CHAPTER 1

INTRODUCTION

1.1. Background and Problem Statement

Energy is considered as an indispensable resource that supports human survival, economic growth, social progress and sustainable development as cited by the International Energy Agency (International Energy Agency, 2014; Kaygusuz, 2012). It is an essential factor in the production process and strategic resources of an industrial society (Yi-Ming, Ying, Zhi-Yong and Gang, 2010). Adequate supplies of clean energy are the basis for raising living standards, improving the quality and quantity of human capital, enhancing the business and natural environment, and increasing the efficiency of government policies (Kaygusuz, 2012).

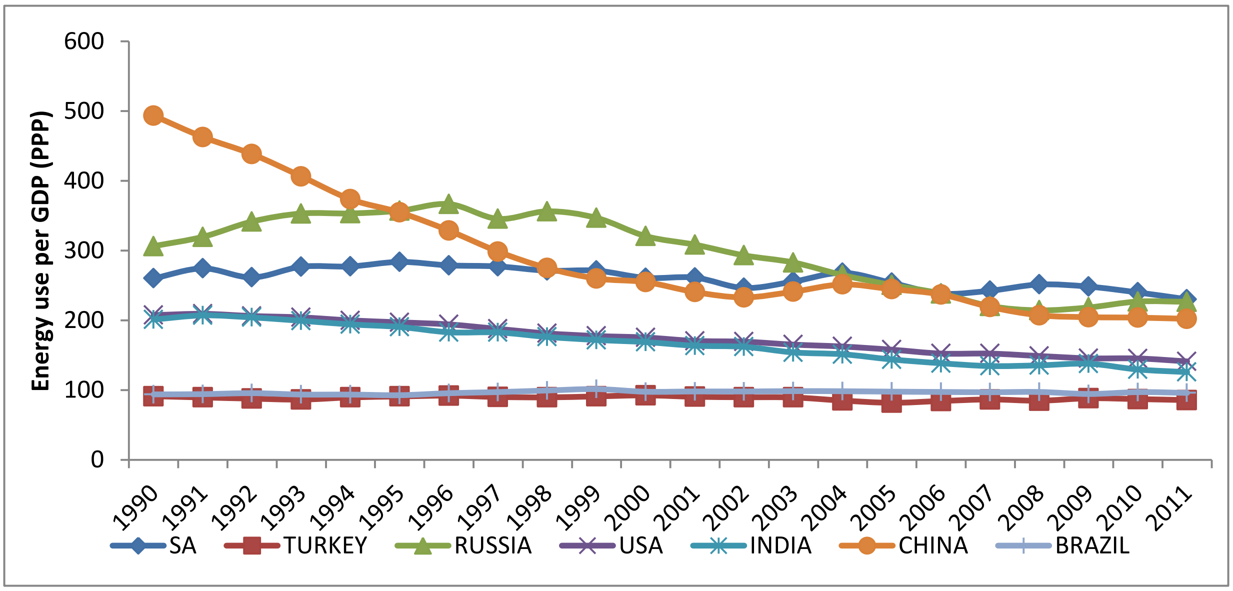
For the last decade, the world economy (especially China and India) and energy consumption have witnessed tremendous growth (Kaygusuz, 2012). The world's gross domestic product (GDP) rose from $46 trillion in 2005 to $74 trillion in 2013, with an average annual increase of 6.30 percent (World Bank, 2014). Similarly, energy consumption rose from 10, 714.4 million tons of oil equivalents to 12, 730.43 million tons of oil equivalents for the same period - an annual increase of 2.19 percent (BP Statistics, 2014)[1]. While the global picture hides much of the details between countries, to understand the diversity among these countries, it is worth observing the per capita GDP and energy use per capita GDP.

Energy consumption per unit of output has changed over the last two decades. This can be attributed to economic structure, technological improvement and inter-fuel substitution. During the course of economic development, changes in the structure of GDP will lead to rising then declining energy use (Gillingham, 2009), although long-run series for energy and output should be treated with caution due to inherent development characteristics that appear (Richard, Michael, Richard, Edmund and Joe, 1981). Energy consumption per unit of output for the United

[1] Data on World GDP was retrieved from World Development Bank Indicator 2014 and measured in current US Dollars while that of Energy consumption was retrieved from BP Statistics of World Energy 2014 and measured in million tonnes of oil equivalent.

States and some emerging economies between 1990 and 2012 (purchasing power parity (PPP)) is illustrated in Figure 1.1.

Figure 1.1: Energy Consumption per Unit of Output (1990-2011)



Source: Constructed based on data retrieved from World Bank (2014).

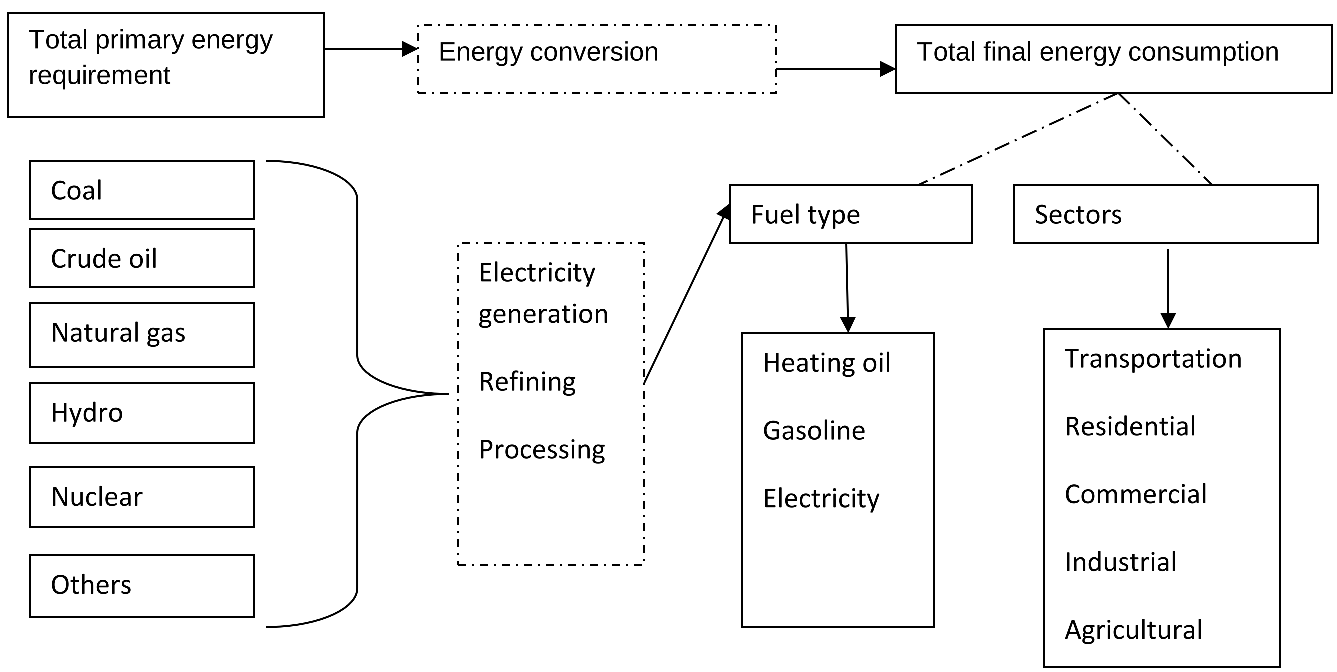
The long-run trend clearly indicates a downward movement which means that lower energy is required per dollar of GDP as the economy develops. The reason for this is that most of these countries are in their post-industrial stage of economic development (Joanne & Lester, 2009). In this case, the tertiary sector grows faster while energy demand grows at a slower rate for a given increase in GDP.

South Africa's economy has grown rapidly since the end of the apartheid era in 1994, and the country is now one of the most developed nations in Africa. South Africa has the second largest economy in Africa after Nigeria (World Bank, 2014) in terms of gross domestic product (GDP), and is the highest energy consumer on the continent (Energy Information Agency, 2014). South Africa accounted for about 30 percent of the total primary energy consumption in Africa in 2012

(BP Statistics, 2013). It required 0.24 tons of oil equivalents to produce US$1000 dollars at purchasing power parity (PPP) of GDP in 2001 (International Energy Agency, 2014). Annual per capita energy consumption in South Africa is 2.4 tons of oil Equivalent. Although large, this value is still much lower than that of the United States of America, where it is 8 tons of oil equivalents (International Energy Agency, 2014; World Bank, 2005).

Energy resources such as coal, crude oil, natural gas, hydro and nuclear are the primary sources of energy in South Africa and they have to be converted to other forms of energy before they can be consumed by end users. A brief examination of the structure of energy balance table provides a clear understanding of the energy data in energy demand analysis. This will assist in tracking the total energy required to facilitate consumption by sector and fuel type (See Figure 1.2).

Figure 1.2: Typical Structure of Energy Balance Table



Source: Joanne and Lester (2009, p. 91)

Energy conversion industries such as electricity generation and refining convert primary energy inputs to products for final consumption (Joanne and Lester, 2009). Figure 1.2 illustrates the general flow of energy balance tables. Total primary energy requirement is the quantity of energy necessary to produce the energy for final consumption. The difference between the total primary energy requirement and the total final consumption can be referred to as the conversion, transmission and distribution losses and this depends on the type of fuel and the efficiency of the conversion, transmission and distribution processes.

Energy crises in the early 1970's which contributed to reducing economic growth in many countries increased concerns about whether or not to implement energy conservation policy as well as placing emphasis on the danger of dependence on exhaustible resources (Jamil and Ahmad, 2010; Lee and Chang, 2006; Richard et al., 1981). Although energy is an essential input for economic growth and development, two major drawbacks have emerged in the way energy resources are sourced, produced and used (Davidson et al., 2006). First, the overall energy system specifically in South Africa has been very inefficient, with the efficiency index standing at 38 percent in 2009 (South Africa Energy Efficiency Report, 2011). Secondly, there are different social and environmental problems, both local and global, which have affected with the energy system. In addition to that, "the workings of the energy sector are socially disruptive – the development of most energy sources results in the dislocation of people and exacerbates differentials among social groups. Reducing the environmental and social burden is thus a major concern for the energy sector" (Davidson et al., 2006, p. 1).

A modern society implies growing reliance on networked information and communication technologies (ICTs), with more and more people using the internet. Other ICTs such as cell phones, digital video recorders, digital music players, personal computers, and so on are quite common now. Therefore, companies, households and economies as a whole exhibit an increasing demand for energy. This demand is driven by such important factors as industrialization, extensive urbanization, population growth, and a rise in the standard of living (Gurgul and Lach, 2012).

Uri (1995) stated that inadequacy of energy resources to meet demand affects economic growth as in the case the USA (Uri, 1995). Limited supply of energy resources and the need for environmental conservation have propelled countries to find a middle ground between energy consumption and economic growth (Lee, 2006). On the other hand, Quedraogo (2013) suggested that the availability of modern energy is not by itself a panacea for the economic and social problems facing a country, as it is now widely recognized that lack of access to reliable and affordable energy resources is a fundamental obstacle to socio-economic development (Ouedraogo, 2013).

Ertugrul et al. (2014) reported that the saving of energy in the industrial, agricultural, service and housing sectors may be necessary if it helps in reducing energy cost, price of goods and services, green-house gas emission and also leads to better resource allocation by shifting capital and labour from the energy sector to more productive sectors. However, if production depend heavily on energy resources (as in the case of South Africa), energy conservation policy, may put constraint on economic growth.

The implication of energy scarcity for future economic growth raises wider issues since much of the argument of "time discounting" depends crucially on the proposition that the future will be more prosperous than the present. The response of higher energy demand due to changes in lifestyle and level of technology in South Africa will affect not only the future standard of living of South Africans but also influence the nature and extent of economic growth in the country.

Also due to the environmental impact of increased energy demand fuelled mainly by increasing economic activities across economies, coupled with the current debate about global warming and climate change which requires policy makers to take some precautions against the high level of greenhouse gas emission, some industrialized countries committed themselves to reducing greenhouse gas emission by restricting fossil fuel consumption in line with the Kyoto protocol. Nevertheless, it is argued that decreasing energy consumption may reduce economic growth and increase unemployment since energy is considered as essential factor of production (Stern, 2000).

The knowledge of the dynamic interaction between energy consumption and economic growth in South Africa plays a crucial role in the design and implementation of energy policies. If, for instance, a decrease in energy consumption hampers economic growth, then adopting energy conserving policies designed to reduce energy consumption will not be desirable. On the other hand, if reducing energy consumption does not affect economic growth, energy conserving policies may be implemented without adversely economic growth.

1.2. Objectives

The main objective of this study is to examine and discuss the growth and pattern of energy consumption in South Africa between 1980 and 2012. More specifically, the study seeks to accomplish the following objectives:

1. To examine the causal relationship between energy consumption as a whole and economic growth in South Africa.

2. To examine the impact of different energy components (coal, crude oil, natural gas and electricity) on overall economic growth (dis-aggregated analysis).

3. To examine the impact of dis-aggregated energy consumption on each of the primary, secondary and tertiary sectors of the economy.

4. To suggest policy recommendations with respect to energy use in the South African economy.

1.3. Need for the Study

The slowdown in global economic growth gave rise to the need for economic reform across economies, with energy reform being critical to accomplishing this agenda (World Bank, 2014). The increasing concern about green-house gas emissions and the implementation of the Kyoto protocol compels nations to curtail their energy requirement and adopt energy conserving technologies (Jamil and Ahmad, 2010). This presents countries with the dilemma of either promoting energy-saving policy at the expense of economic growth or vice versa. Empirical investigation as to whether energy consumption is a consequence or cause of economic growth is therefore essential (Herrerias, Joyeux and Girardin, 2013).

Several empirical studies (e.g Apergis and Payne, 2009a; Bowden and Payne, 2009; Dagher and Yacoubian, 2012; Jinke, Hualing, and Dianming, 2008; Odhiambo, 2009a, 2009c; S. Z. Tsani, 2010), using different approaches and data sets have been conducted on the causal relationship between energy consumption and economic growth in different countries. Their findings are mixed and inconclusive as to the directional of causality and the strength of the impact of energy consumption on economic growth (Ouedraogo, 2013). The disparities in results may be due to the fact that countries have different energy consumption patterns, dissimilar economic structures, disparities in the variables used, and subject to variation in the statistical methods used in the analysis, the various shocks associated with the data used for the period under investigation or due to the fact that different countries have different sources of energy. Bearing the above in mind, it is imperative to study the causal relationship in the context of South Africa so as to provide fresh empirical evidence on the impact of energy consumption on economic growth in the country.

In order to see the potential response of economic growth to variations in energy consumption specifically in South Africa where the economy is highly dependent on energy (energy intensive), there is a need to constantly measure the level of dependence or relationship between energy consumption and economic growth so as to provide fresh empirical evidence on their interrelationship.

Also, most studies (e.g Bildirici and Bakirtas, 2014; Odhiambo, 2009b; Ziramba, 2009) on the relationship between energy consumption and growth including the ones that examined that employs the various energy types (coal, crude oil, natural gas and electricity), have only focused on the aggregate economy ignoring sectoral energy use. Examining the impact of the disaggregated energy consumption on primary, secondary and tertiary output growth tends to give new insights on the impact of sector based energy consumption on growth.

The result of this study will guide policy makers on the right energy policies to formulate in order to bring about sustainable growth in the economy. The result of this study will also be useful in developing energy and environmental policy for South Africa as well as providing valuable material to researchers for further study.

1.4. Scope and Limitations

This study examined the impact of energy consumption on economic growth in South Africa from 1980 to 2012. It focused on the aggregated and disaggregated impact of energy resources on economic growth. The estimation of the variables encompassed both the short-run and long-run time periods.

