used in the VAR and 4 in the VECM where one lag was lost as a result of being in a differenced form. However, the study utilised the assumption of intercept (no trend) in the cointegration vector was used and no intercept in VAR.

5.3.3.15 Long Run Cointegration Vector: Retail Dependent Variable

With reference to the long run cointegration relationship between retail trade (LRET) and electricity price (LWEP) and electricity supply (LES) the following long run results were obtained (see the original copy in Appendix B, Table B4).

$$\boldsymbol{LRET_t = 0.13^{**} - 0.02LWEP_t + 0.4^{**}LES_t} \qquad (\mathbf{5.11})$$

t-statistic $\boldsymbol{-0.05 \qquad 3.83}$

The above equation was estimated using seventh order VAR (P=7) of which 6 lags were included in the VAR and 5 in the VECM model with one lag lost due to being in a difference form. Note that the assumption of intercept (no trend in the cointegration vector was used and no intercept in the VAR model. The results in equation 5.11 suggest that in the long run the weighted price of electricity has no strong effect on the retail trade sector. A percentage rise in electricity supply causes a 0.4 percent growth in retail trade. The coefficient of the electricity supply is highly significant, and it is also realistic in the context of the South African economy. Note further that the equation 5.11 can be turned into the following error correction mechanism framework.

$$\boldsymbol{ECM_{t-1} = LRET_{t-1} - 0.13^{**} + 0.02LWEP_{t-1} - 0.4^{**}LES_{t-1}} \qquad (\mathbf{5.12})$$

Notice that ECM takes account of the disequilibrium that resulted in the previous period, which was then incorporated into the short run model analysis.

5.3.3.16 Short run Analysis: VECM Result

In view of the short run relationship between the above variable, the following results were achieved.

$$\boldsymbol{DLRET_t = 0.13^{**}DLRET_{t-1} - 0.42^{***}}DLRET_{t-2} - 0.17^{**} - 0.01^{**}\boldsymbol{DLWEP_{t-7}} + \boldsymbol{0.07^{**}DLES_{t-6}} \qquad (\mathbf{5.13})$$

According to the results, it is clear that change in retail trade in the current period is affected by the past lags of itself as well as the lags of electricity price and electricity supply. The pervious lags 1 and 2 increase in retail sector causes current trade to moderate downwards. Change in electricity price 7 periods ago causes retail trade to decrease in the current period perhaps due to the increased cost of various commodities associated with electricity price. Furthermore, change in electricity supply 6 periods ago contributed to the current rise in retail trade, hence constant electricity supply is very important for the growth of the retail sector.

The adjustment to the long run cointegration relationship is statistically significant and possesses the correct sign. In other words the LRET short run adjustment coefficient of – 0.008 is statistically significant at the 10% level, suggesting that when retail trade deviated away from it long run relationship with the other variables in the cointegration model in the previous period then in the upcoming period it has to get back to its long run stable condition with about 0.008 %. That means it will take up to 126 months to restore back to equilibrium.

From the justification of this analysis one can draw the conclusion that both in the long run and short run electricity supply play and important role in stimulating retail trade and with slow adjustment speed it is advisable to avoid shock in this sector.

5.3.3.17 Electricity Supply: Dependent Variable

The long run cointegration relationship between electricity supply (LES) and electricity price (LWEP) and retail trade (LERT) was established using electricity supply as a dependent variable (refer to Table 8, Appendix B, for original results)

$$\boldsymbol{LES_t = 0.18^{***} - 0.15^{**}LWEP_t + 0.72^{***}LRET_T} \qquad \textbf{(5.14)}$$

Accordingly, Table B8 (see Appendix B for original results) reports the long run cointegration relationship between the above mentioned variables. The coefficient for retail trade sector of 0.72 is both statistically significant and implies that if sales in the retail trade sector increases by 1 percent, electricity supply will increase by a magnitude of approximately 0.72 percent in the long run, ceteris paribus. This finding is consistent with the theoretical expectation that improvement in electricity supply provides forward linkages to growth in economic activities across all sectors including the retail sector. Conversely, the weighted price of electricity appears to affect electricity supply inversely, thus, a 1 percent rise in electricity price will lead to a 0.15 percent decline in electricity supply. This negative coefficient is statistically significant at the 1 percent level, which strongly suggests that there is a negative influence of electricity price on electricity supply. This finding does conform to economic theory since the retail sector will be forced to economise on all costs involving the use of electricity and that will imply lower overall productivity in this sector. Note, equation 5.14 was estimated using a fifth order VAR (p=5) model in which 5 lags were included in the VAR and 4 lags in the VECM estimated model for one lag lost due to it requires differenced in the method. Moreover, the assumption of intercept (no trend) in cointegration vector was used and VAR. Next follows the reporting of the VECM results for this cointegration relationship.

5.3.3.18 Short run Analysis: VECM Result

Equation 5.14 can be re-written in the following VECM format:

$$\boldsymbol{ECM_{t-1} = LES_{t-1} - 0.18^{***} + 0.15^{**}LWEP_{t-1} - 0.72^{***}LRET_{t-1}} \qquad (\mathbf{5.15})$$

The ECM accounts for the disequilibrium in the long run relationship (i.e. the cointegration vector) in the previous period which is then incorporated into the short run analysis of changes in the electricity supply, as follows:

$$\begin{aligned} \boldsymbol{DLES_t} &= \boldsymbol{-0.35^{***}DLES_{t-1} - 0.34^{***}DLES_{t-2} - 0.28^{**}DLES_{t-4}} \\ &\quad \boldsymbol{+ 0.031^{**}DLWEP_{t-1} + 0.027^{***}DLWEP_{t-4}} \\ &\quad \boldsymbol{+ 0.03^{**}DLWEP_{t-5} - 142^{***}ECM_{t-1}} \qquad (5.16) \end{aligned}$$

The VECM equation 5.16, suggests that current electricity supply is affected by its past previous lags, past lags of weighted electricity price and the error correction term. Note, the previous lag (1, 2 and 4 all of which are negative) increases in electricity supply cause the current supply of electricity to adjust downwards by 0.97% (ie., sum of lag coefficients on DLES). Furthermore, in the short run, electricity price appears to marginally contribute positively to electricity supply, thus, changes in electricity price during the previous lags (1, 4 and 5 periods ago) raise the current electricity supply by 0.088% (sum of lagged coefficients on DLWEP). The alpha coefficient on the ECM term possesses the correct sign and is statistically significant at the 1% level and may be interpreted as a 1% disequilibrium in LES in the previous period causes DLES to readjust in a downwards (opposite) direction by 0.142% so as to restore the long run cointegration relationship between the variables, as captured in equation 5.14. This result suggests that it will take the system 7 months to restore equilibrium.

Notice (refer to the original results in Appendix B, Table B8) that the short run speed of adjustment of electricity price, this period, to a disequilibrium in electricity supply in the previous period, is about -0.55 percent and is statistically significant at the 1%

level. In other words, electricity price accommodates about 55 percent of the adjustment arising from electricity supply overstepping its equilibrium cointegration relationship in the last period. In regard to speed of adjustment, it will take less than 2 months for the electricity price to be restored to the equilibrium point. This short speed of adjustment implies that electricity price is relatively sensitive to the long run cointegration relationship with electricity supply. The tau coefficients (the short run adjustment coefficients highlighted in dark green in Table B8, Appendix B) for only lagged (lags 1 to 4) weighted electricity prices were significant and negative and summed to -0.53%, thus indicating that electricity supply in the current period adjusted downwards to past rises in electricity supply.

Note that the correctly signed short run adjustment (alpha coefficient) of retail sales to electricity supply is also statistically significant at the 1%, which suggests that previous periods' over (or under) supply of electricity are corrected by retail sales in the current period. A 1% oversupply of electricity in the previous period causes retails sales to rise by 0.05% in this period. This is a very slow adjustment for it takes about 20 months for equilibrium to be restored, ceteris paribus. None of the tau coefficients were significant in the relationship governing retail sales.

These results when viewed together confirm the existence of causality (in the sense of adjustment to long run equilibrium) in more than one direction. The negative and positive, statistically significant value of error correction coefficients on electricity price and retails sales, respectively, shows the existence of a long run causality between electricity supply, electricity price and electricity supply and retail sales, respectively. This result states that the significant coefficient of t-statistics implies that there is a long run causality running from electricity supply to the retail trade sector. In summary, the result indicates that in the short run there exists bidirectional causality running from electricity supply to the retail trade sector and a similar causality from electricity price to electricity supply in South Africa.

Table 5.4: Summary of valid VECM Long and Short Run Causal Relationship

Period	Variable and Direction	Hypothesis
Long Run	LES ⇎LMAN	Neutrality (no causality in either direction)
Short Run	DLMAN ⇄ DLES	Feedback (bidirectional causality)
Long Run	LMIN → LES	Conservation (unidirectional causality)
Short Run	DLES → DLMIN	Growth (Unidirectional Causality)
Long Run	LES ⇏LWHOL	Neutrality (no causality unidirectional)
Short Run	DLES→ DLWHOL	Bidirectional (Feedback)
Long Run	LWHOL⇄ LES	Conservation (causality unidirectional)
Long Run	LES ⟶ LRET	Growth (causality unidirectional)
Short Run	DRET ⟶ DLES	Conservation (causality unidirectional)

5.3.4 Dummy Variables

The Dummy variable was also included in this study to differentiate the structural break that took place in the 2007/8 and in 2015 periods (see chapter 4) that is, the periods when South African experienced serious power shedding. But due to the insignificant coefficient results obtained, the researcher excluded dummies from the analysis of the model. These insignificant results can be attributed to the sample periods of the load shedding being very small compared to the sample size of the data, which possibly rendered the results invalid.

5.3.5 Granger Causality Tests Results

The final step in this section is to determine the direction of causations (either unidirectional or bi-directional) between the series through the use of the VAR Granger causality block homogeneity Wald tests. The joint null hypothesis of Granger-non-causality (there is neither unidirectional nor bidirectional causation between the variables under investigation are tested by Wald X^2 and F-statistics obtained from Wald coefficients restriction. Notably, the rejection of the null hypothesis indicates that there is evidence of causation between the variables.