The study encountered several constraints. Prominent among these was the difficulty in accessing energy resources data that dates to 1980 from the main sources such as Statistics South Africa and Department of Energy, among others. This had to be supplemented by data from BP Statistics.

1.5. Outline of the Study

This study comprises six chapters. Chapter 2 gives a brief overview of the South African economy and energy use. Energy intensity and energy efficiency in South Africa are also discussed. Chapter 3 provides discussion on the theoretical and empirical literature on the role of energy in production. The conceptual framework and methodology used for the estimation of the variables are outlined in Chapter 4. Results and discussions of the study are presented in Chapter 5, while Chapter 6 provides the summary of major findings, conclusions and policy recommendations.

CHAPTER 2

AN OVERVIEW OF THE SOUTH AFRICAN ECONOMY AND ENERGY RESOURCES

The overview of the South African economy and energy resources is presented in five sections that support the objectives of the study. Section one focuses on the South African economy. This is followed by an overview of the South African energy resources in section two. The South African energy efficiency and energy intensity literature are discussed in section three, while various energy policies in South Africa are discussed in section four. Summary of the chapter is presented in section five.

2.1. A Brief Overview of the South African Economy

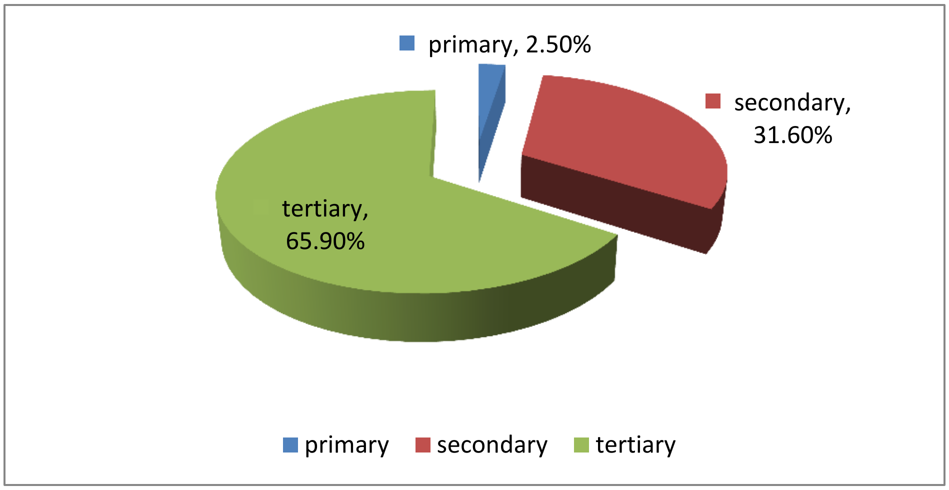
The economy of South Africa is the second largest in Africa, after Nigeria, and third among the emerging economies. It accounts for about 24 percent of Africa's Gross Domestic Product in terms of purchasing power parity, and is ranked as an upper-middle income economy by the World Bank; this makes the country one of only four countries in Africa in this category (the others being Botswana, Gabon and Mauritius (World Bank, 2014). Since 1996, which marked the end of twelve years of international sanctions, South Africa's Gross Domestic Product (GDP) has almost tripled to $400 billion, and foreign exchange reserves have increased from $3 billion to nearly $50 billion, creating a growing and sizable African middle class, within two decades of establishing democracy and ending apartheid (World Bank, 2014). Notwithstanding the growth in gross domestic product, a quarter of the population is unemployed. The number increases to 35 percent when including people who have given up looking for job (United Nations Development Programme, 2008).

A quarter of South Africans live on less than US $1.25 a day (United Nations Development Programme, 2008). South Africa has shifted from a primary and secondary sector based economy in the mid-twentieth century to an economy driven primarily by the tertiary sector which accounts for an estimated 65 percent of gross domestic product or $230 billion in nominal GDP terms (World Bank, 2014).

The country's economy is reasonably diversified, with key economic sectors that contribute to the GDP and keep the economic engine running including: manufacturing, mining, agriculture and fisheries, food processing, telecommunication, energy, financial and business services, real estate, tourism, transportation, wholesale and retail trade (World Bank, 2011).

As per 2012 data, tertiary sector in South Africa is the largest, contributing about 65.9 percent of the total GDP; this is followed by the secondary sector which contributes about 31.6 percent of the total GDP. The primary sector is small and contributes only 2.5 percent of the total GDP (see Figure 2.1).

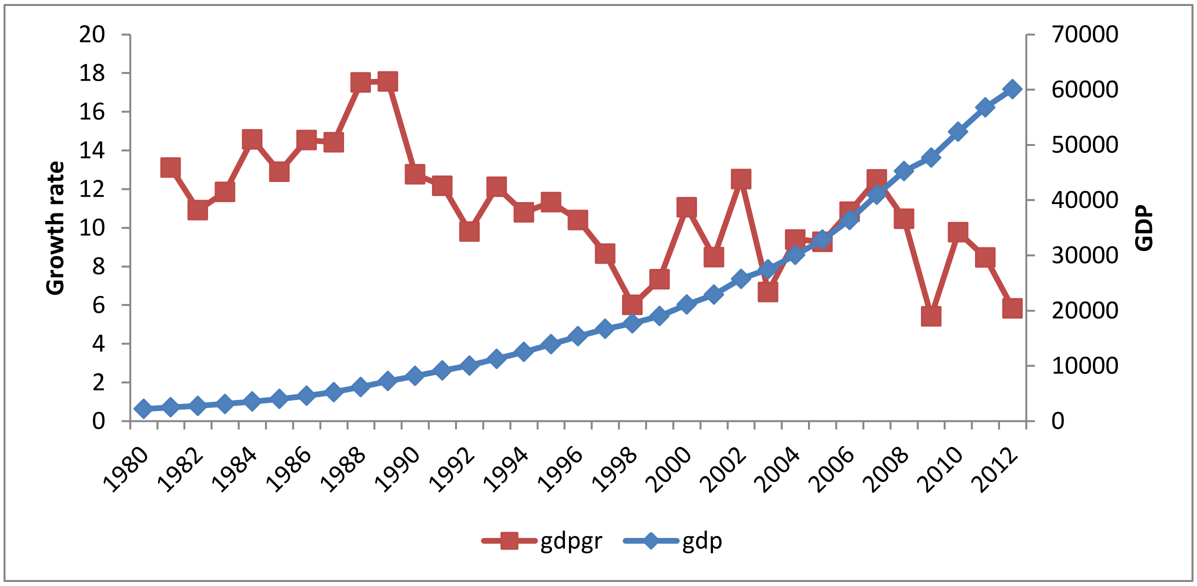
Figure 2.1: Gross Domestic Product by Sectors in South Africa (2012)



Source: Constructed from data retrieved from Statistics South Africa (2012).

Immediately after the 2007/08 financial crisis, the world seemed to be experiencing a two-speed recovery. The global economy experienced an impressive growth of 3.8 percent in 2010 after it contracted by 2.2 percent in 2009, while emerging and developing economies with their GDP growth accelerating by 5.4 percentage points in 2010, contributed to almost half of the year's global growth (World Bank, 2011). This was as a result of vibrant domestic demand, increased financial flow, increased international trade, and higher commodity prices (World Bank, 2011). South Africa, unlike other emerging markets, struggled through the late 2000s recession, and the recovery has been largely led by private and public consumption growth, while export volumes and private investment have yet to fully recover (South African Reserve Bank, 2014). The trend of economic growth between 1980 and 2012 is presented in Figure 2.2.

Figure 2.2: Economic Output (gdp) and its Growth (gdpgr) in South Africa (1980-2012)



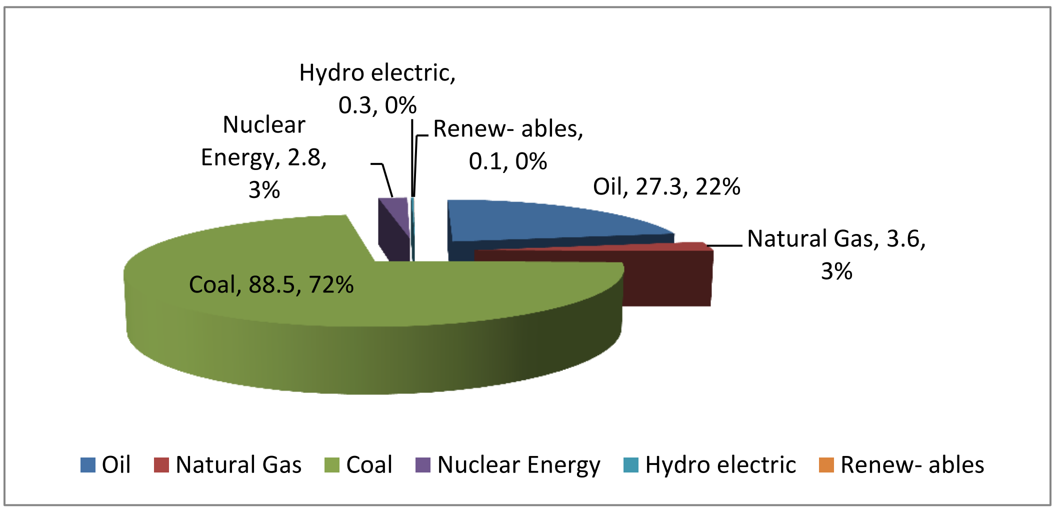
Source: Constructed based on data retrieved from SARB (2014).

Since 1980, South Africa has witnessed stable and continuous growth in output. GDP in real terms grew from R2, 205 million in 1980 to R12, 504 million and R60, 109 million in 1994 and 2012 respectively. South Africa experienced a major decline in growth - an annual average decline of 9.06 percent between 1995 and 1998 but it grew immediately after the financial crisis, though there has been a continuous decline in recent years (see Figure 2.2).

2.2. An Overview of Energy Resources in South Africa

South Africa's energy sector is critical to its economy due to the fact that the economy has a reliable natural resource base and a variety of energy options. As noted above, coal is a major primary energy source in South Africa. In 2012, about 72 percent of South Africa's total primary energy consumption comes from coal, followed by crude oil (22 percent), natural gas (3 percent), nuclear (3 percent), while renewables (primarily from hydropower) contributed less than 1 percent (See Figure 2.3). The overdependence on coal in South Africa was responsible for the country being named as the leading carbon dioxide emitter in Africa and the 14th largest in the world (Energy Information Agency, 2014).

Figure 2.3: Total Primary Energy Consumption by Fuel Type in South Africa (2012)[2]



Source: Constructed from data retrieved from BP Statistics (2013).

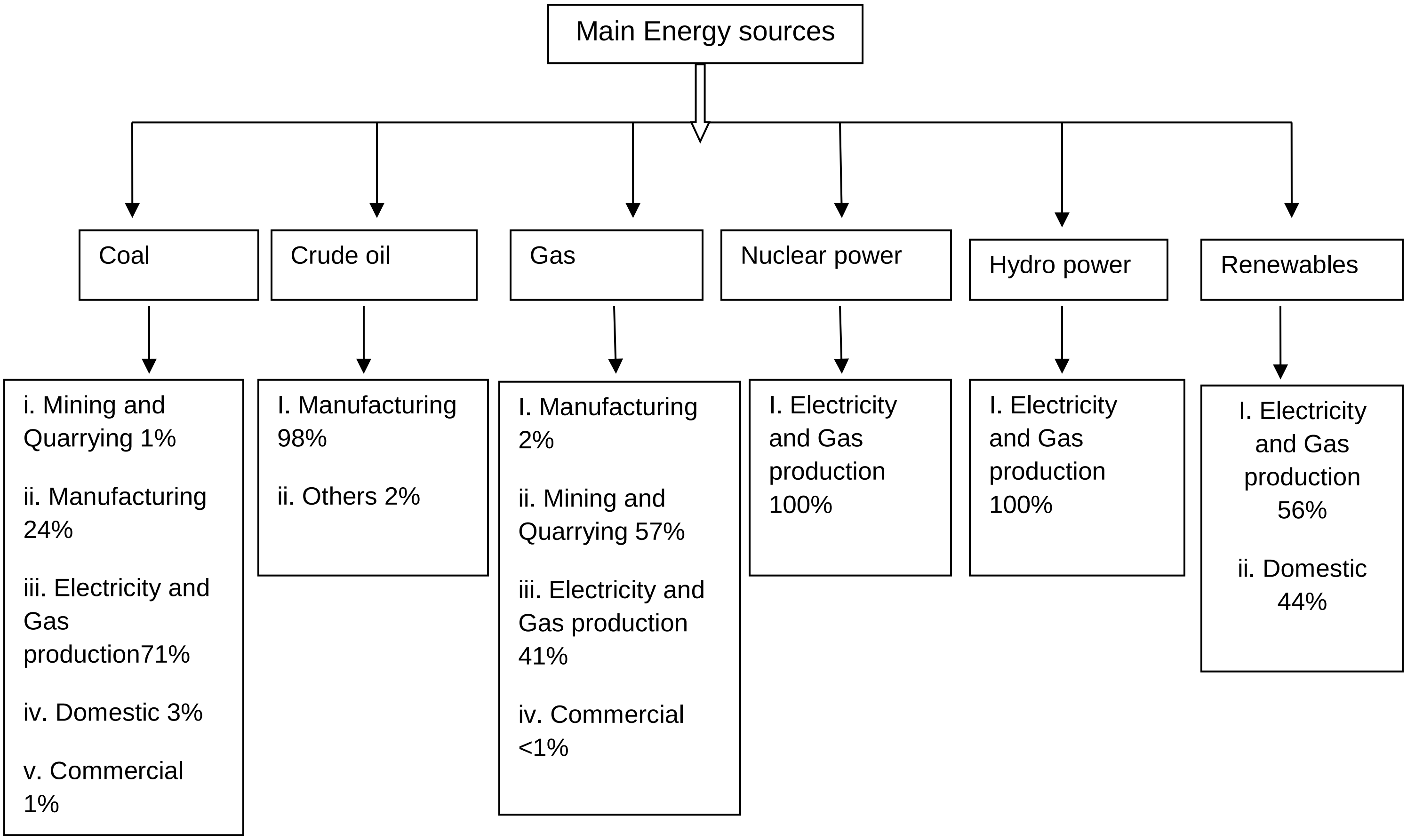
South Africa relies heavily on its large-scale, energy-intensive coal mining industry. It has limited proven reserves of oil and natural gas and uses its large coal deposits to meet most of its

[2]Oil consumption is measured in million tons while other fuel types in million tons of oil equivalent.

energy needs, particularly in the electricity sector (Energy Information Agency, 2014). A large percentage of the oil resource need in the country (used mainly in the transportation and manufacturing sector) is usually catered for through importation from Middle East and West African producers in the Organization of the Petroleum Exporting Countries (OPEC) and is locally refined (Energy Information Agency, 2014). South Africa also has a well-developed synthetic fuels industry, producing gasoline and diesel fuels from the Secunda coal-to-liquids (CTL) and Mossel Bay gas-to-liquids (GTL) plants (Energy Information Agency, 2014). The synthetic fuels industry accounts for nearly all of the country's domestically produced petroleum as crude oil production is very small (Energy Information Agency, 2014). Figure 2.4 illustrates energy flow in South Africa from the primary energy source to the final consumer. Currently, about 33 percent of the coal mined in South Africa is exported. Of the total domestic supply, some 71 percent is used for electricity and gas production, 24 percent for manufacturing, 1 percent for mining and quarrying while the remaining 3 percent is used directly (Statistics South Africa, 2009).