5.3.5.1 Granger Causality for the Manufacturing Sector

In the previous section the Johansen VECM approach considered both long and short run causality relationships which were summarised in Table 5.4 above. In this subsection the Wald Granger causality tests uses the VAR approach to consider only the short run causal relationships between the variables entering the VAR model. Table 5.5A presents the results: (see original copy in Appendix D13 to D16).

Table 5.5A: VAR Granger Causality Manufacturing Sector

Null Hypothesis (Ho)		Chi Square	DF	Pro> Chi2	Conclusion
DLWEP does not Granger cause DLMAN	SR	10.15	4	0.0379	Reject Ho
DLES does not Granger cause DLMAN	SR	43.26	4	0.000	Reject Ho
DLMAN does not Granger cause DLWEP	SR	6.86	4	0.1434	Do not reject Ho
DLES does not Granger cause DLWEP	SR	39.92	4	0.000	Reject Ho
DLMANU does not Granger cause DLES	SR	10.18	4	0.0374	Reject Ho
DLWEP does not Granger cause DLES	SR	1.121	4	0.8909	Do not reject Ho

The above results demonstrate that there is a bidirectional causality between electricity supply and manufacturing output, the results being significant at the 1 and 5 percent levels, respectively. Bidirectional causality implies that the feedback hypothesis operates in respect of the manufacturing sector, e.g., both variables tend to complement one another. Hence lower carbon emission taxes or other pollution-related policies affecting the manufacturing sector are likely to have adverse effects on manufacturing growth.

Additionally note that electricity price has a significant causal influence on manufacturing output at the 5% significance level, hence in order for the manufacturing sector to thrive, reducing electricity prices is critical. As the results show, at the 1% significance level electricity supply influences prices. Thus policy makers need to ensure that surplus electricity supply is made available through appropriate infrastructure development.

5.3.5.2 Granger Causality Test for Mining Sector

In the same vein as the manufacturing case, this subsection presents the VAR- based Wald Granger causality test results between mining output, electricity supply and electricity price. Note that the VAR model focusses entirely on the short run relationship between the variables and is considered inferior to the Johansen VECM relationship which separates out the long (beta coefficients) and short (alpha coefficients) run relationships and also considers how the system readjusts to the long run relationship.

Table 5.6A: VAR Granger Causality Mining Sector

Null Hypothesis		Chi Square	DF	Pro> Chi2	Conclusion
DLWEP does not Granger cause DLMINE	SR	40.38	11	0.0000	Reject Ho
DLES does not Granger cause DLMINE	SR	28.79	11	0.0024	Reject Ho
DLMINE does not Granger cause DLWEP	SR	43.42	11	0.0000	Reject Ho
DLES does not Granger cause DLWEP	SR	16.15	11	0.1354	Do not reject Ho
DLMINE does not Granger cause DLES	SR	33.30	11	0.0005	Reject ho
DLWEP does not Granger cause DLES	SR	36.62	11	0.0001	Reject Ho

5.3.5.3 Granger Causality Test for Wholesale Trade

Following the same procedure as in the previous case, the result between wholesale trade, weighted electricity price and electricity supply based on Wald Granger causality tests in VAR, shows the null hypothesis of LWEP, LES respectively does not Ganger causes Wholesale trade cannot be rejected at the 5 percent significant level. Therefore, there would only be short run unidirectional causality relationship detected between weighted electricity price and electricity supply. Interestingly, when the reversed causality is tested, the null hypothesis that Wholesale trade does not Granger causes LWEP, LES can also not be rejected.

Table 5.7A: VAR Granger Causality Wholesale Trade

Null Hypothesis		Chi-Square	DF	Pro > Chi2	Conclusion
DLWEP does not Granger cause DLWHOL	SR	15.16	11	0.1753	Do not reject Ho
DLES does not Granger cause DLWHOL	SR	9.86	11	0.5424	Do not reject Ho
DLWHOL does not Granger cause DLWEP	SR	9.00	11	0.6219	Do not reject Ho
DLES does not Granger cause DLWEP	SR	33.28	11	0.0005	Reject Ho
DLWHOL does not Granger cause DLES	SR	15.41	11	0.1642	Do not reject Ho
DLWEP does not Granger cause DLES	SR	35.27	11	0.0002	Reject Ho

5.3.5.4 Granger Causality Test for Retail Trade

Testing the causality between the retail trade, weighted electricity price and electricity supply, the VAR method of Wald Granger causality test found no causality between retail trade and weighted electricity price and electricity supply, respectively, in either direction. In other words weighted electricity price and electricity supply have no significant impact on retail trade sector in the short run while bidirectional causality exist between weighted electricity price and electricity supply.

Table 5.8A: VAR Granger Causality Retail Trade

Null Hypothesis		Chi-Square	Df	Pro> Chi2	Conclusion
DLWEP does not Granger cause DLRET	SR	4.84	7	0.6788	Do not reject Ho
DLES does not Granger cause DLRET	SR	5.77	7	0.5662	Do not reject Ho
DLRET does Granger cause DLWEP	SR	2.40	7	0.9343	Do not reject Ho

DLES does not Granger cause DLWEP	SR	88.58	7	0.0000	Reject Ho
DLRET does not Granger cause DLES	SR	5.48	7	0.6011	Do not reject Ho
DLWEP does not Granger cause DLES	SR	28.13	7	0.0002	Reject Ho

5.3.5.5 Summary of the Results with respect to the Hypotheses

Table 5.9: Summary of VAR/VECM Long/ Short Run Causal Relationships

Approach	Duration	Causality	Hypothesis
VECM	Long Run Short Run	LES ⇎LMAN DLMAN ⇄ DLES	Neutrality (no causality in either direction) Feedback (bidirectional causality)
VAR	Short Run	DLMAN ⇄ DLES	Feedback(bidirectional Causality)
VECM	Long Run Short Run	LMIN → LES DLES → DLMIN	Conservation (unidirectional causality) Growth (Unidirectional Causality)
VAR	Short Run	DLMIN ⇄ DLES	Feedback (Bidirectional Causality)
VECM	Long Run Short Run	LWHOL → LES DLES⇄ DLWHOL	Conservation (causality unidirectional) Feedback (bidirectional)
VAR	Short Run	DLWHOL⇎ DLES	Neutrality (no Causality in either direction)
VECM	Long Run Short Run	LES ⇆ LRET DRET ⇆ DLES	Feedback (bidirectional causality) Feedback (bidirectional causality)
VAR	Short Run	DRET ⇎ DLES	Neutrality (no Causality in either direction)

Notes: The long run causal relationships were obtained from the statistically significant coefficients of the long run cointegration vector, while the short run causal relationships was viewed by considering the α_{ij} *coefficients of the short run adjustment coefficients in the VECM alone.*

The VAR short run causal relationship was obtained from the VAR block exogeneity Granger Causality test.

Table 5.9 above summarises the long and short run causality relationships between the variables that were estimated via the Johansen VAR/VECM approach. According to the results the manufacturing sector is characterised by the neutrality hypothesis for there is an absence of causality in either direction between electricity supply and manufacturing output in the long run. However, the short run result suggest that manufacturing output and electricity supply causes each other for there exists a bidirectional relationship between manufacturing output and electricity supply. Notice that this finding is supported by the VAR-based block exogeneity Granger Causality test. Hence the authorities need to ensure a cheap and growing supply of electricity in the short run if they are to promote manufacturing industries. In the long run these industries are likely to adapt to the fluctuations in electricity supply and take measures to weaken the influence of electricity supply on the sector.

In the long run mining output alone determines electricity supply which suggests that mining output is not determined by energy production hence if the authorities conserve energy it will not adversely affect the mining sector. Moreover, in the short run, growth in the mining sector is highly dependent on electricity supply, hence in order to raise sectoral output the authorities must expand electricity supply. However, the short term results are contradicted by the VAR block exogeneity Granger causality test. Given the contradiction this study will lend greater credibility to the VECM results since it is a more sophisticated approach that considers both long and short run relationships.

The wholesale sector, like mining, is governed by the conservation hypothesis where sectoral output is not determined by electricity supply in the long run, but in the short run there is strong bidirectional dependence, implying the authorities who have a strong growth and employment objective in mind should expand electricity output. These short run results are contradicted by the VAR block exogeneity Granger causality test. As noted above the Johansen VECM approach is a superior technique since it focusses on both the long and short rum relationship compared to the VAR model which focusses on the short run relationship alone.

The retail sector demonstrates bidirectional causality both in the long and short run which implies that given the growth and employment objective of national government expanding electricity supply is critical both over the long and short term horizons for the feedback effects will result in a continuous cycle of sectoral growth and electricity supply expansion positively reinforcing one another. The VAR block exogeneity Granger causality test found no causal relationships between the variables under consideration. As mentioned above the Johansen VECM approach is a superior technique since it focusses on both the long and short rum relationship compared to the VAR model which focusses on the short run relationship alone.

Table 5.10: Summary of VECM/VAR Long/Short Run Price Causal Relationships

Approach	Duration	Causality	Conclusion
VECM	Long Run Short Run	LWEP ⇎ LMAN DLMAN → DLWEP	In long run (LR) manufacturing output and electricity price do not affect one another. In the short run (SR) changes in manufacturing output determines electricity prices. Hence an expanding manufacturing sector will put huge pressure on prices if there is not increased supply of electricity to the sector.
VAR	Short Run	DLMAN ⇄ DLWEP	There exists a bidirectional causality in the SR which contracts that of the VECM results slightly, however increasing electricity supply is critical to develop a thriving manufactured sector to maintain low prices
VECM	Long Run Short Run	LWEP → LMIN DLMIN ← DLWEP	In the LR rising electricity prices depresses mining output. Hence authorities need to ensure cheap stable LR supply of electricity to bolster the mining sector. In the SR rising mining output pushes up electricity prices , hence ensuring a cheap stable supply of electricity will reduce this adverse impact.
VAR	Short Run	DLMIN ⇄ DLWEP	There exists a bidirectional causality in the SR which contracts the VECM results slightly, however increasing electricity supply is critical to develop and thriving mining sector and to keep prices low. However higher weighting is attached to the VECM results.
VECM	Long Run Short Run	LWEP ⇎ LWHOL DLWHOL ← DLWEP	In LR no causal relationship between electricity prices and wholesale trade. In the SR electricity price changes depresses

			wholesale trade.
VAR	Short Run	DLWHOL⇎ DLWEP	No causality is predicted between the variables suggesting this sector in unaffected by the rising electricity prices. However precedence is given to the VECM results.
VECM	Long Run Short Run	LWEP ⇎ LRET DRET → DLWEP	In LR no causal relationship between electricity prices and Retail trade. In the SR electricity price places an upward pressure on retails trade.
VAR	Short Run	DLRE⇎ DLWEP	In SR no causal relationship between electricity prices and Retail trade is noted. However, more weighting is given to the VECM results.