Crude oil is mainly used by the manufacturing sector. Gas consumption plays only a minute role in the South African energy mix, accounting for about 2 percent of the total primary energy supply and 1 percent of total final energy consumption (Department of Minerals and Energy, 2005). Renewable energy sources other than biomass have not been fully exploited in South Africa, although renewable energy is to be used for power generation (Department of Minerals and Energy, 2005). However, the total primary energy consumption trend is presented in Figure 2.5.

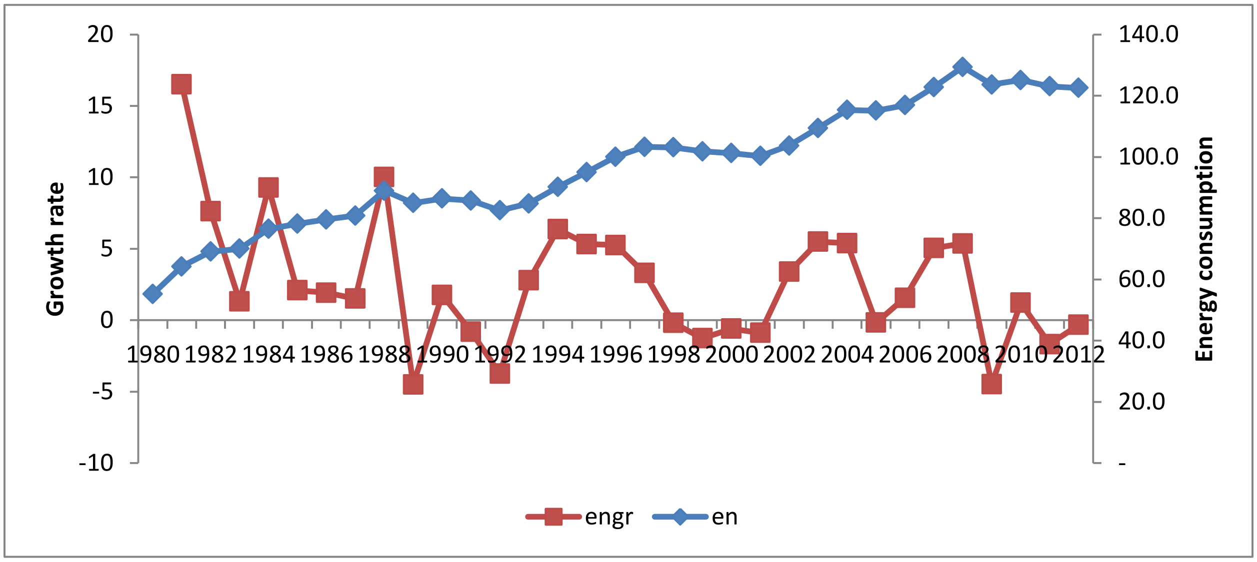
Figure 2.4: Schematic Diagram of Energy Use in South Africa[3]



Source: Statistics South Africa (2009)

[3] Renewables resources include- wind, solar, biomass and wave power.

Figure 2.5: Primary Energy Consumption (en) and its Growth (engr) in South Africa (1980-2012)



Source: Constructed from data retrieved from BP Statistics (2013)

Energy consumption in South Africa since 1980 has been growing relatively slowly despite rapid increase in GDP. For example, it was 55.1 million tons of oil equivalent (MTOE) in 1980 but increase to 90.2 MTOE and 122.6 MTOE in 1994 and 2012 respectively. This supports the view that South Africa as one of the emerging economies in its post-industrial phase and dominated by the service sector, consumes less energy for successive additional unit of output. This confirms the improvement in energy use efficiency. A brief review of each energy input is given below.

2.2.1. Coal Consumption

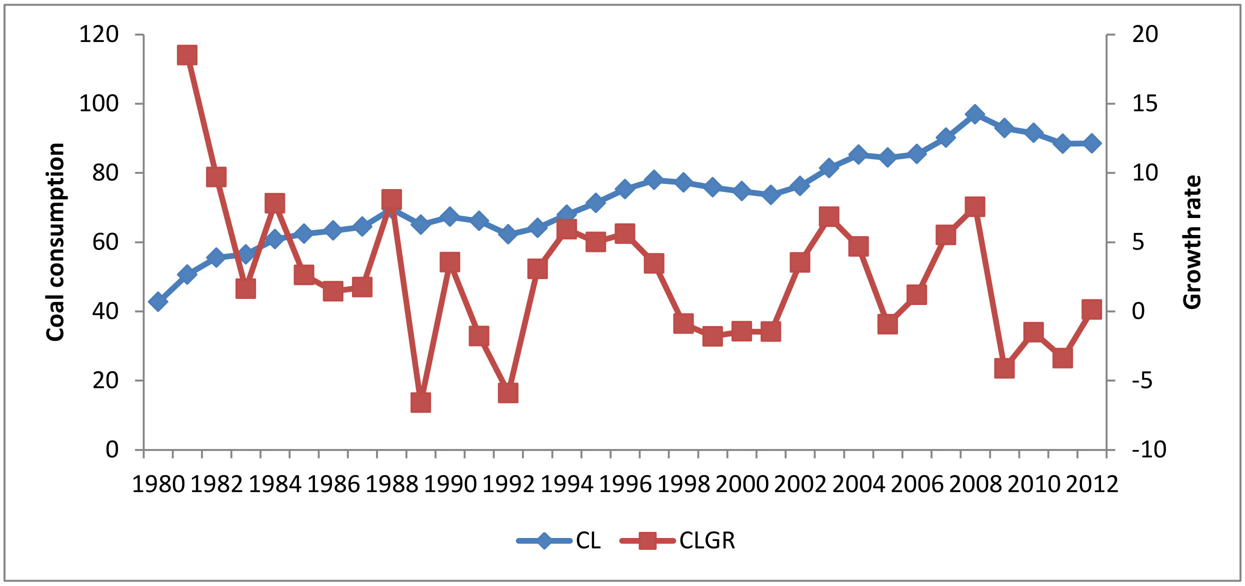
The South African economy is heavily dependent on coal, as it accounts for more than 70 percent of the country's total primary energy consumption as well as its electricity needs (Statistics South Africa, 2014). Coal is a major indigenous energy resource in South Africa and by internationally fuel use comparison, coal is the most widely used primary fuel, accounting for about 36 percent of the total fuel consumption of the world’s electricity production (Statistics

South Africa, 2014). In 2013, South Africa had the world's sixth-largest recoverable coal (Anthracite and bituminous) proven reserve at approximately 30,156 million tons, accounting for 95 percent of total African coal reserves as stated above and almost 4 percent of total world reserves (BP Statistics, 2014).

The country has 19 official coal fields, but 70 percent of recoverable reserves lie in just three areas namely Highveld, Waterberg, and Witbank all of which are located in the Eastern part of the country near Swaziland (Energy Information Agency, 2014). Coal production was 138.0 MTOE in 2006 and 141.2 MTOE in 2009, accounting for 4.13 percent of the world total (BP Statistics, 2013). However, production rose to 145.6 MTOE in 2012, representing a 3.11 percent increase from the 2009 production (BP Statistics, 2013). South Africa is currently the world’s sixth largest coal producer after China, the USA, India, Australia, Russia, (BP Statistics, 2013; Statistics South Africa, 2014).

South Africa is Africa's only significant coal consuming nation; its coal consumption has risen steadily in recent years to meet the increasing energy demands of South Africa's economy. In 2006 about 61 percent of coal consumed in South Africa was used by Eskom, the state electricity entity, in its power stations while the rest was consumed by Sasol's petrochemical industries, metallurgical industries, and domestic heating and cooking (Department of Minerals and Energy, 2009). However, coal consumption in South Africa is expected to continue to increase as new coal-fired power stations are being built in order to meet the rising electricity demand (Energy Information Agency, 2014). In addition to the extensive use of coal in the domestic economy, about 29 percent of South Africa’s production is exported, mainly through the Richards Bay Coal Terminal, making South Africa the fourth-largest coal exporting country in the world (BP Statistics, 2013; Statistics South Africa, 2014). Figure 2.6 below shows the trend of coal consumption for the period under review.

Figure 2.6: Coal Consumption (CL) and Growth Rate (CLGR) in South Africa (1980-2012)



Source: Constructed based on Data from BP Statistics (2013).

Coal consumption has generally increased over the years, although, there was a fall in consumption between 2008 and 2012, which may have been due to various problems that befell the sector during this period including the global financial crisis and strike action by workers in the sector (South African Reserve Bank, 2014). The annual average increase was 3 percent between 2000 and 2008, reaching a peak of 96.9 MTOE, followed by a regular 3 percent per year decrease, bringing coal consumption to 88.4 MTOE in 2011. About 70 percent of the coal is consumed by power plants, with 19 percent being used for the production of synthetic fuels (World Bank, 2013). The coal industry is dominated by five major companies namely; Anglo Coal Division, Exxaro, Sasol Mining, BHP Billiton Energy Coal South Africa and Xstrata Coal (Energy Information Agency, 2014).

2.2.2 Natural and Shale Gas Consumption

There are two kinds of gas used in South Africa – natural gas and shale gas. The natural gas reserve is limited in supply, which is why South Africa imports natural gas from Mozambique via pipeline to supply Sasol's Secunda CTL plants and to fuel some gas-fired power plants. On the other hand, estimates show that shale gas, which is a potential alternative to coal for energy supply, is relatively abundant (Energy Information Agency, 2014). South Africa has about 390 trillion cubic feet (TCF) of technically recoverable shale gas resources, making the country the eighth-largest holder of technically recoverable shale gas resources in the world (Energy Information Agency, 2014).

The natural gas resource is exploited by PetroSA off the coast of Mossel Bay, where it is converted at the PetroSA plant into liquid fuels and mainly used to supply the Mossel Bay GTL plant (Statistics South Africa, 2009). In 2006, South Africa produced about 482 000 million cubic feet and had four production fields (Department of Energy, 2009). In 2012, the country produced about 39 billion cubic feet (BCF) of natural gas and consumed 166 BCF; the difference of 127 BCF was imported from Mozambique via pipeline (Statistics South Africa, 2014). The trend of natural gas consumption in South Africa for the period under review is presented in Figure 2.7.

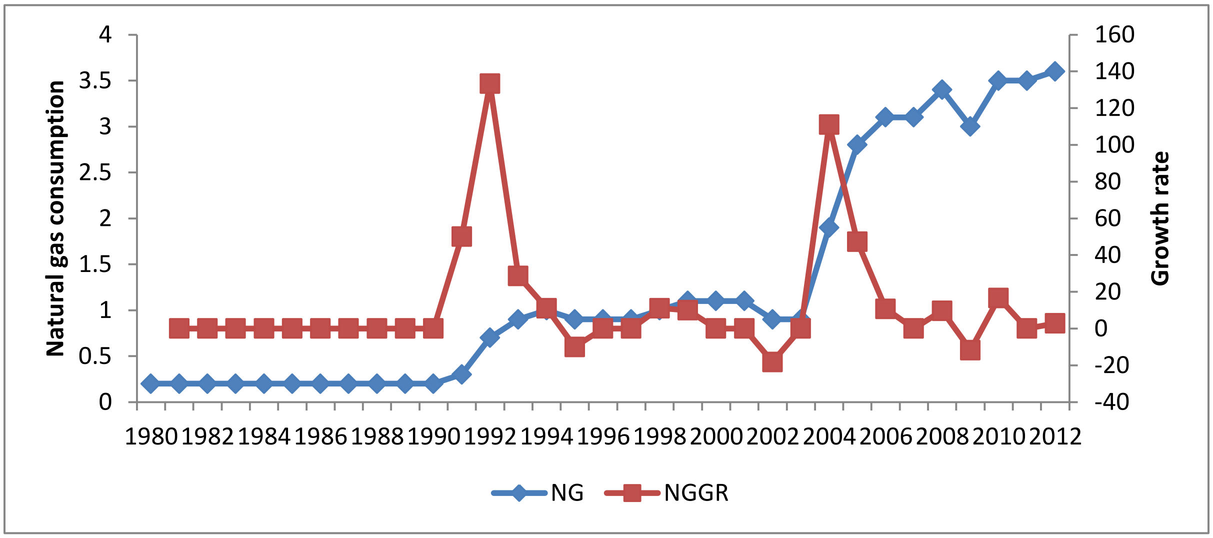
It can be seen that gas consumption was relatively stable at 0.7 million tons of oil equivalent[4] (MTOE) between 1992 and 2002, after which there was a sharp increase in consumption in South Africa from 0.8 MTOE in 2003 to 3.1 MTOE in 2006 - an average annual increase of 72 percent. As of 2012, South Africa consumes about 3.6 MTOE of natural gas (Figure 2.7).

PetroSA, the national company, is a major participant in the industry. It was created in 2002 through the merger of Mossgas, which managed the plant until 2002, and the oil exploration company Soekor. PetroSA operates the FA-EM, South Coast gas fields to supply the GTL plant (Energy Information Agency, 2014). Rompco (Republic of Mozambique Pipeline Investment Company) is a joint venture between Sasol (50 percent), the South African Government through iGas (25 percent) and the Government of Mozambique through "Compania Mozambicana de

[4] Approximate conversion according to BP Statistics (2013): 1 billion cubic feet of natural gas = 0.025 million tons of oil equivalent; 1 million tons of oil equivalent = 39.2 billion cubic feet of natural gas.

Gasoduto" (25 percent) that operates the gas pipeline which import gas from Mozambique (Energy Information Agency, 2014).

Figure 2.7: Natural Gas Consumption (NG) and Growth Rate (NGGR) in South Africa (1980-2012)



Source: Constructed from Data from BP Statistics (2013).

2.2.3. Crude Oil Consumption

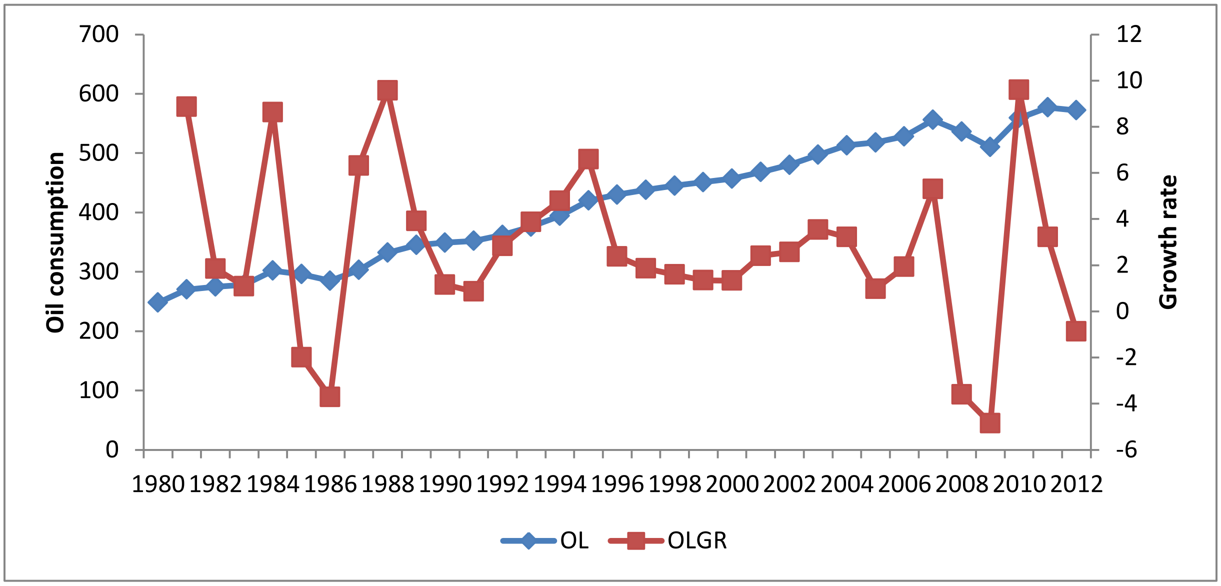
South Africa has limited amounts of proven crude oil reserves and about 76 percent of its crude oil needs are met by import mainly from the Middle East and Africa (Statistics South Africa, 2009). South Africa has proven crude oil reserves of 15 million barrels by end of 2013 (Energy Information Agency, 2014). All of the proved reserves are located in offshore southern South Africa in the Bredasdorp basin and off the west coast of the country near the maritime border with Namibia.

The need to reduce dependence on crude oil imports led to the idea of making liquid fuel from the existing abundant coal resources. Sasol was tasked with the responsibility (Davidson, 2004). The synthetic fuel plants of Mossgas and Sasol supply about 38 percent of the final liquid fuel demand. 100 percent of the natural gas production from Petro SA is converted into liquid fuels, supplying about 7 percent of the country’s liquid fuel requirements (Energy Information Agency, 2014). The rest is refined from imported crude oil. Synthetic fuels, derived from coal and natural gas, account for almost 90 percent of the country's domestic petroleum supply (Energy Information Agency, 2014).

In 2011, Iran was South Africa's largest crude oil supplier, accounting for about 27 percent of South Africa's total crude oil imports, but it shifted to Saudi Arabia due to United States (US) and European Union (EU) sanctions on Iran. In 2012, South Africa imported a total of 378,000 barrels per day of crude oil (Energy Information Agency, 2014). Between January and November 2013 South Africa's crude oil imports averaged 370,000 barrels per day with half of it coming from Saudi Arabia, followed by Nigeria (24 percent), Angola (14 percent), Ghana (5 percent), and small volumes from various producers (7 percent) (Energy Information Agency, 2014; Statistics South Africa, 2014). Figure 2.8 reveals the trend in crude oil consumption in South Africa.

Though the country has limited crude oil deposits, crude oil consumption has been on the increase since 1980. In 2012, South Africa consumed about 27.3 million tons of crude oil. Major suppliers in the industry include: Petrol SA (National Petroleum, Gas and Oil Corporation of South Africa, established in 2001) and Sasol. Several foreign companies are involved in the exploration of oil: Shell, Forest Oil, Pioneer Natural Resources Company, Global Energy (USA) and Ranger Oil (Canada) (Energy Information Agency, 2014).

Figure 2.8: Oil Consumption (OL) and Growth Rate (OLGR) in South Africa (1980-2012)



Source: Constructed from data retrieved from BP Statistics (2013).

2.2.4. Electricity Consumption

Electricity is a secondary energy supplier that relies on the primary resource of coal, crude oil, gas, hydroelectric, nuclear and renewable energy as inputs to the production process and should be excluded when comparing primary energy resources in order to avoid double counting (Department of Energy, 2009). South Africa supplies two-thirds of Africa's electricity and was one of the four cheapest electricity producers in the world (Department of Energy, 2009). Electricity generation is dominated by Eskom, the national wholly state-owned utility while almost 90 percent of South Africa's electricity is generated in coal-fired power stations (Department of Energy, 2009).

The total installed capacity of electricity as at the end of 2011 was 45,170 Megawatts (Energy Information Agency, 2014). The country has a nuclear plant (PWR) which has been operational since 1976 with capacity of 1850MW (2x925 MW), located in Koeberg, a large nuclear station near Cape Town, which provides about 5 percent of capacity. A further 5 percent is provided by hydroelectric and pumped storage schemes. In South Africa there are a few, if any, new economic hydro sites that could be developed to deliver significant amounts of power (see Table 2.1).

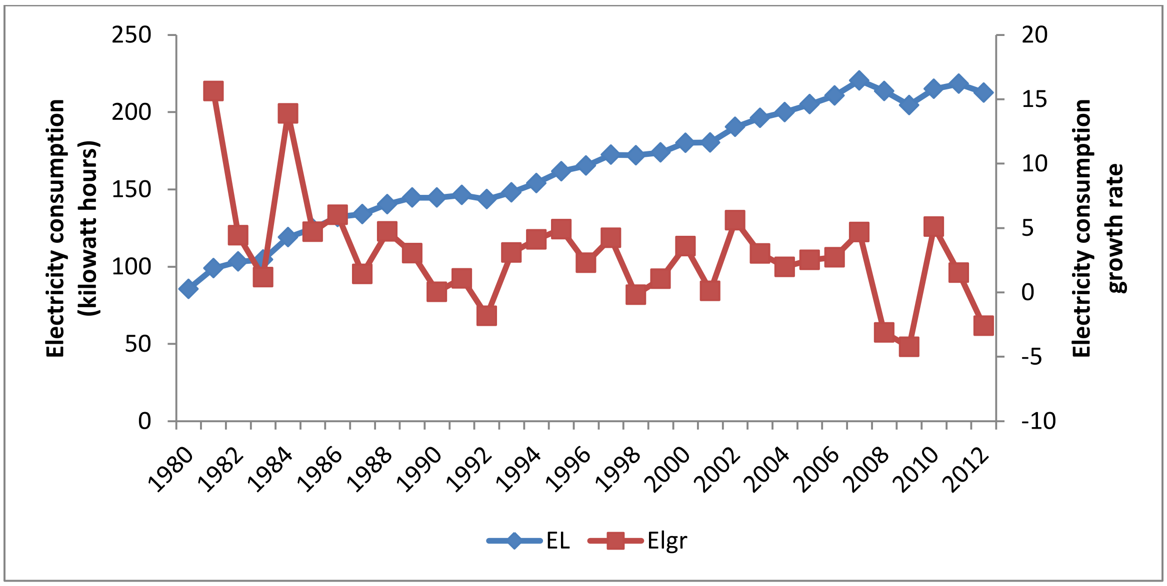
Table 2.1: South Africa's Power Station and Nominal Installed Capacity in Megawatts

Base load station		**Peak demand station**	
Coal-fired plants	**Installed capacity**	**Hydroelectric stations**	**Capacity**
Arnot	2, 352	Garlep	360
Duvha	3, 600	Vanderkloof	240
Hendrina	2, 000	**Pumped storage station**	
Kendal	4, 116	Drakensberg	1, 000
Kriel	3, 000	Palmiet	400
Lethabo	3, 708	Ingula*	1, 332
Majuba	4, 110	**Natural gas turbine station**	
Matimba	3, 990	Acacia	171
Matla	3, 600	Port Rex	171
Tukuka	3, 654	Ankerlig	1, 338
Madupi*	4, 788	Guorikwa	746
Kusile*	4, 800	**Renewable energy station**	
Nuclear plant		Klipheuwel (wind)	3
Koeberg	1850	Sere wind facility*	100
Return - to - service stations (coal)		Concentrating solar power (CSP)*	100
Coal-fired plants		**Distribution (Hydroelectric)**	
Camden	1, 510	First fall	6
Grootvlei	1, 200	Second fall	11
Komati	940	Colley wobbles	42
		Ncora	2
Independent power producer (IPPs)			**Capacity**
Coal, coal &biomass, gas, and pumped storage power station			1, 500
Nominal installed capacity (existing) *Planned additional capacity			45, 710 11,120

Source: Energy Information Agency (2014)

Eskom supplies about 95 percent of South Africa's electricity. In global terms, the utility is among the top seven in generating capacity, among the top nine in terms of sales, and has one of the world's biggest dry-cooled power stations, namely Matimba Power Station (South African Energy Report, 2013; Energy Information Agency, 2014). Eskom generates, transmits and distributes electricity to customers in the industrial, mining, commercial, agricultural and residential sectors, and also to redistributors (South African Energy Report, 2013). The electricity consumption trend in South Africa between 1980 and 2012 is presented in Figure 2.9.

Figure 2.9: Electricity Consumption (EL) and Growth Rate (ELGR) in South Africa (1980-2012)



Source: Constructed from data retrieved from BP Statistics (2013).

It can be seen that total electricity consumption has been rising over the years but due to the electricity crisis of 2007 it declined from 220.48 billion kilowatt-hours in 2007 to 204.57 kilowatt hours in 2009. Towards the end of 2007, the country experienced difficulties as electricity supply was unable to meet the demand. This (electricity) crisis, which was exacerbated by a series of strikes in the mining sector, led to a reduction in generating capacity to about 30,800 Megawatts (South African Energy Report, 2013). Electricity consumption has however been increasing again since 2010 although at a declining rate, rising to 218.30 kilowatt hours in 2011. The state owned electricity entity (Eskom) has however developed strategies to reduce electricity usage by its major consumers and to discourage waste of electricity (South African Energy Report, 2013).

2.2.5. Renewable Energy

Renewable energy sources are energy sources that can be replenished overtime. South Africa is endowed with renewable resources with great potential from biomass, wind, solar, hydro and nuclear power (Department of Energy, 2010). They are mainly used for power generation. Biomass wood fuel is a major energy source in the remote un-electrified rural areas for domestic cooking and space heating. Bagasse from sugar cane production and waste from the pulp and paper industry are major sources of energy for the sugar refining industry. Energy crops such as maize and sugar cane have great potential for providing biofuels while litter from livestock via fermentation can also provide usable energy.

The South African coastal region has great potential for power generation while other areas such as Eastern Highveld, Bushmanland and the Drakensberg Foothills also show moderate potential for power generation through wind (Department of Energy, 2010). South Africa's total onshore wind generation is estimated to be around 1 percent of the electricity requirement (Department of Energy, 2010).

There is also great potential for solar power in South Africa although it has few rivers suitable for generating hydroelectricity and the ones that are available are small (Department of Energy, 2009). Solar power is used for heating, crop drying, and electricity generation among other things. Hydroelectricity accounted for about 2.4 percent of the total electricity generated in South Africa in 2006, although its potential for increasing is limited by its environmental impacts of displacement of people for the development of dams, and flooding (Department of Energy, 2009; 2010).

Nuclear power accounted for about 3 percent of South Africa's total primary energy supply in 2012 (BP Statistics, 2013). The nuclear sector is mainly governed by the Nuclear Energy Act 1999 (Act No. 46, 1999) and the National Nuclear Regulatory Act 1999 (Act No. 47, 1999). South Africa has two nuclear energy reactors which generate about 6 percent of its electricity needs (Statistics South Africa, 2009), but nuclear energy is estimated to contribute about 15 percent of the country's energy needs in the next 30 years (Statistics South Africa, 2009). However, it must be noted that renewable sources other than biomass have not been fully exploited in South Africa.

2.2.6. Energy Consumption by Sectors

For the purpose of energy use, the South African economy is divided into the following sectors: primary, secondary, and tertiary. The tertiary is the largest component of the GDP – contributing about 57 percent of the total GDP followed by the secondary and primary sectors which contribute 41 percent and 2 percent of the total GDP respectively in 2011 (World Bank Development Indicators, 2014). Each of these sectors is discussed briefly while the sub-sector energy use is discussed in Table 2.2.

The primary sector, which is basically agriculture and mining sector, includes large modern commercial farms and small traditional subsistence farms. The primary sector consumed 2.7 percent of the total energy demand (Department of Minerals and Energy, 2009).

The secondary sector (industry) accounts for about 45 percent, of total energy demand (Department of Minerals and Energy, 2009). Coal is the main source of energy for the following industries: iron and steel, chemicals (where it is used as feedstock), non-metallic minerals (where coal is mainly burnt in clamp kilns), pulp and paper, food, tobacco, and beverages (Department of Mineral Energy, 2009). Coal-based industries have low energy conversion efficiencies compared with oil, gas and hydro plants (Eberhard and Van Horen, 1995).

As economies develop, the service sector usually grows faster than other sectors. This is true for South Africa. The service (tertiary) sector includes transport, commerce and public service, and the residential sectors. The service sector consumes a total of 55.7 percent of the total energy demand (Department of mineral and Energy, 2009). Table 2.2 gives a breakdown of energy consumption in the various subsectors of the South African economy.

Table 2.2: Summary of Energy Consumption by Sectors

Sectors	**Sub-sectors**	**Energy consumption**
Primary sector	i) Agriculture	Most of the energy resources are met by biomass; coal contributes about 7 percent of the energy resources.
	ii) Mining	A larger percentage of the energy requirement is met by Gas. It contributes about 57 percent of the total energy requirement
Secondary sector	i) Iron and steel	The main energy source for the iron and steel industry is coal providing about 66.3 percent of energy need, electricity contributes about 26.2 percent while gas contributes 7.5 percent.
	ii) Chemical	South Africa's chemical and petrochemical industry is well developed with coal and natural being the major energy source.
	iii) Non-ferrous metal	Electricity is the major energy source for the non-ferrous metal industry contributing over 95 percent of the energy requirement.
	iv) Pulp and paper	As at 2006, pulp and paper consumed about 66.9 percent of electricity and 33.1 percent of natural gas.
	v) Food, tobacco and beverages	The biggest single user in this segment is the sugar refining industry. Electricity contributes about 66.2 percent of the energy needed while gas contributes the remaining 33.8 percent
Tertiary sector	i) Transport	Transport energy consists mostly of liquid fuels. The dominant is petrol with 53.3 percent, followed by diesel 34 percent and then jet fuel 10 percent while the lowest is Electricity 1.8 percent
	ii) Commerce and public service	Most of the energy used in this sub sector is used for air conditioning, printing, etc. Commerce and public service consumes about 14.8 percent of the total final energy demand.
	iii) Residential	South African households consume about 20 percent of the total final energy demand. As at 2006, about 72.8 percent of the energy consumed was in the form of electricity, 29.1 percent from coal while the rest came from petroleum products.

Source: Statistics South Africa (2009)

2.3. South Africa's Economic Growth, Energy Efficiency and Energy Intensity

The relationship between energy input and economic output can be studied from two different perspectives; energy efficiency and energy intensity. These two dimensions reflect an identical measure of the relationship between energy consumption and economic output but from different perspectives (Yi-Mung Wei et al., 2010).

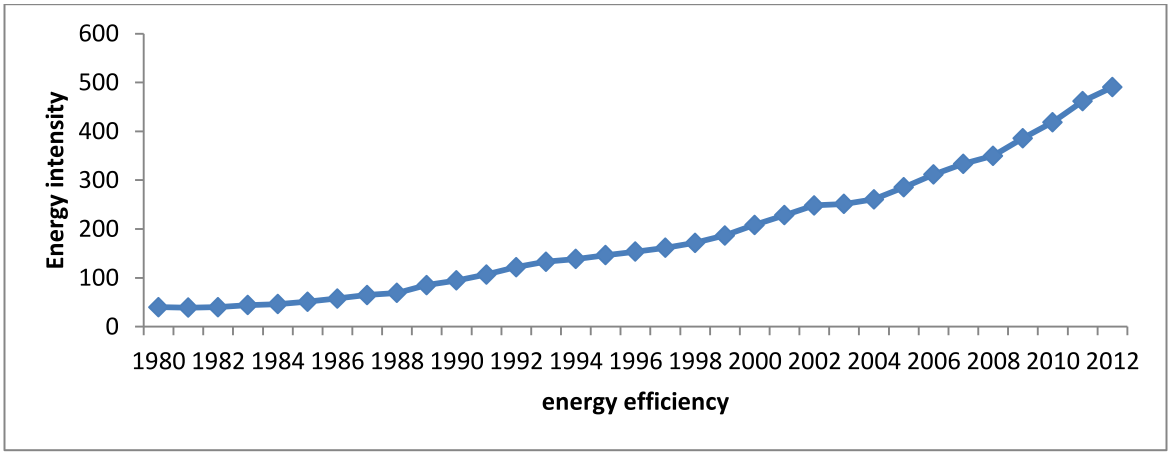
Energy intensity, from the perspective of energy demand represents the extent to which economic output consumes energy resources (i.e. energy input / economic output). While on the other hand energy efficiency; from the perspective of factor supply, represents the extent to which energy resources support economic growth (i.e. economic output / energy input).