Notes: The long run causal relationships were obtained from the statistically significant coefficients of the long run cointegration vector, while the short run causal relationships was viewed by considering the α_{ij} *coefficients of the short run adjustment coefficients in the VECM alone.*

The VAR short run causal relationships were obtained from the VAR block exogeneity Granger Causality test.

The overall findings are that in the long run there are no causal relations between weighted electricity price and the manufacturing, wholesale and retail sectors. However, in the short run weighted electricity price either affects or is affected by the mentioned sectors. The overall finding is that the authorities must make cheap electricity available on a sustained basis in order to eliminate adverse effects at the sectoral level.

5.4 Conclusion

This chapter summarised the analysis of the results in this research work, using the Eviews 8 statistically software properties. The study employed monthly data and the following examinations were also carried out for cointegration and Granger causality, but prior to that, preliminary inspection of the data was conducted and all the times series were found to be stationary at first difference. The overall results shows that there exists a long run relationship between manufacturing output, mining output, wholesale and retail trade, weighted electricity price and electricity supply.

The VECM result suggests that the weighted electricity price has no significant impact on the manufacturing output but electricity supply has. On the ECM result the previous (lags, 2, 3 and 4) increases in manufacturing output cause current output to adjust downwards perhaps due to build-up in inventories. However, in the mining output equation, the result further suggests that an increase in weighted electricity price will negatively affect mining output downwards while the past lags of the mining output (1, 2, 3,4,5,6,7,10 and 11) have a significant negative adjustment impact on current changes in mining production shown by the ECM result.

Furthermore, weighted electricity price and electricity supply both exhibit a positive relationship with wholesale trade; however these impacts are not statistically significant. Regarding the retail sector, weighted electricity price has no major impact while a rise in electricity supply raises the retail sector by 0.4%. The ECM result also supports the, that change in retail trade in the current period is affected by the past lags of itself as well as the lags of electricity price and electricity supply. These results when viewed altogether confirm the existence of causality in at least more than one direction. The VAR based Wald Granger causality test results confirms the existence of bidirectional causality in manufacturing and mining output with weighted electricity price and electricity supply. In wholesale and retail trade sector no causality was found in either direction with weighted electricity price and electricity supply which implies the existence neutrality hypothesis.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

This chapter summarises the study and offers policy recommendations based on the findings. The chapter is made up of three sections. Section 6.1 provides a summary of the study and discusses the empirical results while Section 6.2 presents the strengths and weaknesses of the study (limitations of study) and policy prescriptions. Recommendations for future research are presented in section 6.3.

6.1 Summary of the study

One of the objectives of any government is to stimulate economic growth. Previously, South Africa's economy was built on the low cost of electricity supply and it enjoyed an excess of electricity reserve margins. Recently, the constant increases in electricity prices and the consistent decline in electricity supply have posed serious challenges to the various sectors of the economy. In endogenous growth theory discussed, previously in chapter two of this study, electricity has been considered as one of the inputs used in the production factor and also a strong pillar that supports economic growth as well as the most important infrastructural input that stimulates all economic activities. According to Alam (2006) electricity has been described as an indispensable force that derives all economic activities. This current study aims to investigate the relationships between electricity supply, electricity price and sectoral output (economic growth) in South Africa using monthly time series data.

The researcher selected these key macroeconomic variables for empirical analysis of the research work in this thesis through statistical estimation techniques prescribed by Solow (1974) and other similar studies specifically in this field. The study firstly treated electricity supply and electricity price as determinant variables that influence changes in dependent variables such as manufacturing, mining output, wholesale and retail trade which represents sectoral output sectors. The thesis centred around the main hypothesis that sectoral output growth responds to change in electricity supply and electricity price and that a valid cointegrating relationship exists between these variables with relevant short run dynamic adjustments to the long run relationship.

In order to fulfil the study's objectives and to comment on the various hypotheses, preliminary examinations of the variables were first subjected to unit root tests and all were found to be non-stationary in levels and stationary in their first difference. The Johansen VECM procedure was used to estimate the long and short run relationships between the variables the study further estimated the Granger causality tests under the VAR framework to check short run relationships between the various variables which is a standard way of testing the growth, feedback, conservation and neutrality hypotheses.

6.1.2 VECM results summary on electricity consumption and sectoral growth

In the long run the growth hypothesis dominates only in the retail sector where causality runs from electricity supply to retail sales. Thus, to grow the retail sector more electricity needs to be supplied. However, in the short run there is bidirectional causality between the variables hence electricity supply is essential to the growth of the sector. While in the case of the mining and wholesale trade sectors causality runs from the respective sectoral growth to the electricity supply, implying that electricity constraints will not harm these sectors, perhaps because they have already found alternative reliable sources of electricity supply. In the short run causality runs from electricity supply to mining output hence, supply is crucial to growth. In regard to the manufacturing sector in the long run electricity supply neither of the variables influences the other. Therefore, a constraint on electricity supply will not harm this sector in the long run. However, in the short run wholesale sector growth is dependent on electricity supply, while the retail sector causes a rise in electricity supply.

6.1.3 VAR results summary

According to the VAR results the mining and manufacturing sectors respectively have bidirectional causality with respect to electricity supply. Hence electricity infrastructure and electricity supply increase are critical for growth in labour intensity and the strategic sector respectively. According to VAR analysis the retail and wholesale sectors do not impact on and are not impacted by, the provision of electricity supply, but these results somewhat contradicts the VECM hypotheses. However, since the VECM results are considered to be superior from a methodological perspective because they deal with the instability present in cointegration relations via the inclusion of an ECM, they should be given credence. Thus the results on the wholesale sector suggest that in the short run it is critical for South African to increase electricity supply.

6.1.4 VECM and VAR summary on electricity price and sectoral growth

In the long run electricity price does not affect the manufacturing, wholesale and retail sectors and not the mining sector. This implies that the manufacturing, retail and wholesale sector can absorb the price increases in the long run but the mining sector is adversely affected by such price increases. In the short run the VECM results suggest that price adversely affects the mining and wholesale sectors, while manufacturing and retail sectoral growth both tend to affect price. However, the VAR results suggest that there is a bidirectional causality between electricity price and the manufacturing and mining sectors in the short run. Moreover, there is no causality between electricity price and the retail and wholesale sectors respectively.

When the above results pertaining to price are viewed as a whole, it is safe to say that there is evidence of causality, at least in some sectors, viz., in a labour intensive sector like mining and in the reasonably labour intensive wholesale and manufacturing sectors, hence electricity supply ought to be expanded in the economy to keep price of commodities down.

6.2 Strengths, Weaknesses and Policy Prescriptions

The general finding of this study supports the policy prescription that electricity supply is a key pillar that stimulates sectoral economic growth in South Africa in the short run and that policy measures should be targeted improving electricity supply and reducing the cost of electricity as this will lead to an increase in the cost of goods and services hence the government's emphasis on wholesale and retail trade sector working together to revive the economy and put on a growth path.

The first weakness of this study is that different prices are charged at peak and off-peak hours, meaning no consistent electricity price is available. STATS SA or ESKOM ought to remedy this inadequacy by obtaining a consistent data set that all researchers can access so that the results of various studies are comparable. Moreover only ESKOM data was used in this study, meaning that private sector electricity prices were excluded which NERSA, ESKOM or STATS SA ought to incorporate into the overall electricity price. The second weakness of this study is that it failed to produce valid results on the impact of load-shedding through the use of dummy variables, probably because the period of load shedding effects is relatively small compared to the date set used in our analysis. A thirdly weakness identified on this study is that it does not look into the agricultural and industrial sectors which are very important sectors in the economy and necessitates special investigation.

6.3 Recommendations for Future Research

The VECM results in some cases were contradictory to the VAR results but precedence was given to the VECM results due to its ability to deal with instabilities within a VAR model through the use of error correction mechanisms. Future research ought to find alternative methods to confirm the VECM results, perhaps through the use of DSGE (dynamic stochastic general equilibrium) models.

Additionally, data for the various sectors could be collected for other African or Brics economies to conduct panel VAR/VECM models to assess whether the conclusions drawn in this study are consistent.

6.4 Conclusion

This chapter discussed the essential part of the entire dissertation, summarised the results, provide policy recommendation and prescriptions, underlined the strengths and weaknesses, and pointed to areas of future study. Based on the study’s results it is evident that electricity supply is vital to economic growth in the short and long run scenarios and in order to promote growth both in the short term, it is important for the South African government and other policymakers to give attention to, and harness, other key growth sectors and also to consider short run economic adjustment factors.

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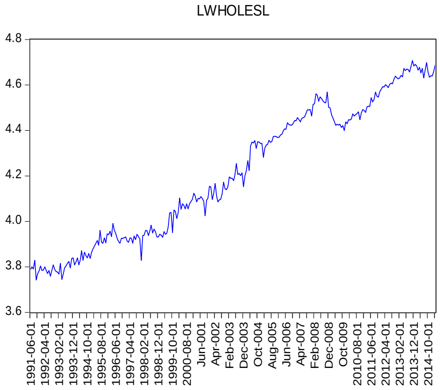
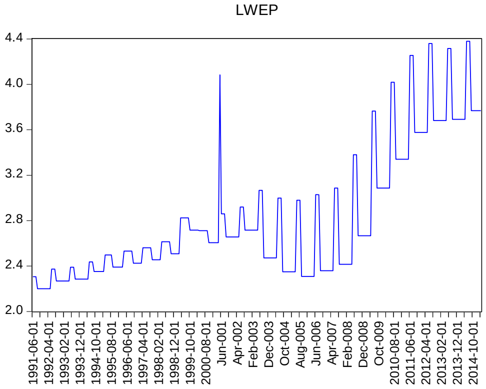
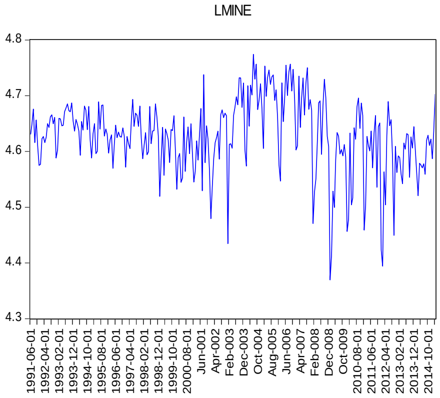
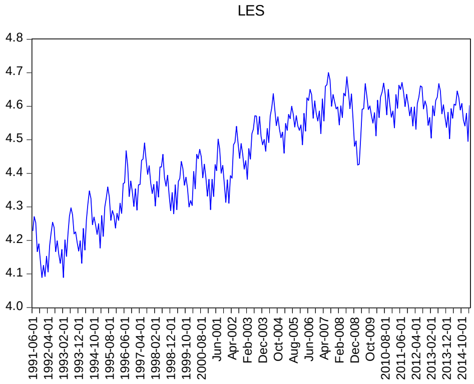
APPENDIX A

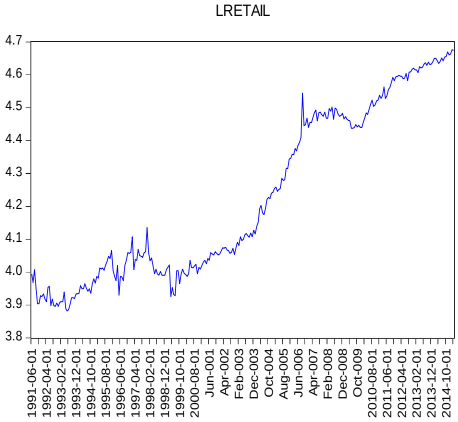
Figure A1: Graphic Plots of Variables in First Differences











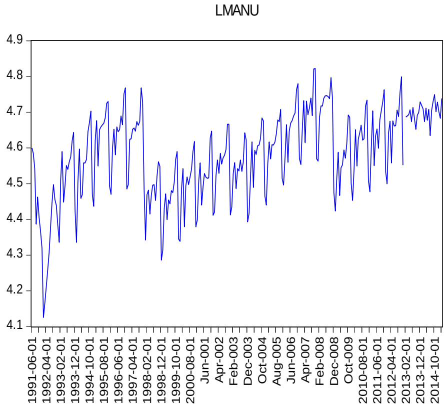


Table A2: Autoregressive Roots Result

Roots of Characteristic Polynomial

Endogenous variables: LMANU LES LWEP

Exogenous variables:

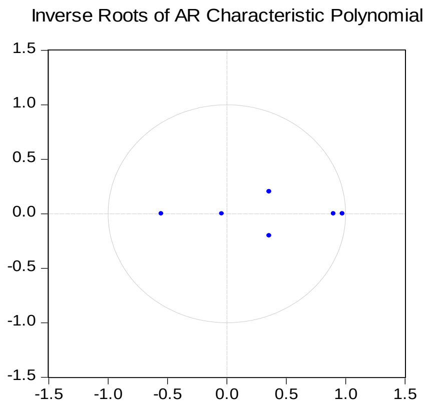
Lag specification: 1 4

Date: 02/11/16   Time: 14:22

Root	Modulus
1.000000	1.000000
1.000000	1.000000
0.825512	0.825512
-0.649277 - 0.488652i	0.812613
-0.649277 + 0.488652i	0.812613
0.358262 - 0.715518i	0.800198
0.358262 + 0.715518i	0.800198
0.024396 - 0.689399i	0.689831
0.024396 + 0.689399i	0.689831
0.434785 - 0.427162i	0.609512
0.434785 + 0.427162i	0.609512
-0.580134 - 0.109545i	0.590385
-0.580134 + 0.109545i	0.590385
0.317641	0.317641
-0.246840	0.246840

VEC specification imposes 2 unit root(s).

Figure A2: Autoregressive Roots Result



APPENDIX B

Table B1: VECM Results for manufacturing output

Vector Error Correction Estimates

Date: 02/15/16 Time: 13:31

Sample (adjusted): 6 286

Included observations: 275 after adjustments

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
LMAN(-1)	1.000000		
LWEP(-1)	0.011431		
	(0.04716)		
	[0.24241]		
LES(-1)	-0.274883		
	(0.16333)		
	[-1.68296]		
C	-3.389285		
	(0.64927)		
	[-5.22016]		
Error Correction:	**D(LMAN)**	**D(LWEP)**	**D(LES)**
CointEq1	-0.208644	-0.205159	-0.107359
	(0.05185)	(0.16253)	(0.03394)
	[-4.02405]	[-1.26231]	[-3.16295]
D(LMAN(-1))	-0.090181	0.227624	0.052620
	(0.07276)	(0.22807)	(0.04763)

	[-1.23947]	[0.99806]	[1.10476]
D(LMAN(-2))	-0.481799	-0.040964	0.101779
	(0.06911)	(0.21662)	(0.04524)
	[-6.97195]	[-0.18911]	[2.24980]
D(LMAN(-3))	-0.155150	0.178523	-0.034536
	(0.06273)	(0.19663)	(0.04107)
	[-2.47332]	[0.90791]	[-0.84100]
D(LMAN(-4))	-0.127690	0.327845	0.071855
	(0.06103)	(0.19129)	(0.03995)
	[-2.09241]	[1.71387]	[1.79862]
D(LWEP(-1))	-0.009413	-0.261161	0.011133
	(0.02043)	(0.06405)	(0.01338)
	[-0.46066]	[-4.07730]	[0.83223]
D(LWEP(-2))	-0.013813	-0.162260	0.000822
	(0.01931)	(0.06052)	(0.01264)
	[-0.71541]	[-2.68100]	[0.06500]
D(LWEP(-3))	0.045154	-0.388542	0.008746
	(0.01911)	(0.05991)	(0.01251)
	[2.36254]	[-6.48542]	[0.69900]
D(LWEP(-4))	0.033085	-0.120824	0.008062
	(0.01993)	(0.06247)	(0.01305)
	[1.66024]	[-1.93426]	[0.61798]
D(LES(-1))	-0.210555	1.635072	-0.393544

	(0.10812)	(0.33891)	(0.07078)
	[-1.94742]	[4.82448]	[-5.56009]
D(LES(-2))	0.194204	1.151039	0.233287
	(0.12339)	(0.38676)	(0.08077)
	[1.57396]	[2.97609]	[2.88817]
D(LES(-3))	0.553439	0.297278	0.025524
	(0.11738)	(0.36795)	(0.07684)
	[4.71479]	[0.80793]	[0.33216]
D(LES(-4))	0.590961	-1.034892	-0.316949
	(0.10303)	(0.32295)	(0.06745)
	[5.73586]	[-3.20446]	[-4.69921]
R-squared	0.476722	0.309241	0.366834
Adj. R-squared	0.452755	0.277603	0.337834
Sum sq. resids	1.138182	11.18334	0.487777
S.E. equation	0.065911	0.206602	0.043148
F-statistic	19.89083	9.774422	12.64949
Log likelihood	364.3011	50.11442	480.8087
Akaike AIC	-2.554917	-0.269923	-3.402245
Schwarz SC	-2.383942	-0.098948	-3.231270
Mean dependent	0.000561	0.003395	0.001200
S.D. dependent	0.089097	0.243079	0.053025
Determinant resid covariance (dof adj.)		2.19E-07	
Determinant resid covariance		1.89E-07	
Log likelihood		957.8434	
Akaike information criterion		-6.653407	

Table B2: VECM Results For Mining output

```
 Vector Error Correction Estimates
 Date: 02/15/16   Time: 14:28
 Sample (adjusted): 13 286
 Included observations: 274 after adjustments
 Standard errors in ( ) & t-statistics in [ ]
================================================================
 Cointegrating Eq:      CointEq1
================================================================
 LMIN(-1)               1.000000

 LWEP(-1)               0.095516
                       (0.02591)
                      [ 3.68697]

 LES(-1)                0.075656
                       (0.15667)
                      [ 0.48291]

 @TREND(1)             -0.000609
                       (0.00039)
                      [-1.56091]

 C                     -5.147538
================================================================
 Error Correction:      D(LMIN)      D(LWEP)      D(LES)
================================================================
 CointEq1              -0.169111    -1.810730     0.004875
                       (0.10169)    (0.32637)    (0.06556)
                      [-1.66300]   [-5.54814]   [ 0.07437]

 D(LMIN(-1))           -0.506317     1.536060     0.040028
                       (0.11222)    (0.36015)    (0.07234)
```

	[-4.51191]	[4.26502]	[0.55331]
D(LMIN(-2))	-0.413027	1.242922	0.030855
	(0.11668)	(0.37448)	(0.07522)
	[-3.53974]	[3.31903]	[0.41019]
D(LMIN(-3))	-0.310569	1.329690	0.039632
	(0.12053)	(0.38682)	(0.07770)
	[-2.57678]	[3.43751]	[0.51007]
D(LMIN(-4))	-0.400308	1.051200	0.082199
	(0.12212)	(0 .39194)	(0.07873)
	[-3.27790]	[2.68201]	[1.04408]
D(LMIN(-5))	-0.330955	0.273874	0.022568
	(0.12272)	(0.39384)	(0.07911)
	[-2.69694]	[0.69539]	[0.28528]
D(LMIN(-6))	-0.209260	0.323879	-0.089035
	(0.12257)	(0.39337)	(0.07902)
	[-1.70729]	[0.82334]	[-1.12680]
D(LMIN(-7))	-0.237797	0.006197	0.046234
	(0.11506)	(0.36926)	(0.07417)
	[-2.06678]	[0.01678]	[0.62332]
D(LMIN(-8))	-0.169672	0.401452	0.134779
	(0.10589)	(0.33986)	(0.06827)
	[-1.60228]	[1.18124]	[1.97432]
D(LMIN(-9))	-0.078879	0.063347	0.051547