2.3.1. Energy Efficiency

Energy efficiency improvement is the cheapest and most environmentally friendly way to meet a significant portion of the world's energy need (Kaygusuz, 2012). It is also seen as a mechanism for reducing energy dependence and meeting energy sustainability goals although there are still disputes about how the economy responds to such efficiency improvement (Stern, 2007). Energy efficiency is an important element in energy policy and has received renewed attention in the wake of the global policy debate on climate change. Policy makers believe that reduction of energy demand is essential to meeting these challenges. Energy efficiency is the energy services provided per unit of energy input or the extent to which energy resources supports economic output. For example, the energy efficiency of an air conditioner is the amount of heat removed from air per kilowatt-hour (KWH) of electricity input. At the aggregate level or whole economy, energy efficiency is measured as the level of gross domestic product per unit of energy consumed in its production (Gillingham, Newell, and Palmer, 2009).

Energy efficiency is mainly driven by improved technology. However, it must be noted that different energy resources have different abilities in supporting the economy which means that the total energy efficiency can also be affected by change in the energy structure (Yi-Mung Wei, et.al, 2010). Figure 2.10 presents the energy efficiency trend in South Africa between 1980 and 2012.

Figure 2.10: Energy Efficiency in South Africa (1980-2012)[5]



Source: Constructed from data retrieved from SARB (2014) and BP Statistics (2013).

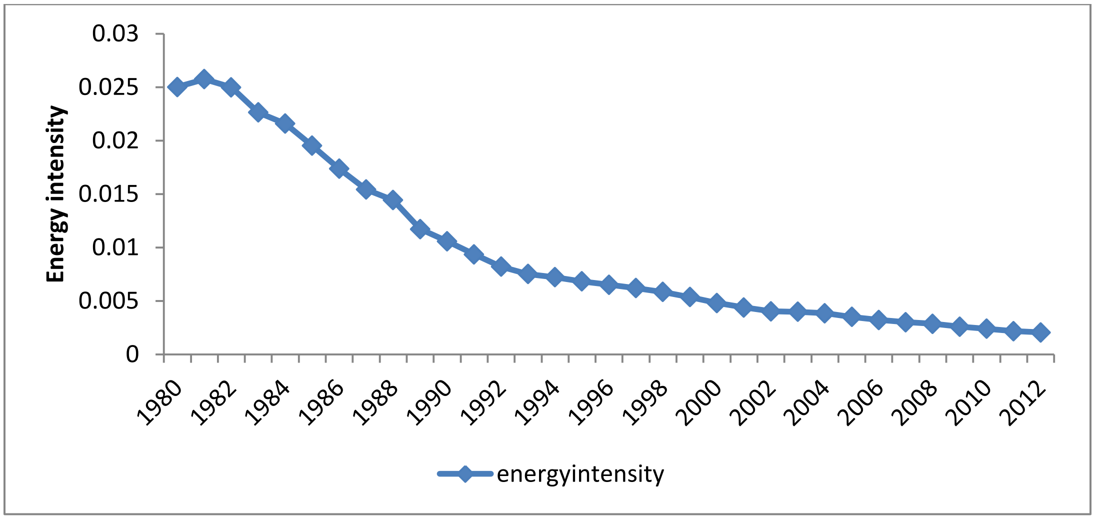
Energy efficiency in South Africa had witnessed a continuous increase over the years. A major option for future energy policy lies in the field of energy efficiency. While some progress has been made, many potential gains remain underutilised. Some of the energy efficiency policies are highlighted in section 2.4.5.

2.3.2. Energy Intensity

The energy intensity of the county shows how much energy is needed to produce a single unit of GDP or, in order words, the total energy consumption input to produce a unit of economic output. High energy intensities indicate a high price or cost of converting energy into GDP, while low energy intensities indicate a lower price or cost of converting energy into GDP. For the past 20 years South Africa's energy intensity had witnessed a continuous and steady decline although it is still four times higher than OECD countries (Hawkes, 2005: 19). The energy intensity trend from the period under review is presented in Figure 2.10.

[5] It is calculated by dividing GDP by Energy consumption

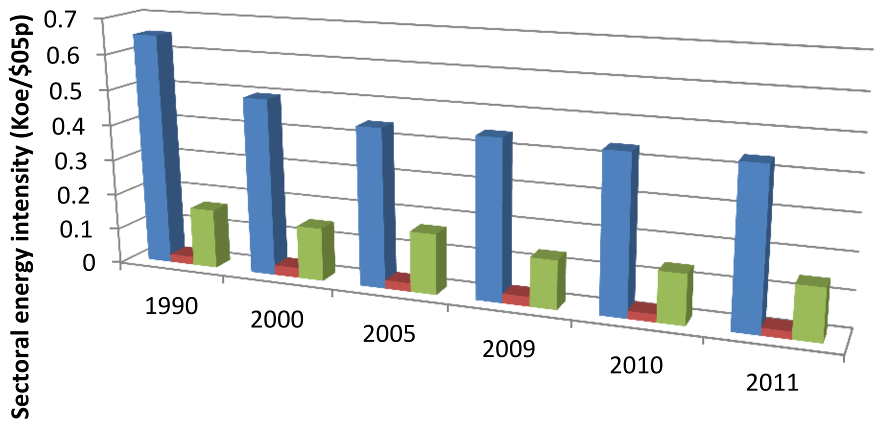
Figure 2.11: Energy Intensity in South Africa (1980-2012)



Source: Constructed from data retrieved from SARB (2014) and BP Statistics (2013).

The fact that the economy was growing and energy intensity declining may attract some serious questions as to the underlying factor behind the steady decline in energy intensity. We might assume that as the economy grows, the share of energy consumption for each unit of output should rise. However, it must be noted that the decline in energy intensity in South Africa is largely due to the economy's structure being dominated by the service sector as well as technological advancement. Although, energy consumption in the tertiary sector is high as stated in section 2.2.6, the energy intensity is relatively low compared to other sectors of the economy. Energy intensity in the tertiary sector is 0.021 in 2011 kilogram of oil equivalent per dollar of 2005 in purchasing power ratio (koe/$05p) compared to the primary and secondary sector with intensity of 0.143 (koe/$05p) and 0.436 (koe/$05p) respectively (See Figure 2.12).

Figure 2.12: Energy Intensity by Sectors



	1990	2000	2005	2009	2010	2011
Secondary	0.652	0.497	0.444	0.445	0.437	0.436
Tertiary	0.023	0.028	0.024	0.027	0.022	0.021
Primary	0.167	0.149	0.169	0.135	0.138	0.143

Secondary   Tertiary   Primary

Source: Constructed from data retrieved from World Development Indicators (2014)

2.3.3. Impact of South Africa's Energy Structure on Energy Efficiency

Similar to the study of Yi-Ming et al., (2010) in the case of China, this study examined the impact of South Africa's energy structure on energy efficiency. Energy resources include coal, oil and natural gas which are all measured in million tons of oil equivalents. The use of a similar measurement of oil equivalent implies that different energy resources will produce the same economic output. Generally, energy efficiency is measured as the ratio of economic output to energy resource input which is expressed in Equation (2.1) below.

$$ef = \frac{GDP}{EN} \tag{2.1}$$

where GDP means gross domestic product and EN means energy input. Let us assume that $EN_1(i = 1, 2, 3, \dots)$ represents the input of different energy resources, that is, coal, oil and natural gas respectively, and $GDP_i(i = 1, 2, 3, \dots\dots)$ represents sector-wise economic output supported by different energy resources. Thus we can formulate the energy efficiency model of different energy resources as follows:

$$ef_i = \frac{GDP_i}{EN_i} \qquad (i = 1, 2, 3, \dots.) \tag{2.2}$$

from Equation (2.2) making GDP the subject of the formula we have

$$GDP = \sum ef_i \times EN_i \qquad (i = 1, 2, 3, \dots.) \tag{2.3}$$

therefore, the aggregate energy efficiency ef can be formulated as

$$ef = \frac{GDP}{EN} = \sum_i ef_i \times \frac{EN_i}{EN} = \sum_i ef_i \times S_i \qquad (i = 1, 2, 3, \dots \dots) \tag{2.4}$$

where S_i represents the share of different energy sources in the total energy input, that is, $\frac{EN_i}{EN}$.

Using a multivariate regression model for the estimation of the impact of energy structure on aggregate energy efficiency we use the regression model formulated by Yi-Ming et al. (2010)

$$ef = \sum_i a_i * S_i + \varepsilon \tag{2.5}$$

To allow for increase in energy efficiency due to improvement in technology, we introduce t variable in the model with the assumption that the time element is linear, that is $t = 1, 2, 3, \dots \dots.., n$. We can therefore re-formulate Equation (2.5) above as follows:

$$ef = b * t + \sum_i a_i * S_i + \varepsilon \tag{2.6}$$

where: $b \; and \; a_i$ are coefficients of the regression equation.

Using data on South Africa's energy component, and economic growth from 1980-2012, a regression equation was estimated as follows:

$$ef = 204.4771t - 53.84LNC + 2.18LNNG - 62.51LNOL + \varepsilon \tag{2.7}$$

(t = 1.85) (t = -1.93) (t = 0.61) (t = -1.97)

$R^2 = 0.99$, F = 3067.

All the variables pass the significance test at 10 percent except the coefficient of natural gas which failed to pass the test. This implies that there exists no significant relationship between natural gas and energy efficiency. Therefore, it was excluded from the model and re-estimated. Using the same data set, the following result was found:

$$ef = 160.31t - 53.34LNCL - 51.74LNOL + \varepsilon \tag{2.8}$$

(t = 1.94) (t = -1.93) (t = -1.98)

$R^2 = 0.99$, f = 3925.

The coefficients of the energy component pass the significance test at 10 percent. This indicates the extent to which changes in the energy component affect South Africa's energy efficiency.

2.4 Energy Policies

South Africa has implemented a series of energy policies especially regarding wider access and high quality electricity since the emergence of a democratically elected government and they are specifically designed to provide basic services to the poor and disadvantaged that form the majority of the population. This includes the 1998 White Paper on energy policy, the 2003 White Paper on renewable energy, the national electrification programme, accelerated electrification, and several energy efficiency policies. They are briefly discussed below:

2.4.1. The White Paper on Energy

The South African energy policy is captured in the White Paper on Energy Policy (1998). The White Paper sets out government's policy with regards to the supply and consumption of energy. The policy aims at ensuring wider access to energy services as well as minimizing the environmental impact of energy conversion and use in the economy (Department of Mineral Energy, 2005).

The White Paper on Energy Policy states:

> *"Significant potential exists for energy efficiency improvements in South Africa. In developing policies to achieve greater efficiency of energy use, government is mindful of the need to overcome shortcomings in energy markets. Government will create energy efficiency consciousness and will encourage energy efficiency in commerce and industry, will establish energy efficiency norms and standards for commercial buildings and industrial equipment and voluntary guidelines for the thermal performance of housing. A domestic appliance-labeling program will be introduced and publicity campaigns will be undertaken to ensure that appliance purchasers are aware of the purpose of the labels. Targets for industrial and commercial energy efficiency improvements will be set and monitored"* (Department of Mineral Energy, 1998, pp. 14–15).

The White Paper was published in 1998 after a public hearing under the auspices of the Parliament Portfolio Committee. The following five policy objectives were agreed on:

> *1. Increasing access to affordable energy services.*
>
> *2. Improving energy governance – clarification of the relative roles and functions of various energy institutions within the context of accountability, transparency and inclusive membership, particularly participation by the previously disadvantaged.*
>
> *3. Stimulating economic development – encouragement of competition within energy markets.*
>
> *4. Managing energy-related environmental and health effects – promotion of access to basic energy services for poor households while reducing negative health impacts arising from energy activities.*
>
> *5. Securing supply through diversity – increased opportunities for energy trade, particularly within the Southern African region, and diversity of both supply sources and primary energy carriers (Davidson et al., 2006, pp. 8; Department of Mineral Energy, 1998, pp. 8-9).*

On the demand side, the emphasis of the White Paper is targeted at addressing the problems of inadequate energy services to the low-income groups and rural areas. The White Paper also aimed at providing efficient energy to industry, commerce and mining both for its environmental and cost benefits (Department of Mineral Energy, 2005).

On the supply side, the White Paper is aimed at restructuring the electricity distribution industry into an independent regional distributor as well as achieving universal access to electricity services by households. The coal industry which was deregulated in 1992 will remain deregulated while deregulation of crude oil procurement and refining was also emphasized in the White Paper. The White Paper also sought to develop the gas industry with appropriate legislation for the transmission, storage, distribution and trading of piped gas (Department of Mineral Energy, 2005). The 1998 White Paper also pledged government's support for the development and implementation of renewable energy sources for both small-scale and large-scale application. This and the 2002 World Summit on Sustainable Development formed the basis for the development of the White Paper on renewable energy.

2.4.2. White Paper on Renewable Energy

The White Paper on renewable energy (2003) sets out government's principles, goals and objectives for renewable energy as well as ensuring that renewable energy becomes a significant part of the South African energy portfolio. The vision of the government with regards to the role of renewable energy is:

> *An economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout South Africa, thus contributing to sustainable development and environmental conservation (Department of Mineral Energy, 2003).*

However, many renewable energy technologies are expensive due to high capital costs, compared to other sources of energy supplies – something which poses a great challenge for the government to provide incentives for renewable energy-based industry to develop and grow (Department of Mineral Energy, 2003).

2.4.3. Accelerated Electrification

The accelerated electrification programme was formulated to serve the disadvantaged groups in the underdeveloped urban and rural areas. A national meeting organized Department of Economic Planning of the African National Congress (ANC) in conjunction with the Energy and Development Research Centre (EDRC) of the University of Cape Town on electrification in South Africa formed the basis for the current electrification programme. The results of the South African Energy Policy Research and Training Project (EPRET) undertaken by EDRC provided major inputs to this meeting (Davidson et al., 2006; Marquard, 1999). This and other forums led to the development of the electrification programme within the ANC's Reconstruction and Development Programme (RDP) which formed the basis of all energy programmes that followed (Davidson et al., 2006).

2.4.4. The National Electrification Programme

The National Electrification Programme was implemented between 1994 and 1999, with the objective of connecting the rural and urban low-income households who had been deprived of access to electricity to the national grid. The Electrification Programme expected newly electrified households to switch from using fuel wood, candles, and batteries to electricity for their household needs. Eskom had already embarked on a programme in 1991 termed 'Electricity for all'. The Government of National Unity that emerged in 1994 endorsed the electrification programme (Davidson et al., 2006).

Phase 1 aimed at electrifying an additional 2.5 million households over and above the three million already electrified by 1993, which would increase the national proportion of households electrified to 66 percent (Davidson et al., 2006).

2.4.5. Energy Efficiency Policies

The 1998 White Paper on Energy Policy provided the background for the National Energy Efficiency Strategy (NEES) which was approved in 2005. It set an objective of a 12 percent reduction in final energy demand by 2015, although it was later reviewed in 2008 by breaking down the objective into specific sectoral targets: 10 percent for the residential, 15 percent for the commercial sector, industry, mining and power generation and 9 percent for transport (South African Energy Report, 2013). Energy efficiency has great potential across all sectors of the South African economy with the largest energy savings coming from the industrial and transport sectors (Davidson et al., 2006).