	(0.09855)	(0.31630)	(0.06353)
	[-0.80035]	[0.20027]	[0.81131]
D(LMIN(-10))	-0.258541	0.257993	-0.027978
	(0.08763)	(0.28123)	(0.05649)
	[-2.95051]	[0.91738]	[-0.49528]
D(LMIN(-11))	-0.273347	0.413519	0.036116
	(0.06753)	(0.21674)	(0.04354)
	[-4.04762]	[1.90791]	[0.82956]
D(LWEP(-1))	0.017435	-0.532785	-0.037050
	(0.01797)	(0.05767)	(0.01158)
	[0.97025]	[-9.23806]	[-3.19818]
D(LWEP(-2))	-0.006980	-0.456873	-0.022330
	(0.01916)	(0.06149)	(0.01235)
	[-0.36431]	[-7.42981]	[-1.80783]
D(LWEP(-3))	0.036949	-0.587729	-0.014023
	(0.01763)	(0.05658)	(0.01137)
	[2.09583]	[-10.3874]	[-1.23383]
D(LWEP(-4))	-0.002972	-0.487912	-0.027522
	(0.02004)	(0.06431)	(0.01292)
	[-0.14834]	[-7.58691]	[-2.13056]
D(LWEP(-5))	-4.25E-05	-0.414830	-0.030732
	(0.02062)	(0.06619)	(0.01330)
	[-0.00206]	[-6.26694]	[-2.31139]

D(LWEP(-6))	-0.036564	-0.476553	-0.038275
	(0.01940)	(0.06225)	(0.01250)
	[-1.88511]	[-7.65548]	[-3.06101]
D(LWEP(-7))	-0.069328	-0.474497	-0.044417
	(0.01997)	(0.06408)	(0.01287)
	[-3.47208]	[-7.40435]	[-3.45059]
D(LWEP(-8))	-0.064450	-0.406740	-0.049080
	(0.01965)	(0.06308)	(0.01267)
	[-3.27909]	[-6.44795]	[-3.87349]
D(LWEP(-9))	-0.017295	-0.638096	-0.024404
	(0.01747)	(0.05608)	(0.01126)
	[-0.98975]	[-11.3782]	[-2.16636]
D(LWEP(-10))	-0.042546	-0.538437	-0.038044
	(0.01840)	(0.05906)	(0.01186)
	[-2.31209]	[-9.11710]	[-3.20704]
D(LWEP(-11))	-0.018910	-0.481441	-0.000952
	(0.01769)	(0.05676)	(0.01140)
	[-1.06923]	[-8.48209]	[-0.08352]
D(LES(-1))	0.078982	0.316823	-0.575682
	(0.09246)	(0.29673)	(0.05960)
	[0.85426]	[1.06772]	[-9.65859]
D(LES(-2))	0.197157	-0.181929	-0.133820
	(0.10760)	(0.34533)	(0.06936)
	[1.83234]	[-0.52683]	[-1.92922]

D(LES(-3))	0.138321	-0.574755	-0.286647
	(0.10492)	(0.33672)	(0.06764)
	[1.31840]	[-1.70694]	[-4.23813]
D(LES(-4))	0.131049	-0.704423	-0.413653
	(0.10196)	(0.32724)	(0.06573)
	[1.28525]	[-2.15259]	[-6.29296]
D(LES(-5))	0.370250	-0.204810	-0.358687
	(0.10321)	(0.33125)	(0.06654)
	[3.58729]	[-0.61830]	[-5.39081]
D(LES(-6))	-0.004284	-0.492491	-0.483867
	(0.09764)	(0.31335)	(0.06294)
	[-0.04388]	[-1.57169]	[-7.68750]
D(LES(-7))	-0.009847	-0.261998	-0.443691
	(0.10117)	(0.32470)	(0.06522)
	[-0.09733]	[-0.80690]	[-6.80285]
D(LES(-8))	0.162750	-0.271340	-0.331255
	(0.10127)	(0.32502)	(0.06529)
	[1.60710]	[-0.83485]	[-5.07398]
D(LES(-9))	0.075710	-0.515431	-0.299307
	(0.10129)	(0.32508)	(0.06530)
	[0.74745]	[-1.58554]	[-4.58367]
D(LES(-10))	-0.067253	-0.559413	-0.163218
	(0.10323)	(0.33131)	(0.06655)

	[-0.65147]	[-1.68847]	[-2.45256]
D(LES(-11))	0.098843	-0.598765	-0.397942
	(0.08797)	(0.28233)	(0.05671)
	[1.12361]	[-2.12081]	[-7.01707]
C	-0.000370	0.045805	0.009652
	(0.00287)	(0.00921)	(0.00185)
	[-0.12912]	[4.97383]	[5.21799]
R-squared	0.647028	0.742750	0.775587
Adj. R-squared	0.596815	0.706154	0.743662
Sum sq. resids	0.414254	4.266951	0.172161
S.E. equation	0.041633	0.133616	0.026839
F-statistic	12.88553	20.29579	24.29415
Log likelihood	500.9442	181.4362	621.2369
Akaike AIC	-3.401052	-1.068877	-4.279101
Schwarz SC	-2.939521	-0.607346	-3.817570
Mean dependent	0.000282	0.005723	0.001526
S.D. dependent	0.065567	0.246490	0.053011

Determinant resid covariance (dof adj.)	2.17E-08
Determinant resid covariance	1.44E-08
Log likelihood	1307.327
Akaike information criterion	-8.746911
Schwarz criterion	-7.309572

Table B3: VECM Results for WHOLESALE Trade

Vector Error Correction Estimates

Date: 12/07/15 Time: 14:35

Sample (adjusted): 13 286

Included observations: 274 after adjustments

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LWHOL(-1)	1.000000
LWEP(-1)	0.143389
	(0.36462)
	[0.39325]
LES(-1)	1.016398
	(1.30668)
	[0.77785]
C	-9.172114

..Error Correction:	D(LWHOL)	D(LWEP)	D(LES)
CointEq1	-6.62E-05	0.039462	-0.009890
	(0.00343)	(0.01956)	(0.00376)
	[-0.01929]	[2.01773]	[-2.63287]
D(LWHOL(-1))	-0.427110	-0.026535	0.083653
	(0.06446)	(0.36732)	(0.07055)
	[-6.62616]	[-0.07224]	[1.18579]
D(LWHOL(-2))	-0.221595	-0.421141	0.032624
	(0.06984)	(0.39800)	(0.07644)
	[-3.17275]	[-1.05814]	[0.42680]
D(LWHOL(-3))	-0.035762	-0.203306	0.142968
	(0.07021)	(0.40011)	(0.07684)
	[-0.50934]	[-0.50813]	[1.86050]

D(LWHOL(-4))	-0.002692	-0.354133	0.013307
	(0.06978)	(0.39766)	(0.07637)
	[-0.03858]	[-0.89054]	[0.17424]
D(LWHOL(-5))	-0.030553	-0.791635	-0.023655
	(0.06986)	(0.39807)	(0.07645)
	[-0.43737]	[-1.98867]	[-0.30940]
D(LWHOL(-6))	0.042435	-0.866156	0.071722
	(0.07029)	(0.40053)	(0.07693)
	[0.60374]	[-2.16250]	[0.93235]
D(LWHOL(-7))	-0.071907	-0.782501	0.020768
	(0.07079)	(0.40338)	(0.07747)
	[-1.01583]	[-1.93988]	[0.26807]
D(LWHOL(-8))	-0.088593	-0.812562	-2.42E-05
	(0.06990)	(0.39830)	(0.07650)
	[-1.26751]	[-2.04007]	[-0.00032]
D(LWHOL(-9))	-0.004363	-0.568306	-0.124003
	(0.07082)	(0.40359)	(0.07751)
	[-0.06160]	[-1.40813]	[-1.59978]
D(LWHOL(-10))	0.064542	-0.727664	-0.125181
	(0.06921)	(0.39440)	(0.07575)
	[0.93254]	[-1.84501]	[-1.65262]
D(LWHOL(-11))	0.124968	-0.857284	-0.088397
	(0.06303)	(0.35916)	(0.06898)

	[1.98277]	[-2.38690]	[-1.28148]
D(LWEP(-1))	-0.003367	-0.660694	-0.028696
	(0.00998)	(0.05689)	(0.01093)
	[-0.33733]	[-11.6141]	[-2.62643]
D(LWEP(-2))	0.005456	-0.569741	-0.025918
	(0.01039)	(0.05922)	(0.01137)
	[0.52496]	[-9.62000]	[-2.27858]
D(LWEP(-3))	0.005121	-0.727927	-0.029450
	(0.00930)	(0.05301)	(0.01018)
	[0.55050]	[-13.7322]	[-2.89269]
D(LWEP(-4))	-0.009640	-0.610519	-0.027056
	(0.01106)	(0.06302)	(0.01210)
	[-0.87167]	[-9.68702]	[-2.23524]
D(LWEP(-5))	0.003355	-0.526556	-0.026245
	(0.01131)	(0.06443)	(0.01238)
	[0.29672]	[-8.17196]	[-2.12078]
D(LWEP(-6))	-0.015584	-0.612584	-0.044426
	(0.01041)	(0.05932)	(0.01139)
	[-1.49715]	[-10.3276]	[-3.89971]
D(LWEP(-7))	-0.004363	-0.549184	-0.044664
	(0.01112)	(0.06339)	(0.01218)
	[-0.39223]	[-8.66312]	[-3.66843]
D(LWEP(-8))	-0.001113	-0.458854	-0.048877

	(0.01087)	(0.06197)	(0.01190)
	[-0.10236]	[-7.40489]	[-4.10687]
D(LWEP(-9))	-0.017839	-0.673158	-0.032426
	(0.00926)	(0.05275)	(0.01013)
	[-1.92708]	[-12.7613]	[-3.20061]
D(LWEP(-10))	-0.009748	-0.580303	-0.039338
	(0.01031)	(0.05878)	(0.01129)
	[-0.94503]	[-9.87250]	[-3.48462]
D(LWEP(-11))	0.012407	-0.461960	-0.006768
	(0.01020)	(0.05813)	(0.01116)
	[1.21637]	[-7.94754]	[-0.60630]
D(LES(-1))	0.021402	0.182086	-0.624754
	(0.04977)	(0.28362)	(0.05447)
	[0.43002]	[0.64201]	[-11.4694]
D(LES(-2))	0.037737	-0.453166	-0.264162
	(0.05913)	(0.33697)	(0.06472)
	[0.63818]	[-1.34483]	[-4.08176]
D(LES(-3))	0.050245	-0.709748	-0.309767
	(0.05826)	(0.33197)	(0.06376)
	[0.86249]	[-2.13798]	[-4.85848]
D(LES(-4))	0.062171	-0.902399	-0.421089
	(0.05660)	(0.32254)	(0.06195)
	[1.09840]	[-2.79777]	[-6.79758]