Eskom also launched a Demand-Side Management (DSM) initiative in 2008 to audit energy use in the industrial, commercial and household sectors with three focused areas: load management, industrial equipment and efficient lighting. Later, in 2010, the electricity pricing policy was implemented by the Energy Regulator (NERSA). According to the Inclining Block Tariffs (IBTs), the largest consumers are charged a higher rate, whereas the electricity bills of lower consumption households are reduced (Davidson et al., 2006; South African Energy Report, 2013). The South African National Energy Development Institute (SANEDI) was established in April 2011 through the merger of the South African National Energy Research Institute (SANERI) and the National Energy Efficiency Agency (NEEA) with the mandate to explore and undertake energy efficiency measures in the country (South African Energy Report, 2013).

2.5. Summary

This chapter focused on the fact that South Africa is an energy intensive country which depends largely on energy resources for production and domestic consumption. Coal, oil, natural gas, nuclear power, hydropower and renewable energy are the main energy resources in South Africa. South Africa's energy supply is dominated by coal. Due to limited availability of crude oil and gas, most of the country's gas and crude oil needs are met through importation and coal to liquid transformation. South Africa's renewable energy sources have not been optimally exploited except biomass which is a major source of energy to the South African sugar refining industry as well as meeting the electricity needs of the un-electrified rural dwellers.

Furthermore, energy efficiency and energy intensity in South Africa were examined together with their impact on economic growth. Energy efficiency was seen as a mechanism for improving optimal energy utilization. Also, several energy policies implemented in South Africa ranging from the White Paper on energy policy and renewable energy to the national electrification programme were highlighted. The next chapter focuses on the review of theoretical and empirical literatures on the role of energy in economic growth.

CHAPTER 3

A REVIEW OF ECONOMIC GROWTH THEORY AND EMPIRICAL LITERATURE

The aim of this chapter is to provide a review of theoretical and empirical literature on the role of energy in economic growth. A proper knowledge of the role of energy resources in economic growth cannot be achieved without understanding the role of energy in production (Stern, 2004). Both neoclassical and the ecological views on the role of energy in economic growth are discussed[6]. Neoclassical economists regard capital, labour and land as primary factors of production while considering energy as an intermediate factor input but ecological economists, on the other hand, have placed a very heavy emphasis on the role of energy and its availability in the economic production and growth processes, i.e. energy plays a primary role in production rather than intermediate role as asserted by the neoclassical economists (Stern, 2004). The relevant empirical literature is also summarized into four testable hypotheses namely; growth hypothesis, conservation hypothesis, neutrality hypothesis and feedback hypothesis.

The Chapter is divided into five sections. The first section presents the neoclassical theory of economic growth. Section two presents the arguments of the ecological economic growth theorists, which is followed by a theoretical assessment of the theoretical literature in section three. Empirical studies on the relationship between energy consumption and economic growth are presented in section four, while the summary of the chapter is presented in section five.

3.1. The Neoclassical Approach to Economic Growth

The neoclassical theorists of economic growth pay little attention to the role of energy in economic growth. They ascribe a less important role to energy in production based on the following assumptions: the productivity of the different production factors is equal to their respective cost shares; technological progress can effectively decouple energy use for economic growth and that energy should be regarded as an intermediate factor of production. Considering the theories of production, the neoclassical economic theory explains the economy as a closed

[6] This section is based on the works of David I. Stern, (2003, 2004, 2010)

system where output is produced by inputs of labour and capital. Therefore, economic growth is the result of an increase in inputs or their quality. Energy inputs have indirect importance and are thus categorized as intermediate inputs other than primary inputs.

Economists accept the concept of primary and intermediate factors of production but as noted earlier, primary factors of production are inputs that exist at the beginning of the period under consideration and are not directly used up in production, while intermediate inputs are those created during the production period under consideration and are used up entirely in the production process. Capital, labour and land are the primary factors of production, while goods such fuels and materials are intermediate inputs (Stern, 1999). The prices paid for all the different inputs are eventually seen as being payment to owners of primary inputs for the services provided directly or indirectly through the intermediate inputs (Stern, 1999, 2004; Vlahinic-Dizdarevic and Zikovic, 2010).

The neoclassical theorist of growth have also not paid enough attention to the role of energy in production and they explain economic growth by technological progress (Joanne and Lester, 2009; Stern, 2010). Generally, neoclassical production function explains economic growth by an increase in labour, capital and technology, where total factor productivity (TFP) is the portion of output that cannot be explained by the amount of inputs (capital accumulation and labour force expansion) used in the production (Vlahinic-Dizdarevic and Zikovic, 2010). TFP growth is usually measured by the Solow residual, although it accurately measures TFP growth only if the production function is neoclassical, that is, if there is perfect competition in factor markets and constant returns to scale (Vlahinic-Dizdarevic and Zikovic, 2010).

Solow (1957) in his estimation of the contribution of technical change to the overall growth rate of the US economy aggregated the production function as follows:

$$Q = f(l, k;\ t) \tag{3.1}$$

where Q represents output, and k and l represents capital and labour input and t represents technical change.

Following the Hicks-neutral technical change, Solow postulated the production function in the special form as:

$$Q = A(t)f(k,l) \tag{3.2}$$

where $A(t)$ is an index of technical change which is called total factor productivity.

Differentiating Equation (3.2) totally with respect to time and dividing by (Q)

$$\frac{\hat{Q}}{Q} = \frac{\hat{\dot{A}}}{A} + A\frac{\delta F}{\delta K}.\frac{K}{Q} + A\frac{\delta L}{\delta F}.\frac{L}{Q} \tag{3.3}$$

where ^ indicates time derivatives.

Under the assumption of constant returns to scale, the capital share and labour share add to 1. If $\alpha\ (t)$ is the capital share, the share of labour is $1 - \alpha\ (t)$. Substituting this value in Equation (3.3), we have:

$$\frac{\hat{Q}}{Q} = \frac{\hat{A}}{A} + \alpha\ (t)\frac{\hat{K}}{K} + [1 - \alpha\ (t)]\frac{\hat{L}}{L} \tag{3.4}$$

Equation (3.4) reveals that the growth rate of output $\frac{\hat{Q}}{Q}$ is equal to the rate of technical change $\frac{\hat{\dot{A}}}{A}$ plus weighted average of the growth rate of capital $\frac{\hat{K}}{K}$ and the growth rate of labour $\frac{\hat{L}}{L}$.

The residual factor from Equation (3.4) can be written as:

$$\frac{\hat{A}}{A} = \frac{\hat{Q}}{Q} - \alpha\ (t)\frac{\hat{K}}{K} + [1 - \alpha\ (t)]\frac{\hat{L}}{L} \tag{3.5}$$

Thus the TFP (residual) can be measured by subtracting from the rate of change of output that part of the growth rate which is accounted for by a weighted sum of the rates of change of capital and labour factor inputs. This is the general growth model and its variants are discussed below.

3.1.1. Growth Models without Resources

In Solow’s (1957) original growth model - known as the neoclassical growth model – the economy must reach a stationary state in which there is no net investment (the rate of increase in stock of capital). Growth is a transitional phase, where a country is moving towards the stationary state. A less developed economy, with a small capital stock per worker, can accomplish fast growth while it is building up its capital stock. But if the savings rate remains constant the economy will eventually reach zero growth equilibrium. No country can grow forever merely by capital accumulation. An increase in saving rate will bring about growth for a while until new equilibrium is attained, though, the higher the savings rate, the lower the current living standard of the people. According to this basic neoclassical growth theory, the only cause of long run economic progress is by expanding labour force and technical progress. Intuitively, increases in the state of technological knowledge raise the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth.

The initial Solow growth models (1956), did not explain the source of technical progress, they are just treated as exogenous factors in the growth process, meaning that these models are said to have exogenous technological change (Stern, 2003; 2010). He, this way disregarded the problem of inducing technological advancement through the process of learning, investment in research and capital accumulation (Jhingan, 2007). More recent models attempt to endogenize technological change by explaining technological progress within the growth model as the outcome of decisions taken by firms and individuals (Stern, 2010). The endogenous growth models emphasise technological progress resulting from the rate of investment, size of the capital stock, and the stock of human capital (labour). There are a few other variants of endogenous growth models (Aghion and Howitt, 1998). They are explained below.

Early endogenous technological growth models such as Arrow's (1962) learning by doing model or Hicks' (1932) induced innovation model allowed the state of technology to respond to changes in one of the variables in the model but do not explicitly model an optimising process (Stern, 2010). In learning-by-doing models the state of technology is a function of cumulative production. In the original Arrow (1962) model his hypothesis was that at any given time new capital goods incorporate all the knowledge then available based on the accumulated experience, but once built their productive deficiency cannot be changed by subsequent learning. Arrow's model can be expressed in a simplified form as follows:

$$Y_i = A(K)F(K_i, L_i) \qquad (3.6)$$

where Y_i denotes output of firm i, K_i denotes capital stock, K_i denotes labour stock, K without subscript denotes the aggregate stock of capital and A is the technological factor (Jhingan, 2007).

In other versions, the learning curve implies rising productivity in the production of a good, as more of the good is cumulatively produced. In induced technological change models, originated by Hicks (1932), innovation rises when the price of an input such as energy rises.

In the second type of endogenous growth model, the relationship between capital and output can be written in the form Y = AK, where A is constant and K is a composite of manufactured capital and disembodied technological knowledge thought of as a form of capital. Therefore, economic growth can continue indefinitely as this very broadly defined capital is accumulated, as output is not likely to be affected by diminishing returns. In AK models saving is directed to either manufactured capital accumulation or the increase of knowledge. However, the models do not clearly model Research and Development (R&D) activities (Stern, 2004; 2010). Technological knowledge has two special attributes. First it is a non-rival good - the stock of this form of capital is not depleted with use. Second, it creates positive externalities in production. While the firm doing R&D derives benefits from the knowledge acquired, there are beneficial spillovers to the economy from the R&D activities so that the social benefits of innovation outweighs the private benefits to the original innovator (Stern, 2004; Jhingan, 2007).

Their emphasis was based on the spillover effect of increased knowledge as the source of knowledge, and that the source of knowledge or learning-by-doing is investment by each firm. They also assumed that knowledge of a firm is a public good which other firms can have at zero cost. Thus knowledge is non-rival in consumption with spillover effect cutting across all the firms in the economy. In this case, endogenous technical progress in terms of knowledge or learning-by-doing is reflected in an upward rising of the production function and economic growth is explained in terms of aggregate increasing returns being consistent with competitive equilibrium. As some of the gains of knowledge generation are external to those producing it, the growth rate of the economy is below the socially optimal level (Jhingan, 2007).

King-Robson model in Jhingan (2007) emphasized learning-by-watching in their technological growth function, in the model, firm’s investment represents innovation to solve the problems in phases. When this is successful, other firms will adapt the innovation to their own needs. These create an external effect which will lead to economic growth. Their study shows that innovation in one sector of the economy has a beneficial effect on the other sectors which will lead to productivity of other sectors, thereby causing economic growth.

However, Romer (1986) developed a variant of the Arrow's model which is known as learning by investment. He assumes creation of knowledge as a side product of investment. Knowledge is taken as an input in the production function in the following form:

$$Y = A(R)F(R_i, K_i, L_i) \tag{3.7}$$

where Y represent aggregate output, A is the public stock of knowledge from research and development R, R_i is the stock of results from expenditure on research and development by firm i, and K_i *and* L_i are capital stock and labour stock of firm i respectively. Three important elements of Romer's model are externalities, increasing returns to production and output and diminishing returns in the production of new knowledge. The spillovers from research by a firm lead to creation of new knowledge by other firms. His argument is based on the fact that new knowledge is the ultimate determinant of long run economic growth, which is determined by investment in research and technology. Research technology exhibits diminishing returns which means that investments in research technology will not double knowledge. But it must be noted that the firm investing in research will not be the sole beneficiary of the increased knowledge. Other firms can also make use of the new knowledge, due to inadequate patent protection, to increase their productivity.

Thus the production from increased knowledge will lead to increasing returns and competitive equilibrium is consistent with increasing aggregate returns due to externalities. Romer takes investment in research as an endogenous factor in terms of the acquisition of knowledge by a rational profit maximisation firm (Jhingan, 2007).

3.1.2. Growth Models with Natural Resources and No Technological Change

Natural resources exist in finite quantities. Relatively many of these resources are renewable while others are non-renewable (Stern, 2004). Finiteness and exhaustibility of resources make the notion of continuous economic growth problematic. The availability of more than one input such as capital and natural resources implies that there are many different paths that economic growth can take. The path taken is determined by the assumed institutional arrangements. The neoclassical literature on growth and resources centres on conditions that allow continuing growth. Technological and institutional conditions determine whether sustainability which is defined as non-declining consumption is possible.

Solow (1974) postulated a continuous production function linking output to input of labour and capital which are assumed to be substitutable (Jhingan, 2007). He showed that in a model with finite and non-renewable natural resources, sustainability can be achieved with no extraction costs and non-depreciating capital, which is produced using capital and the natural resource when the elasticity of substitution between the two inputs is unity, and certain other assumptions are met (Jhingan, 2007; Stern, 2004). Sustainability occurs when the satisfaction of individuals is given equal weight without reference to the time they happen to live and the aim is to maximize the sum total of satisfaction over time. In fact, growth in consumption can occur indefinitely. However, the same model economy under competition results in exhaustion of the resource and consumption and social welfare eventually diminish to zero (Stiglitz, 1974).

Several analysts (Dasgupta and Heal, 1974; Dixit, Hammond, and Hoel, 1980) argue that substitution and technical change can effectively de-couple economic growth from energy and other resources and that depleted resources can be replaced by more abundant substitutes, or by equivalent forms of human-made capital such machine (Stern, 2004). But according to Stern (2004) this is a misinterpretation. As earlier explained, the neoclassical economists are primarily interested in the institutional arrangements, and not the technical arrangements, that will lead to sustainability, so they typically assume *a priori* that sustainability is technically feasible and then investigated the institutional arrangements that should be employed to achieve the sustainability.

Solow (1974) explicitly rejected of cases where the elasticity of substitution between non-renewable resources and capital is greater or less than unity. In the former case substitution possibilities are large and therefore the possibility of non-sustainability is not an issue. In the latter case, sustainability is not feasible if an economy uses only nonrenewable resources. Of course, where there are renewable resources sustainability is technically feasible, at least in the absence of population growth. However, there is a tendency among mainstream economists to assume that sustainability is technically feasible unless proved otherwise (Solow, 1993).

3.1.3. Growth Models with Natural Resources and Technological Change

In addition to substitution of capital for resources, technological change will enhance optimal utilization of resource in the face of a finite resource base. Due to this enhanced technical progress, sustainability will be technically easier to achieve and sustainability may be possible even with an elasticity of substitution of less than unity (Stern, 2003, 2010). However, Smulders (2005) noted that technical feasibility is not a guarantee that sustainability will be achieved (Stern, 2010). Technological enhancement implies that production per unit resource will be higher in the future. Base on preferences between current and future consumption, technological improvement might lead to a rapid depletion of the resources thereby not guaranteeing sustainability.