D(LES(-5))	0.086754	-0.681834	-0.456500
	(0.05493)	(0.31301)	(0.06012)
	[1.57940]	[-2.17830]	[-7.59358]
D(LES(-6))	0.031286	-1.049412	-0.545978
	(0.05132)	(0.29246)	(0.05617)
	[0.60961]	[-3.58824]	[-9.72024]
D(LES(-7))	-0.015371	-0.555391	-0.500578
	(0.05458)	(0.31102)	(0.05973)
	[-0.28163]	[-1.78571]	[-8.38015]
D(LES(-8))	0.077525	-0.454986	-0.381018
	(0.05650)	(0.32198)	(0.06184)
	[1.37206]	[-1.41307]	[-6.16138]
D(LES(-9))	0.133043	-0.909494	-0.295976
	(0.05748)	(0.32755)	(0.06291)
	[2.31459]	[-2.77665]	[-4.70483]
D(LES(-10))	0.091265	-0.960592	-0.247397
	(0.05890)	(0.33564)	(0.06446)
	[1.54948]	[-2.86194]	[-3.83781]
D(LES(-11))	-0.000525	-0.603742	-0.528000
	(0.04941)	(0.28159)	(0.05408)
	[-0.01062]	[-2.14408]	[-9.76317]
C	0.004266	0.078420	0.010767
	(0.00205)	(0.01168)	(0.00224)
	[2.08067]	[6.71172]	[4.79828]

DUMMY	0.011479	-0.050023	0.001030
	(0.00875)	(0.04988)	(0.00958)
	[1.31149]	[-1.00292]	[0.10754]
R-squared	0.264550	0.701606	0.762024
Adj. R-squared	0.156396	0.657725	0.727028
Sum sq. resids	0.152415	4.949395	0.182566
S.E. equation	0.025306	0.144207	0.027696
F-statistic	2.446045	15.98866	21.77435
Log likelihood	637.9266	161.1100	613.1976
Akaike AIC	-4.393625	-0.913212	-4.213121
Schwarz SC	-3.918907	-0.438494	-3.738404
Mean dependent	0.003301	0.005723	0.001526
S.D. dependent	0.027552	0.246490	0.053011

Determinant resid covariance (dof adj.)	9.99E-09
Determinant resid covariance	6.55E-09
Log likelihood	1415.280
Akaike information criterion	-9.520289
Schwarz criterion	-8.056576

Table B4: VECM Results for RETAIL TRADE

Vector Error Correction Estimates

Date: 12/07/15 Time: 15:06

Sample (adjusted): 9 286

Included observations: 278 after adjustments

Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LRET(-1)	1.000000

LWEP(-1)	0.014692
	(0.27529)
	[0.05337]
LES(-1)	-3.935697
	(1.02529)
	[-3.83863]
C	13.27217

Error Correction:	D(LRET)	D(LWEP)	D(LES)
CointEq1	-0.008377	-0.025412	0.013936
	(0.00389)	(0.03637)	(0.00679)
	[-2.15597]	[-0.69868]	[2.05271]
D(LRET(-1))	-0.423912	-0.145985	0.078267
	(0.06223)	(0.58250)	(0.10873)
	[-6.81227]	[-0.25062]	[0.71983]
D(LRET(-2))	-0.170250	0.049846	0.071976
	(0.06757)	(0.63250)	(0.11806)
	[-2.51964]	[0.07881]	[0.60964]
D(LRET(-3))	-0.007382	0.307135	0.072620
	(0.06820)	(0.63839)	(0.11916)
	[-0.10824]	[0.48111]	[0.60942]
D(LRET(-4))	-0.052680	0.020398	0.017204
	(0.06703)	(0.62747)	(0.11713)
	[-0.78588]	[0.03251]	[0.14689]

D(LRET(-5))	-0.037057	-0.584476	0.017372
	(0.06573)	(0.61529)	(0.11485)
	[-0.56377]	[-0.94991]	[0.15125]
D(LRET(-6))	0.025902	-0.246676	0.129297
	(0.06504)	(0.60884)	(0.11365)
	[0.39824]	[-0.40516]	[1.13771]
D(LRET(-7))	-0.056437	-0.685894	0.174456
	(0.06040)	(0.56537)	(0.10553)
	[-0.93442]	[-1.21318]	[1.65310]
D(LWEP(-1))	0.000467	-0.328717	0.002658
	(0.00689)	(0.06451)	(0.01204)
	[0.06770]	[-5.09550]	[0.22075]
D(LWEP(-2))	0.005134	-0.289854	-0.000204
	(0.00713)	(0.06670)	(0.01245)
	[0.72049]	[-4.34543]	[-0.01637]
D(LWEP(-3))	0.002454	-0.521000	-0.008472
	(0.00731)	(0.06841)	(0.01277)
	[0.33583]	[-7.61556]	[-0.66343]
D(LWEP(-4))	-0.005295	-0.214189	0.010220
	(0.00788)	(0.07375)	(0.01377)
	[-0.67211]	[-2.90432]	[0.74242]
D(LWEP(-5))	-0.004806	-0.085603	0.040526
	(0.00709)	(0.06633)	(0.01238)

	[-0.67821]	[-1.29063]	[3.27336]
D(LWEP(-6))	-0.005574	-0.137472	-0.009440
	(0.00705)	(0.06600)	(0.01232)
	[-0.79061]	[-2.08290]	[-0.76628]
D(LWEP(-7))	-0.011407	-0.010874	0.000712
	(0.00654)	(0.06126)	(0.01143)
	[-1.74314]	[-0.17751]	[0.06225]
D(LES(-1))	-0.015838	1.372779	-0.533310
	(0.03678)	(0.34426)	(0.06426)
	[-0.43064]	[3.98762]	[-8.29923]
D(LES(-2))	-0.012911	0.916666	0.147298
	(0.04009)	(0.37524)	(0.07004)
	[-0.32209]	[2.44288]	[2.10297]
D(LES(-3))	-0.012657	0.903254	0.059819
	(0.03985)	(0.37301)	(0.06963)
	[-0.31762]	[2.42154]	[0.85915]
D(LES(-4))	0.011056	-0.139215	-0.189716
	(0.03904)	(0.36545)	(0.06822)
	[0.28318]	[-0.38094]	[-2.78114]
D(LES(-5))	0.034214	-0.564535	-0.263590
	(0.03870)	(0.36222)	(0.06761)
	[0.88419]	[-1.55856]	[-3.89859]
D(LES(-6))	0.074097	-1.468871	-0.509661

	(0.03922)	(0.36713)	(0.06853)
	[1.88923]	[-4.00091]	[-7.43708]
D(LES(-7))	0.041053	-0.522318	-0.300409
	(0.03640)	(0.34072)	(0.06360)
	[1.12787]	[-1.53300]	[-4.72351]
C	0.004702	0.019220	0.002349
	(0.00150)	(0.01401)	(0.00261)
	[3.14234]	[1.37211]	[0.89848]
DUMMY	-0.003090	-0.083450	-0.004175
	(0.00723)	(0.06772)	(0.01264)
	[-0.42707]	[-1.23227]	[-0.33029]
R-squared	0.203687	0.382965	0.542873
Adj. R-squared	0.131579	0.327092	0.501479
Sum sq. resids	0.116803	10.23470	0.356602
S.E. equation	0.021444	0.200734	0.037469
F-statistic	2.824777	6.854181	13.11495
Log likelihood	686.2440	64.49045	531.1020
Akaike AIC	-4.764345	-0.291298	-3.648216

Determinant resid covariance	2.62E-08
Log likelihood	1252.196
Akaike information criterion	-8.572828
Schwarz criterion	-7.897796

Table B5: VECM Result for (LES) Electricity supply

Vector Error Correction Estimates
Date: 10/11/16 Time: 12:02
Sample (adjusted): 6 286
Included observations: 275 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1

LES(-1)	1.000000
LWEP(-1)	0.163434 (0.01710) [9.55835]
LMANU(-1)	0.084446 (0.06606) [1.27837]
@TREND(1)	-0.002612 (0.00012) [-21.3290]
C	-4.926368

Error Correction:	D(LES)	D(LWEP)	D(LMANU)
CointEq1	-0.405542 (0.04613) [-8.79200]	-1.420641 (0.23143) [-6.13857]	-0.461127 (0.07599) [-6.06804]
D(LES(-1))	-0.186518 (0.06454) [-2.89014]	2.283092 (0.32380) [7.05102]	0.064672 (0.10632) [0.60826]
D(LES(-2))	0.403447 (0.07138) [5.65195]	1.649335 (0.35814) [4.60523]	0.438069 (0.11760) [3.72503]
D(LES(-3))	0.352814 (0.07638) [4.61948]	1.396917 (0.38320) [3.64542]	0.950491 (0.12583) [7.55388]
D(LES(-4))	-0.049835 (0.06734) [-0.74004]	-0.110318 (0.33787) [-0.32651]	0.901453 (0.11094) [8.12531]
D(LWEP(-1))	0.048576 (0.01278) [3.80058]	-0.127801 (0.06413) [-1.99293]	0.032288 (0.02106) [1.53336]
D(LWEP(-2))	0.030763 (0.01187) [2.59089]	-0.055170 (0.05957) [-0.92609]	0.019266 (0.01956) [0.98487]
D(LWEP(-3))	0.029642 (0.01144) [2.59144]	-0.316912 (0.05739) [-5.52213]	0.069816 (0.01884) [3.70483]
D(LWEP(-4))	0.024672 (0.01186) [2.08046]	-0.062101 (0.05950) [-1.04373]	0.051999 (0.01954) [2.66153]
D(LMANU(-1))	0.034014 (0.03642) [0.93396]	0.294036 (0.18272) [1.60919]	-0.177949 (0.06000) [-2.96582]
D(LMANU(-2))	0.113438 (0.03590) [3.15964]	0.119273 (0.18013) [0.66214]	-0.528902 (0.05915) [-8.94187]