3.2. The Ecological Approach to Economic Growth

The ecological growth theorists proposed an approach to the theory of production that is opposed to the neoclassical theoretical stance. They challenged the neoclassical assumption that energy is merely an 'intermediate input' in the production process which can be substituted by human made capital (Joanne and Lester, 2009). Energy is regarded as an essential input in economic activities which is used to produce an integral part of many economic activities. This implies that energy is more of a complement to labour and capital rather than a substitute. While they argue that energy plays an important role in the production process just as labour and capital, the neoclassical economist assume that labour and capital are the only factor inputs (Jhingan, 2007; Vlahinic-Dizdarevic & Zikovic, 2010). They also abandoned the assumption that factor productivity must be equal to factor shares (see Ayres and van den Bergh, 2005; Cleveland, Costanza, Hall, and Kaufmann, 1984; Georgescu-Roegen, 1971). The ecological economists are also of the view that the energy required for producing fuels and other intermediate resources increases as the quality of resources such as oil reservoirs decline over time, implying that changing resource quality can be represented by changes in the embodied energy of the intermediate inputs (Stern, 2004).

The ecological economists make a clear distinction between energy as an intermediate input and energy as a primary input. When energy is regarded as an intermediate input, it means that, it can be created during the production period and used up entirely in production, while if it is referred to as primary inputs, it must exist at the beginning of the production period but not used up in production, although it can be degraded (Joanne and Lester, 2009).

The oil crisis of the early 1970s led to the development of an energy-production function that ascribed a major role to energy input along with other factor inputs such as labour and capital (Vlahinic-Dizdarevic and Zikovic, 2010).

Cleveland et al., (1984) along with Hall, Cleveland and Kaufmann (1986) in Stern (2010) stated that energy is basic and at the extreme the only factor of production in an economy and that increase in energy use is the main source of growth as opposed to the role of technical change advocated by the neoclassical economist and the Neo-Ricardian models developed by Perrings (1987) and O'Connor (1993). The Neo-Ricardian model, have a fixed proportion technology in terms of capital stocks instead of the flows in the input-output model. They do not distinguish between primary and intermediate factors of production, yet the approach can take the biophysical constraints of mass balance and energy conservation into account (Stern, 1999).

> *If the economy could actually be represented as an input-output model where there is no substitution between factors of production, and a single source of uniform quality energy, the embodied knowledge in the factors of production can itself be ignored, although its embodied energy content is of course counted. The contribution of knowledge to production cannot be assumed to be proportional to its embodied energy. Though thermodynamics places constraints on substitution, the actual degree of substitutability among capital stocks embodying knowledge and energy is an empirical question. Neither the Leontief input-output model nor the Neo-Ricardian model allows substitution between inputs* (Stern and Cleveland, 2004, p. 7).

3.3. Summary of the Theoretical Literature

The neoclassical and ecological growth theories reviewed are relevant to the study. Both theories use a production function based approach to growth. The neoclassical theory assumes that capital and labour are the fundamental determinants of economic growth. However, the theory predicts that an economy will reach a steady state of equilibrium due to diminishing marginal product of capital and technology. The weakness of the neoclassical theory is that it assumes a secondary role to energy resources in the production process. Due to this weakness, the ecological growth theory becomes relevant. The ecological growth model becomes relevant because it considers energy to be endogenous. That is, its role is primary and co-equal with labour and capital. The next section presents empirical literature relevant to the study which is primarily based on the ecological approach.

3.4. Empirical Literature

From the advent of the oil crisis in the 1970s to the recent concerns on energy prices, energy-security and the impact of environmental policy to conserve energy and reduce green-house-gas emissions, there has been a growing interest in the examination of the relationship between energy and economic growth. This has resulted in a vast literature on the causal relationship between energy consumption and economic growth. These studies have employed a variety of time series econometric techniques. However, the results have been inconclusive. The first relevant study on energy consumption and growth dates back to the late 1970s. In their pioneering work, Kraft and Kraft (1978) used annual U.S. data from 1947 to 1974 to study the relationship between gross national product (GNP) and gross energy inputs. They employed the Sims causality test procedure to examine the causal relationship, and discovered that increased GNP leads to increased energy consumption. Substituting employment with economic growth, Akarca and Long (1979) showed that increased energy consumption leads to higher levels of employment. However, when using different methodology (i.e. Sims technique) and different data set (i.e., annual U.S. data from 1950 to 1970), Akarca and Long (1980) found no causal relationship between energy consumption and GNP.

Although it is a fact that there is a strong interdependence between energy consumption and economic growth, the direction of causality is not clearly defined (Vlahinic-Dizdarevic and Zikovic, 2010). The literature on the causal relationship between energy consumption and economic growth has been summarized into four testable hypotheses namely; growth hypothesis, conservation hypothesis, neutrality hypothesis and feedback hypothesis (Apergis and Payne, 2009a, 2009b; Gurgul and Lach, 2012; Jumbe, 2004; Vlahinic-Dizdarevic and Zikovic, 2010).

3.4.1. Growth Hypothesis

The growth hypothesis asserts that energy consumption plays an important role in economic growth both as a direct input in the production process or indirectly as a complement to labour and capital inputs (Apergis and Payne, 2009a). The growth hypothesis suggests that an increase in energy consumption causes an increase in real GDP and in that case the economy is energy dependent. Under the growth hypothesis, energy conservation policies which reduce energy consumption may have a negative impact on real GDP (Apergis and Payne, 2009a, 2009b). For example Apergis and Payne (2009) in their study examined the relationship between energy consumption and economic growth for six central American countries over the period 1980 to 2004 using a multivariate framework. Their findings revealed that there exists both short and long run causality running from energy consumption to economic growth which supports the growth hypothesis.

Chiou-Wei, Chen, and Zhu (2008) examined the relationship between energy consumption and economic growth in a sample of Asian newly industrialized countries as well as the USA using both linear and nonlinear Granger causality tests. Empirical evidence shows that energy consumption drives economic growth for Taiwan, Hong Kong, Malaysia and Indonesia. Tsani (2012) investigated the relationship between aggregate and dis-aggregate levels of energy consumption and economic growth. Her findings suggest that there exists a unidirectional causal relationship running from total energy to real GDP at the aggregate level.

Also, Yıldırım, Sukruoglu, and Aslan (2014) examined the causality between energy consumption and economic growth in a number of countries (Turkey, Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Pakistan, and the Philippines) using the bootstrapped autoregressive metric causality approach. Estimating a trivariate model consisting of GDP per capita, energy consumption per capita and gross capita formation, the growth hypothesis was supported in the case of Turkey, as a unidirectional causal relationship was found running from energy consumption to economic growth. Soytas & Sari (2003) studied the causal relationship between energy consumption and GDP in G-7 countries and emerging markets including Argentina, Italy, Korea, Turkey, France, Germany and Japan. The study reveals evidence of causality from energy consumption to GDP in Turkey, France, Germany and Japan. Hence, energy conservation may harm economic growth in Turkey, France, Germany, and Japan. Akinlo (2009) examined the relationship that existed between electricity consumption and real GDP in Nigeria between 1980 and 2006 using the cointegration and causality method. The causality result shows that electricity consumption Granger cause real GDP.

Yuan, Zhao, Yu, and Hu (2007) in their own study examined the trend of the relationship that exists between electricity consumption and economic growth in China and tried to establish if there is a long run relationship between the variables using the cointegration method and also how they influence each other in the short run. The result shows that there exists a long-run relationship, i.e. GDP and electricity consumption are cointegrated and there exists only a unidirectional relationship running from electricity to real GDP. Similarly, Odhiambo (2009b) examined the inter-temporal causal relationship between energy consumption and economic growth in Tanzania during the period 1971–2006. Unlike the majority of the previous studies, the study employed the autoregressive distributed lag (ARDL) bounds testing approach by Pesaran *et al*., (2001) to examine this linkage. The results of the bounds test show that there is a stable long-run relationship between each of the proxies of energy consumption and economic growth. The results of the causality test, on the other hand, show that there is a unidirectional causal flow from total energy consumption to economic growth and a prima-facie causal flow from electricity consumption to economic growth. This means that energy consumption spurs economic growth in Tanzania.

However, Squalli (2007) suggested "the possibility that an increase in energy consumption may have a negative impact on real GDP. Such a possibility could result from excessive energy consumption in relatively unproductive sectors of the economy, capacity constraints, or inefficiencies in energy production. Another possibility for the negative impact of increase energy consumption on real GDP could be attributed to the case of a growing economy which requires a decreasing amount of energy consumption as production moves towards less energy intensive sectors of the economy (Apergis and Payne, 2009b).

3.4.2. Conservation Hypothesis

The conservation hypothesis suggests that economic growth is the dynamic which causes the consumption of energy resources. That is to say, economic growth drives energy consumption. The validity of the conservation hypothesis is proved if there is unidirectional causality from economic growth to energy consumption. In this situation, energy conservation policies which may prevent or reduce energy consumption will not have negative impact on economic growth. The conservation hypothesis is confirmed if an increase in real GDP causes an increase in energy consumption (Apergis and Payne, 2009a, 2009b). For example, Herrerias et al., (2013) examined the causality between energy consumption and economic growth across regions in China from 1995-2009. Their findings revealed a unidirectional causality running from economic growth to energy consumption. Onuonga (2012) also examined the relationship between economic growth (GDP) and commercial energy consumption in Kenya using the vector error correction model for the period 1970 to 2005. The result reveals that economic growth granger caused energy consumption in Kenya for the period under investigation. The findings of Soytas and Sari (2003) as mentioned earlier revealed a unidirectional causality running from GDP to energy consumption in Italy and Korea.

Furthermore, the study of Chiou-Wei, Chen, and Zhu (2008) as mentioned earlier found empirical evidence supports the conservation hypothesis in the case of the Philippines and Singapore, as it reveals a unidirectional causality running from economic growth to energy consumption. Similarly, the findings Jinke, Hualing, and Dianming (2008) revealed that there exist unidirectional causality running from GDP to coal consumption in Japan and China. However, Squalli (2007) argued political influence, inadequate infrastructure, and mismanagement of resources is capable of constraining economic growth, thereby, generating inefficiencies as well as reduction in the consumption of goods and services including energy".

3.4.3. Neutrality Hypothesis

The neutrality hypothesis considers energy consumption to be a small component of overall output and thus may have little or no impact on real GDP. As in the case of the conservation hypothesis, energy conservation policies would not have an adverse impact on real GDP. The neutrality hypothesis is supported by the absence of a causal relationship between energy consumption and real GDP. Empirical studies by Bowden and Payne (2009) who used the Toda–Yamamoto procedure within a multivariate model framework by including measures of capital and employment and analyzed the causal relationship between renewable and non-renewable energy consumption and real GDP in the USA over the period 1949–2006. Results showed that there exists no causal relationship between renewable and non-renewable energy consumption and economic growth, indicating the presence of the neutrality hypothesis.

Empirical evidence from the study of Chiou-Wei, Chen, and Zhu (2008) as mentioned earlier revealed that there is no causal relationship in the case of USA thereby supporting the neutrality hypothesis. Jinke, Hualing, and Dianming (2008) as also mentioned earlier investigated the differences of the causal relationship between coal consumption and GDP in major OECD and non OECD countries, their findings revealed that there exists no causal relationship between coal consumption and GDP in India, South Korea and South Africa. Similarly, the neutrality hypothesis was valid for all countries examined in the study of Yıldırım, Sukruoglu and Aslan (2014) as mentioned earlier except turkey.

3.4.4. Feedback (Bidirectional) Hypothesis

Under the feedback (bidirectional) hypothesis, energy consumption and real GDP are inter-related and may very well serve as complements to each other. The presence of bidirectional causality between energy consumption and real GDP supports the feedback hypothesis in an energy policy oriented toward improvements in energy consumption efficiency may not have an adverse impact on real GDP (Apergis and Payne, 2009a). Soytas and Sari (2003) studied the causal relationship between energy consumption and GDP in G-7 countries and emerging markets. The study reveals bidirectional causality in Argentina.

In a similar study Nasreen and Anwar (2014) examined the relationship between trade openness, economic growth and energy consumption for fifteen Asian countries. Their analysis reveals that there exists bidirectional causality between economic growth and energy consumption, trade openness and energy consumption. Shahiduzzaman and Alam (2012) investigated the cointegration and causal relationship between energy consumption and economic output in Australia over a period of five decades. Empirical evidence reveals that there exists bi-directional causality between GDP and energy use.

Furthermore, Tsani (2012) investigated the relationship between aggregate and dis-aggregate level of energy consumption and economic growth. Her findings suggest that there exists a bidirectional relationship between industrial, residential energy consumption and real GDP. Belke, Dobnik and Dreger (2011) examined the long-run relationship between energy consumption and real GDP, including energy prices, for 25 OECD Countries from 1981-2007 using principal component analysis to distinguish between development at an international and a national level as driver of the long run relationship. The cointegration result between the components indicates that international development dominates the long run relationship between energy consumption and real GDP. Furthermore, the result suggests that energy consumption is price elastic and there exists a bidirectional relationship between energy consumption and economic growth.

Bildirici and Bakirtas (2014) examined the causal relationship between economic growth and coal, natural gas and oil consumption using the ARDL (autoregressive distributed lag bounds) testing approach from 1980 to 2011 in Brazil, Russia, India, China, Turkey and South Africa. Their findings reveal a strong bi-directional causal relationship between oil energy consumption and GDP for all countries. For coal consumption and GDP, there exists a strong bi-directional causal relationship for China and India. However, in the case of natural gas, there exists a bi-directional causal relationship only in the case of Brazil, Russia and Turkey. Zou and Chau (2006) examined the equilibrium relationship and predictability between oil consumption and economic growth in China. The cointegration test revealed that the two variables tend to move together in the long run. Furthermore, the Granger causality test indicates that oil consumption granger causes economic growth both in the short run and in the long run. On the other hand, economic growth granger causes oil consumption in the long run.

Oh and Lee (2004) investigated the causal relationship between energy consumption and economic growth by applying a multivariate model to capital, labour, energy and GDP in China. The study employed a vector error correction model for a data set between 1970 and 1999. Empirical results of the study suggest a long run bidirectional causal relationship between energy and GDP. Similarly, Odhiambo (2009a) investigated the causal relationship between electricity consumption and economic growth in South Africa. He Incorporated employment rate as an intermittent variable in the bivariate model between electricity consumption and economic growth, thereby, creating a simple trivariate causality framework. The empirical findings reveal that there is distinct bidirectional causality between electricity consumption and economic growth in South Africa. Erdal, Erdal, and Esengün (2008) examined the causal relationship between primary energy consumption and real GNP for Turkey during the period 1970-2006. The empirical results reveal that the variables are cointegrated and that there exist a bidirectional causal relationship running from electricity consumption to economic growth.

3.4.5. Mixed Results

There are other studies on the relationship between energy consumption and economic growth yielding mixed result with regards the aforementioned hypothesis. For example earlier study by Erol and Yu (1987) applied both the Sims and Granger causality procedures to examine the causal relationships between energy consumption and real GNP for Japan, Germany, Italy, Canada, France and the U.K. The results showed that there was bidirectional causality between the two variables in Japan. For the case of Germany and Italy, increased GNP led to increased energy consumption. Increased energy consumption led to increased GNP in Canada, but there were no causal relationships between the two in France and the U.K.

Similarly, Bozoklu and Yilanci (2013) reexamined the causality between energy consumption and economic growth for selected OECD countries using the Granger causality test to distinguish between the short run and long run causality. The empirical findings revealed that there was causality running from GDP to energy in the short run for Australia, Austria, Canada, Italy, Japan, Mexico, the Netherlands, Portugal, the UK, and the USA, and long run causality for Austria, Belgium, Denmark, Germany, Italy, Japan, the Netherlands, Norway, and the USA. On the other hand, in terms of causality running from energy consumption to GDP, there was short run causality for Austria, Denmark, Italy, the Netherlands, Norway, and Portugal, while there is a permanent or long run causality for Belgium, Finland, Greece Italy, Japan, and Portugal.