D(LMANU(-3))	-0.022331 (0.03528) [-0.63302]	0.289902 (0.17700) [1.63789]	-0.175966 (0.05812) [-3.02766]
D(LMANU(-4))	0.096307 (0.03516) [2.73928]	0.466348 (0.17640) [2.64374]	-0.126642 (0.05792) [-2.18640]
C	-0.000340 (0.00235) [-0.14502]	-0.000221 (0.01178) [-0.01872]	-0.002830 (0.00387) [-0.73168]
R-squared	0.493538	0.393341	0.513121
Adj. R-squared	0.468312	0.363124	0.488870
Sum sq. resids	0.390167	9.821776	1.059010
S.E. equation	0.038664	0.193988	0.063699
F-statistic	19.56462	13.01732	21.15905
Log likelihood	511.5101	67.96516	374.2144
Akaike AIC	-3.618255	-0.392474	-2.619741
Schwarz SC	-3.434129	-0.208347	-2.435615
Mean dependent	0.001200	0.003395	0.000561
S.D. dependent	0.053025	0.243079	0.089097

Determinant resid covariance (dof adj.)	1.70E-07
Determinant resid covariance	1.45E-07
Log likelihood	994.3513
Akaike information criterion	-6.897101
Schwarz criterion	-6.292113

Table B6: VECM Result for (LES) Electricity supply

Vector Error Correction Estimates
Date: 10/11/16 Time: 14:45
Sample (adjusted): 8 286
Included observations: 279 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LES(-1)	1.000000
LWEP(-1)	0.320302 (0.04355) [7.35558]
LMINE(-1)	1.531990 (0.32161) [4.76344]
@TREND(1)	-0.003179 (0.00023) [-13.7727]
C	-11.99054

Error Correction:	D(LES)	D(LWEP)	D(LMINE)

CointEq1	-0.135822	-0.924976	-0.134150
	(0.03344)	(0.16812)	(0.04294)
	[-4.06221]	[-5.50180]	[-3.12418]
D(LES(-1))	-0.423704	1.761663	0.353796
	(0.05602)	(0.28170)	(0.07195)
	[-7.56296]	[6.25367]	[4.91741]
D(LES(-2))	0.191177	0.793863	0.257604
	(0.06735)	(0.33863)	(0.08649)
	[2.83873]	[2.34432]	[2.97848]
D(LES(-3))	0.070910	0.815004	0.043310
	(0.06731)	(0.33848)	(0.08645)
	[1.05340]	[2.40786]	[0.50099]
D(LES(-4))	-0.105392	0.322670	0.241675
	(0.06700)	(0.33687)	(0.08604)
	[-1.57312]	[0.95785]	[2.80892]
D(LES(-5))	-0.124376	0.311526	0.485953
	(0.06869)	(0.34538)	(0.08821)
	[-1.81072]	[0.90197]	[5.50888]
D(LES(-6))	-0.268217	-0.438157	-0.023073
	(0.06273)	(0.31541)	(0.08056)
	[-4.27591]	[-1.38917]	[-0.28641]
D(LWEP(-1))	0.022779	-0.197800	0.088941
	(0.01298)	(0.06528)	(0.01667)
	[1.75468]	[-3.03020]	[5.33480]
D(LWEP(-2))	0.015146	-0.119970	0.057290
	(0.01280)	(0.06436)	(0.01644)
	[1.18327]	[-1.86397]	[3.48512]
D(LWEP(-3))	0.023534	-0.372521	0.086479
	(0.01210)	(0.06086)	(0.01554)
	[1.94447]	[-6.12135]	[5.56391]
D(LWEP(-4))	0.011518	-0.170713	0.064490
	(0.01166)	(0.05863)	(0.01497)
	[0.98773]	[-2.91159]	[4.30649]
D(LWEP(-5))	0.039966	-0.044707	0.080746
	(0.01157)	(0.05819)	(0.01486)
	[3.45362]	[-0.76832]	[5.43318]
D(LWEP(-6))	-0.021070	-0.119075	0.022552
	(0.01121)	(0.05635)	(0.01439)
	[-1.88007]	[-2.11306]	[1.56695]
D(LMINE(-1))	0.263451	1.539830	-0.455206
	(0.06617)	(0.33274)	(0.08498)
	[3.98119]	[4.62774]	[-5.35642]
D(LMINE(-2))	0.212503	1.754651	-0.413026
	(0.06676)	(0.33567)	(0.08573)
	[3.18328]	[5.22737]	[-4.81771]
D(LMINE(-3))	0.150883	2.027946	-0.215194
	(0.06704)	(0.33712)	(0.08610)

	[2.25047]	[6.01552]	[-2.49929]
D(LMINE(-4))	0.040503	1.075124	-0.354369
	(0.06714)	(0.33759)	(0.08622)
	[0.60327]	[3.18466]	[-4.10990]
D(LMINE(-5))	0.052999	0.013206	-0.316576
	(0.06116)	(0.30754)	(0.07855)
	[0.86653]	[0.04294]	[-4.03042]
D(LMINE(-6))	-0.179208	-0.402206	-0.019907
	(0.04963)	(0.24955)	(0.06374)
	[-3.61090]	[-1.61172]	[-0.31233]
C	0.002162	0.007122	-0.003584
	(0.00210)	(0.01057)	(0.00270)
	[1.02840]	[0.67360]	[-1.32744]
R-squared	0.603242	0.527502	0.565239
Adj. R-squared	0.574136	0.492840	0.533345
Sum sq. resids	0.309979	7.837296	0.511240
S.E. equation	0.034595	0.173954	0.044429
F-statistic	20.72580	15.21845	17.72261
Log likelihood	553.0598	102.4545	483.2629
Akaike AIC	-3.821218	-0.591072	-3.320881
Schwarz SC	-3.560916	-0.330770	-3.060579
Mean dependent	0.001842	0.005620	0.000459
S.D. dependent	0.053013	0.244265	0.065038

Determinant resid covariance (dof adj.)	6.89E-08
Determinant resid covariance	5.51E-08
Log likelihood	1143.868
Akaike information criterion	-7.740989
Schwarz criterion	-6.908023

Table B7: VECM Result for (LES) Electricity supply

Vector Error Correction Estimates
Date: 10/11/16 Time: 12:09
Sample (adjusted): 6 286
Included observations: 281 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LES(-1)	1.000000
LWEP(-1)	0.101515
	(0.02262)
	[4.48701]
LWHOLESL(-1)	-0.604165
	(0.04062)
	[-14.8731]
C	-2.183819
	(0.12907)
	[-16.9191]

Error Correction:	D(LES)	D(LWEP)	D(LWHOLESL)
CointEq1	-0.266803	-0.830447	0.062417
	(0.04455)	(0.22065)	(0.02756)
	[-5.98829]	[-3.76361]	[2.26479]
D(LES(-1))	-0.262565	2.069589	-0.054229
	(0.06299)	(0.31196)	(0.03896)
	[-4.16831]	[6.63420]	[-1.39180]
D(LES(-2))	0.420699	1.574214	-0.039653
	(0.07105)	(0.35185)	(0.04395)
	[5.92145]	[4.47405]	[-0.90230]
D(LES(-3))	0.232876	1.184559	-0.039604
	(0.07603)	(0.37652)	(0.04703)
	[3.06303]	[3.14604]	[-0.84213]
D(LES(-4))	-0.152204	-0.292019	-0.056298
	(0.06732)	(0.33338)	(0.04164)
	[-2.26100]	[-0.87592]	[-1.35201]
D(LWEP(-1))	0.028324	-0.215584	-0.002742
	(0.01278)	(0.06327)	(0.00790)
	[2.21711]	[-3.40743]	[-0.34702]
D(LWEP(-2))	0.008869	-0.142553	-0.001550
	(0.01174)	(0.05815)	(0.00726)
	[0.75533]	[-2.45133]	[-0.21339]
D(LWEP(-3))	0.016498	-0.380353	0.008485
	(0.01167)	(0.05778)	(0.00722)
	[1.41405]	[-6.58264]	[1.17573]
D(LWEP(-4))	0.014560	-0.107535	-0.011185
	(0.01193)	(0.05911)	(0.00738)
	[1.22000]	[-1.81937]	[-1.51510]
D(LWHOLESL(-1))	-0.045560	-0.046373	-0.365718
	(0.09739)	(0.48232)	(0.06024)
	[-0.46780]	[-0.09615]	[-6.07079]
D(LWHOLESL(-2))	0.012669	-0.303830	-0.174765
	(0.10395)	(0.51481)	(0.06430)
	[0.12188]	[-0.59017]	[-2.71794]
D(LWHOLESL(-3))	0.075697	0.095139	-0.000870
	(0.10382)	(0.51415)	(0.06422)
	[0.72914]	[0.18504]	[-0.01355]
D(LWHOLESL(-4))	0.151532	0.119788	0.034373
	(0.09597)	(0.47527)	(0.05936)
	[1.57902]	[0.25204]	[0.57904]
R-squared	0.418712	0.323849	0.164115
Adj. R-squared	0.392684	0.293573	0.126687
Sum sq. resids	0.457271	11.21532	0.174961
S.E. equation	0.041307	0.204568	0.025551
F-statistic	16.08710	10.69675	4.384843
Log likelihood	503.4056	53.83912	638.3860
Akaike AIC	-3.490431	-0.290670	-4.451146
Schwarz SC	-3.322109	-0.122347	-4.282823

Mean dependent	0.001472	0.005580	0.003367
S.D. dependent	0.053004	0.243391	0.027341
Determinant resid covariance (dof adj.)		4.12E-08	
Determinant resid covariance		3.57E-08	
Log likelihood		1213.019	
Akaike information criterion		-8.327537	
Schwarz criterion		-7.770778	

Table B8: VECM Result for (LES) Electricity Supply

Vector Error Correction Estimates
Date: 10/11/16 Time: 12:26
Sample (adjusted): 7 286
Included observations: 280 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LES(-1)	1.000000
LWEP(-1)	0.147701
	(0.04469)
	[3.30491]
LRETAIL(-1)	-0.721143
	(0.09173)
	[-7.86136]
C	-1.807716
	(0.29797)
	[-6.06687]

Error Correction:	D(LES)	D(LWEP)	D(LRETAIL)
CointEq1	-0.141747	-0.546502	0.049129
	(0.03350)	(0.16394)	(0.01727)
	[-4.23154]	[-3.33347]	[2.84537]
D(LES(-1))	-0.349308	1.965392	-0.034588
	(0.06601)	(0.32305)	(0.03402)
	[-5.29205]	[6.08394]	[-1.01662]
D(LES(-2))	0.344721	1.543138	-0.049135
	(0.07279)	(0.35622)	(0.03752)
	[4.73614]	[4.33195]	[-1.30967]
D(LES(-3))	0.128231	1.122010	-0.045607
	(0.07590)	(0.37145)	(0.03912)
	[1.68957]	[3.02064]	[-1.16580]
D(LES(-4))	-0.281441	-0.312021	-0.009512
	(0.07537)	(0.36890)	(0.03885)
	[-3.73388]	[-0.84582]	[-0.24484]
D(LES(-5))	-0.116882	0.105941	-0.005019

```
                             (0.06751)      (0.33040)      (0.03480)
                            [-1.73134]     [ 0.32064]     [-0.14423]

         D(LWEP(-1))          0.030809      -0.225153      -0.002947
                             (0.01341)      (0.06563)      (0.00691)
                            [ 2.29760]     [-3.43082]     [-0.42638]

         D(LWEP(-2))          0.024886      -0.171098       0.004167
                             (0.01357)      (0.06640)      (0.00699)
                            [ 1.83431]     [-2.57682]     [ 0.59582]

         D(LWEP(-3))          0.021636      -0.385963       0.003175
                             (0.01222)      (0.05980)      (0.00630)
                            [ 1.77078]     [-6.45438]     [ 0.50415]

         D(LWEP(-4))          0.026957      -0.132729       0.000122
                             (0.01311)      (0.06414)      (0.00676)
                            [ 2.05690]     [-2.06930]     [ 0.01810]

         D(LWEP(-5))          0.033399      -0.071754      -0.000263
                             (0.01223)      (0.05986)      (0.00630)
                            [ 2.73067]     [-1.19868]     [-0.04167]

        D(LRETAIL(-1))        0.037527      -0.316979      -0.372280
                             (0.11862)      (0.58056)      (0.06114)
                            [ 0.31636]     [-0.54599]     [-6.08860]

        D(LRETAIL(-2))        0.080296       0.117068      -0.119415
                             (0.12467)      (0.61016)      (0.06426)
                            [ 0.64407]     [ 0.19186]     [-1.85828]

        D(LRETAIL(-3))        0.108862       0.465632       0.042744
                             (0.12299)      (0.60193)      (0.06339)
                            [ 0.88513]     [ 0.77356]     [ 0.67425]

        D(LRETAIL(-4))       -0.016749       0.091493      -0.008527
                             (0.12273)      (0.60064)      (0.06326)
                            [-0.13647]     [ 0.15233]     [-0.13480]

        D(LRETAIL(-5))       -0.047487      -0.367144      -0.009383
                             (0.11543)      (0.56493)      (0.05950)
                            [-0.41139]     [-0.64989]     [-0.15770]
====================================================================
 R-squared                    0.404650       0.326093       0.157409
 Adj. R-squared               0.370823       0.287803       0.109534
 Sum sq. resids               0.466669       11.17807       0.123988
 S.E. equation                0.042044       0.205770       0.021671
 F-statistic                  11.96243       8.516371       3.287941
 Log likelihood               498.2666       53.61417       683.8275
 Akaike AIC                  -3.444761      -0.268673      -4.770197
 Schwarz SC                  -3.237059      -0.060970      -4.562494
 Mean dependent               0.001660       0.005600       0.002753
 S.D. dependent               0.053005       0.243827       0.022966
====================================================================
 Determinant resid covariance (dof adj.)     3.12E-08
```

APPENDIX C

Table C9: Cointegration Test Result

Date: 12/07/15 Time: 13:08
Sample (adjusted): 6 286
Included observations: 275 after adjustments
Trend assumption: Quadratic deterministic trend
Series: LMANU LWEP LES
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.279394	101.0952	35.01090	0.0000
At most 1	0.030883	10.98796	18.39771	0.3902
At most 2	0.008550	2.361226	3.841466	0.1244

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.279394	90.10727	24.25202	0.0000
At most 1	0.030883	8.626735	17.14769	0.5349
At most 2	0.008550	2.361226	3.841466	0.1244

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table C10: Cointegration Test Result

Date: 02/01/16 Time: 15:38
Sample (adjusted): 6 286
Included observations: 281 after adjustments
Trend assumption: Linear deterministic trend
Series: LMINE LES LWEP
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.263587	93.87023	29.79707	0.0000

At most 1	0.018189	7.894122	15.49471	0.4768
At most 2	0.009690	2.736056	3.841466	0.0981

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.263587	85.97611	21.13162	0.0000
At most 1	0.018189	5.158066	14.26460	0.7217
At most 2	0.009690	2.736056	3.841466	0.0981

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table C11: Cointegration Test Result

Date: 12/07/15 Time: 14:06
Sample (adjusted): 5 286
Included observations: 282 after adjustments
Trend assumption: Linear deterministic trend
Series: LWHOLESL LWEP LES
Exogenous series: DUMMY
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.236710	81.76170	29.79707	0.0000
At most 1	0.018191	5.588757	15.49471	0.7435
At most 2	0.001458	0.411565	3.841466	0.5212

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.236710	76.17295	21.13162	0.0000
At most 1	0.018191	5.177192	14.26460	0.7193
At most 2	0.001458	0.411565	3.841466	0.5212

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

```
 * denotes rejection of the hypothesis at the 0.05 level
 **MacKinnon-Haug-Michelis (1999) p-values
```

Table C12: Cointegration Test Result

```
Date: 12/07/15   Time: 14:59
Sample (adjusted): 6 286
Included observations: 281 after adjustments
Trend assumption: Linear deterministic trend
Series: LRETAIL LWEP LES 
Exogenous series: DUMMY 
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)
==========================================================================
 Hypothesized                      Trace           0.05
  No. of CE(s)     Eigenvalue     Statistic    Critical Value     Prob.**
==========================================================================

    None *          0.114087      42.41123       29.79707        0.0011
  At most 1         0.028489      8.371740       15.49471        0.4265
  At most 2         0.000890      0.250098       3.841466        0.6170
==========================================================================

 Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
 * denotes rejection of the hypothesis at the 0.05 level
 **MacKinnon-Haug-Michelis (1999) p-values



Unrestricted Cointegration Rank Test (Maximum Eigenvalue)
==========================================================================
 Hypothesized                    Max-Eigen         0.05
  No. of CE(s)     Eigenvalue     Statistic    Critical Value     Prob.**
==========================================================================

    None *          0.114087      34.03949       21.13162        0.0005
  At most 1         0.028489      8.121642       14.26460        0.3665
  At most 2         0.000890      0.250098       3.841466        0.6170
==========================================================================

 Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
 * denotes rejection of the hypothesis at the 0.05 level
 **MacKinnon-Haug-Michelis (1999) p-values
```

APPENDIX D

Table D13: VAR Granger Causality Results

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 02/15/16 Time: 13:45
Sample: 1 286
Included observations: 275

Dependent variable: D(LMANU)

Excluded	Chi-sq	df	Prob.
D(LWEP)	10.15561	4	0.0379
D(LES)	43.26345	4	0.0000
All	91.88246	8	0.0000

Dependent variable: D(LWEP)

Excluded	Chi-sq	df	Prob.
D(LMANU)	6.861221	4	0.1434
D(LES)	39.92718	4	0.0000
All	57.39912	8	0.0000

Dependent variable: D(LES)

Excluded	Chi-sq	df	Prob.
D(LMANU)	10.18916	4	0.0374
D(LWEP)	1.121470	4	0.8909
All	12.33673	8	0.1368

Table D14: VAR Granger Causality Results

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 02/15/16 Time: 14:31
Sample: 1 286
Included observations: 274

Dependent variable: D(LMINE)

Excluded	Chi-sq	df	Prob.
D(LWEP)	40.38675	11	0.0000

D(LES)	28.79263	11	0.0024
All	67.88353	22	0.0000

Dependent variable: D(LWEP)

Excluded	Chi-sq	df	Prob.
D(LMINE)	43.42155	11	0.0000
D(LES)	16.15755	11	0.1354
All	71.47692	22	0.0000

Dependent variable: D(LES)

Excluded	Chi-sq	df	Prob.
D(LMINE)	33.30030	11	0.0005
D(LWEP)	36.62925	11	0.0001
All	88.24737	22	0.0000

Table D15: VAR Granger Causality Results

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 02/15/16 Time: 14:54
Sample: 1 286
Included observations: 274

Dependent variable: D(LWHOLESL)

Excluded	Chi-sq	Df	Prob.
D(LWEP)	15.16026	11	0.1753
D(LES)	9.866500	11	0.5424
All	27.27640	22	0.2009

Dependent variable: D(LWEP)

Excluded	Chi-sq	Df	Prob.
D(LWHOLESL)	9.000030	11	0.6219
D(LES)	33.28657	11	0.0005
All	44.99052	22	0.0027

Dependent variable: D(LES)

Excluded	Chi-sq	Df	Prob.
D(LWHOLESL)	15.41701	11	0.1642

D(LWEP)	35.27226	11	0.0002
All	57.66099	22	0.0000

Table D16: VAR Granger Causality Results

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 02/15/16   Time: 15:05
Sample: 1 286
Included observations: 278

Dependent variable: D(LRETAIL)

Excluded	Chi-sq	df	Prob.
D(LWEP)	4.845957	7	0.6788
D(LES)	5.775543	7	0.5662
All	8.402934	14	0.8673

Dependent variable: D(LWEP)

Excluded	Chi-sq	df	Prob.
D(LRETAIL)	2.402335	7	0.9343
D(LES)	88.58548	7	0.0000
All	93.50225	14	0.0000

Dependent variable: D(LES)

Excluded	Chi-sq	Df	Prob.
D(LRETAIL)	5.484336	7	0.6011
D(LWEP)	28.13753	7	0.0002
All	32.28591	14	0.0036

Ethical Clearance Certificate