Yuan, Kang, Zhao and Hu (2008) examined the existence and direction of causality between output growth and energy use in China at both aggregated total energy and dis-aggregated levels such as coal, oil and electricity using the Johansen cointegration technique. This empirical result shows that there exists causality running from electricity and oil consumption to GDP but there is no causality running from coal and total energy to GDP. On the other hand, the short run causality does exist from GDP to coal, oil production and total energy but does not exist from to electricity consumption.

Also, Zamani (2007) examined the causal relationship between overall GDP, industrial and agricultural value added, and consumption of different kinds of energy, using the vector error correction model for the case of Iran between 1967 and 2003. Empirical evidence revealed a long-run unidirectional relationship from GDP to total energy and a bidirectional relationship between GDP and gas as well as GDP and petroleum products consumption for the whole economy. Causality ran from industrial value added to total energy, electricity, and gas and petroleum products consumption and from gas consumption to value added in the industrial sector. The long-run bidirectional relations hold between values added and total energy, electricity and petroleum products consumption in the agricultural sector. There was short-run causality from GDP to total energy and petroleum products consumption, and also from industrial value added to total energy and petroleum products consumption in this sector. This means that Energy conservative policies had no adverse effects on economics growth in short term but in the long-run it would slow down the growth.

In the case of Turkey, Araç and Hasanov (2014) studied the dynamic interrelationship between energy consumption and economic growth in Turkey for the 1960-2010 period by using a smooth transition vector autoregressive model and generalized impulse response functions (GIRFs) to trace the effect of one variable over another (positive vs negative and small versus large energy consumption shock on output growth and vice versa). Their findings revealed that negative energy shock has greater effect on output growth than the positive energy shock and that big negative shocks affect output growth more than the small negative energy shock. On the other hand they found out that positive output shock has a greater effect on energy consumption, whereas negative shocks have little or no effect on energy consumption.

Ouedraogo (2013) examined the long run relationship between energy consumption and economic growth for fifteen African countries for the period 1980-2008 using a panel cointegration technique. The result showed that there was causality running from GDP to energy in the short run, and from energy consumption to economic growth in the long run. There is also evidence of unidirectional causality running from electricity to GDP in the long run. Belloumi (2009), in his study of Tunisia, uses the Johansen cointegration technique and vector error correction model to examine the causal relationship between per capita energy consumption (PCEC) and per capita gross domestic product (PCGDP) for the 1971–2004 period. The results indicate that the PCGDP and PCEC for Tunisia are related by one cointegrating vector and that there is a long-run bi-directional causal relationship between the two series and a short- run unidirectional causality from energy to gross domestic product (GDP).

Bowden and Payne (2009) tested the sectoral causal relationship between renewable and non-renewable energy consumption and economic growth in the USA over the period 1949–2006 by employing the Toda–Yamamoto causality procedure within a multivariate model framework by including gross fixed capital formation and labour. Findings revealed that there is no causality between renewable energy consumption in the commercial and industrial sectors and real GDP, which supports the neutrality hypothesis, whereas positive uni-directional causality exists from residential renewable energy consumption to real GDP, supporting the growth hypothesis. On the other hand, causality test results also indicated the positive bi-directional causality between non-renewable energy consumption in both the commercial and residential sectors and real GDP, supporting the feedback hypothesis, and the negative uni-directional causality from industrial non-renewable energy consumption to real GDP, indicating the applicability of the growth hypothesis.

Sari, Ewing and Soytas (2008), employing the variance decomposition technique in VAR specification, investigated the effects of different sources of energy consumption on industrial output in the USA for the period 2001–2005 and concluded that while total energy consumption explains about 9.5 percent of the forecast error variance of industrial production, non-renewable energy consumption explains 10 percent. On the other hand, the consumption of renewable energy sources explains only about 2.5 percent of the forecast error variance of industrial production, indicating that consumption of non-renewable energy sources is stronger in explaining the variation of industrial production relative to consumption of renewable energy sources.

Wolde-Rufael (2009) in his study of the long run relationship between energy demand and economic growth of nineteen African countries for the period 1971 to 2001 found empirical evidence that shows that there was a long run relationship between the two series for only eight countries and causality for ten countries.

Lee and Chang (2005) studied the linear and non-linear effect of energy consumption on economic growth in Taiwan using data between 1954 and 2003. Their finding suggests that there exists a uni-directional causal relationship between oil, gas and electricity consumption to GDP on one hand and evidence of bidirectional causality between GDP aggregate energy consumption and coal consumption on the other hand.

Mairet and Decellas (2009) in their study analysed the change in energy consumption of the service sector in France for the period 1995 to 2006, using the logarithmic mean divisia index1 (LMDI 1) decomposition method. The analysis was carried out at various dis-aggregated levels to highlight the specifics of each subsector and end-use according to their respective determinants. The result shows that during this period economic growth of the service sector was the main factor that led to the increase in total energy consumption.

Ighodaro (2010) re-examined the cointegration and causal relationship between energy consumption and economic growth in Nigeria. He used a data set that from 1970 to 2005. Unlike previous studies for Nigeria, different proxies of energy consumption (electricity demand, domestic crude oil consumption, and gas utilisation) were used for estimation. It also included government activities proxied by health expenditure and monetary policy proxied by broad money supply. The cointegration tests revealed that there exists long run relationship among the series and that the variables were stationary at first difference I (1). The causality tests revealed that there exists causality between electricity consumption and economic growth as well as between gas utilisation and economic growth, while causality runs from economic growth to domestic crude oil consumption.

3.5. Summary

Theoretical and empirical literature on the relationship between energy consumption and economic growth was reviewed in this chapter. It is evident from the empirical review that energy is an important factor that determines economic growth. Studies reviewed from different countries including South Africa were useful in revealing the real impact of energy consumption on economic growth. The ecological and neoclassical approaches to economic growth theory were examined.

The ecological theorists assert that all production involves the transformation or conversion either directly or indirectly and energy in needed for such transformation. Therefore there must be limits to the substitution of other factors of production for energy, as all economic processes require energy, so that energy is always an essential factor of production. The neoclassical growth theorists on the other hand focus on primary inputs, and in particular, capital and labour, and the attribution of a lesser and somewhat indirect role to energy. The empirical literature discussed in this chapter is divided into four testable hypotheses namely; growth hypothesis, conservation hypothesis, neutrality hypothesis as well as the feedback/bidirectional hypothesis. The next chapter presents the conceptual framework and methodology of this dissertation.

CHAPTER 4

CONCEPTUAL FRAMEWORK AND METHODOLOGY

This chapter presents the conceptual framework, methodology and data. The theoretical framework is presented in section one. Methodologies of estimation are discussed in section two. The data and software for empirical analysis are enumerated in section three while a summary is presented in section four.

4.1. Theoretical Model

As stated above, energy as a separate factor input in the production process has been neglected as its contribution is considered to be marginal because the cost of energy accounts for only a very small proportion of GDP compared to the cost of labour (Ghali and El-sakka, 2004; Lee and Chang, 2006). However, Moroney, 1992 stated that, "it is one thing to correctly cite energy's small cost share in GNP, but an error to conclude, on this account, that energy plays a secondary role. Its role is primary, co-equal with capital formation".

Recently numerous studies have highlighted the importance of energy in the production process by incorporating energy in addition to labour and capital (see Beaudreau, 2005; Ghali and El-sakka, 2004; Lee and Chang, 2006; Narayan and Smyth, 2008; Oh and Lee, 2004; Soytas and Sari, 2007; Ugur and ramazan, 2006; Wolde-Rufael, 2009b; Yuan et al., 2008) as a third factor of production. In this study, the causal relationship between energy consumption and economic growth will be examined in a conventional neoclassical one-sector aggregate production model where capital, labour and energy are treated as separate factor inputs[7]:

$$Y_t = f(L_t,\ K_t,\ E_t) \qquad (4.1)$$

where,

Y= Output

L= Labour

[7] Adapted from the works of Chien-Chiang Lee, Chun-Ping Chang (2005)

K= Capital

E= Aggregate energy consumption

This can be written mathematically as:

$$Y_t = \beta_0 + \beta_1 L_t + \beta_2 K_t + \beta_3 E_t + \mu_t \tag{4.2}$$

where Y is the aggregate output or real gross domestic product, K is the capital stock, L is the level of employment, and E is the total energy consumption in aggregated level. The subscript ‘t’ denotes the time period while μ is the error term.

We can further consider the two-sector model of the economy, which is propounded by Feder (1982) and Ram (1986) in Lee and Chang (2005), in order to study the effect of the export sector on economic growth. By reformulating the model using an energy sector instead of the original export-domestic sector division, a specification for the assessment of the energy-growth nexus which is empirically tractable can be found. The model is set up as follows. Assume that the economy is composed of two sectors—the energy sector (G) and the non-energy sector (C). The production functions of both sectors are expressed as follows:

$$C = C(L_C, K_C, G) \tag{4.3}$$

$$G = G(L_G, K_G) \tag{4.4}$$

$$Y = C + G \tag{4.5}$$

$$L_C + L_G = L \tag{4.6}$$

$$K_C + K_G = K \tag{4.7}$$

$$\frac{G_L}{C_L} = \frac{G_K}{C_K} = (1 + \delta) \tag{4.8}$$

where,

Y= Output

G= Energy sector

C= Non-energy sector

L= Labour

K= Capital

L_C= Labour in the non-energy sector

K_C= Capital in the Non-Energy sector

L_G= Labour in the Energy sector

K_G= Capital in the Energy sector

G_L= Marginal productivity of labour input in the energy sector

G_K= Marginal productivity of capital input in the energy sector

C_L= Marginal productivity of labour input in the non-energy sector

C_K= Marginal productivity of labour input in the non-energy sector

δ = The difference in the marginal productivities of the factor inputs in the two sectors.

Equation (4.3) indicates the production function of the non-energy sector and Equation (4.4) is the production function of the energy sector. Equation (4.5) indicates that total output (Y) is the sum of C and G, and Equation (4.6) shows that the total labour force (L) is the sum of the non-energy labour input (L_C) and energy labour input (L_G). Equation (4.7) indicates that the total capital stock (K) is the sum of non-energy sector capital input (K_C) and energy sector capital inputs(K_G). Equation (4.3) indicates that energy sector output (G) creates an externality effect on non-energy sector output (C). The difference in the marginal productivities of the factor input in the two sectors is illustrated in Equation (4.8). δ>0 indicates that the marginal productivity of the energy sector is greater than that of the non-energy sector, while δ<0 indicates that the opposite is the case.

We take the totally differentiated Equations (4.3) and (4.4) and substitute the results into Equations (4.5) and (4.6), which are total differentials. From Equation (4.8), we can then conclude that

$$dY = C_L dL + C_K dK + C_G dG + \frac{\delta}{1+\delta} dG \tag{4.9}$$

Also dividing Equation (4.9) by Y, and setting $\alpha \equiv C_K$ and$\beta = C_L \frac{L}{Y}$ and dK = I (Investment) where α means the marginal production of capital in the non-energy sector and β means the production elasticity of labour in the non-energy sector we find the Equation as follows:

$$\frac{dY}{Y} = \alpha \frac{I}{Y} + \beta \hat{L} + (\frac{\delta}{1+\delta} + C_G) \frac{dG}{G} \frac{G}{Y} \tag{4.10}$$

In Equation (4.10), C_G indicates the marginal externality effect which comes from the production of the energy sector imposed on the production of the non-energy sector. From Equation (4.10) we can make the empirical regression equation as follows:

$$\widehat{Y_t} = \alpha_0 + \alpha_1 \left(\frac{I_t}{Y_t}\right) + \alpha_2 \widehat{L_t} + \alpha_3 \widehat{G_t} \frac{G_t}{Y_t} + \mu_t \tag{4.11}$$

Equation (4.11) shows that the variables which effect economic growth ($\hat{Y}$) include the investment rate ($\frac{I}{Y}$), labour force growth ($\hat{L}$), and the multiple effects of the growth of energy expenditure ($\hat{G}$) and energy use size ($\frac{G}{Y}$).

According to the growth theory, α_1 and α_2 are both positive coefficients given that the investment rate and labour force growth have a positive impact on the real aggregate output growth. In addition, the multiple effect is identified through the sign of α_3. This indicates that the energy sector has a reciprocal effect on economic growth in two ways: one is the direct contribution of the energy sector and the other is the indirect effect of the energy sector through the non-energy sector (the externality effect). This shows that all economic activities are connected either directly or indirectly to the consumption of energy (Lee and Chang, 2006).

The above model is used as a guide to specify the linear models model for the estimation of the impact of energy consumption on economic growth. Employing economic output (both at aggregated and disaggregated level) as the dependent variable and energy consumption (both at aggregated and dis aggregated level) as well as labour and capital as independent variables, the following models are derived. Model 1 is the aggregate energy consumption model; model 2 is the dis-aggregated energy consumption model, while model 3, 4 and 5 are the primary sector, secondary sector and tertiary sector energy consumption models respectively.

Model 1: $GDPGR_t = \beta_0 + \beta_1 LABGR_t + \beta_2 CAPGR_t + \beta_3 ENYGR_t + \mu_t$ (4.12)

Model 2: $GDPGR_t = \beta_0 + \beta_1 LABGR_t + \beta_2 CAPGR_t + \beta_3 COLGR_t + \beta_4 ELCGR_t +$

$\beta_4 OILGR_t + \mu_t$ (4.13)

Model 3: $PRYGR_t = \beta_0 + \beta_1 LABGR_t + \beta_2 CAPGR_t + \beta_3 COLGR_t + \beta_4 ELCGR_t +$

$\beta_4 OILGR_t + \mu_t$ (4.14)

Model 4: $SEYGR_t = \beta_0 + \beta_1 LABGR_t + \beta_2 CAPGR_t + \beta_3 COLGR_t + \beta_4 ELCGR_t +$

$\beta_4 OILGR_t + \mu_t$ (4.15)

Model 5: $TEYGR_t = \beta_0 + \beta_1 LABGR_t + \beta_2 CAPGR_t + \beta_3 COLGR_t + \beta_4 ELCGR_t +$

$\beta_4 OILGR_t + \mu_t$ (4.16)

where,

GDPGR = Gross domestic product growth rate

LABGR = Employment growth rate

CAPGR = Capital formation growth rate

ENYGR = Total energy consumption growth rate

COLGR = Coal consumption growth rate

ELCGR = Electricity consumption growth rate

OILGR = Oil consumption growth rate

PRYGR= Primary sector output growth rate

SEYGR = Secondary sector output growth rate

TEYGR = Tertiary sector output growth rate

$\beta_0, \dots\dots\dots.., \beta_n$ are parameter estimates

μ = error term

t= time period.

4.2. Methodology of Estimation[8]

This study carried out a preliminary examination of the data series. Descriptive statistical analysis is essential because it enables one to examine the basic features of the variables used i.e whether a given data set approximates normal distribution (Pindyck and Rubinfeld, 1998). The informal way of testing for normality is by checking to see if the mean and median are nearly equal, whether skewness is approximately zero and whether kurtosis is close to three. The Jarque-Bera (JB) statistic is considered to be a more formal way of testing for normality. This is a joint hypothesis that the skewness coefficient (S) and kurtosis coefficient (K) is three. The JB statistic follows Chi square distribution with 2 degrees of freedom (df) (Pindyck and Rubinfeld, 1998). We reject the null hypothesis of normality if the JB statistic is greater than the critical value of the chi square or if the p-value is less than 5 percent (Pindyck and Rubinfeld, 1998).

[8] This section is heavily based on the works of William, H. Greene (2000), Gujarati, D. (2011), Dimitrios, A. and Stephen, G.H. (2007).

Table 4.1: Summary of the Methodology of Estimation

S/N	Tests	Instruments	Comments
1	Descriptive	Mean, median, minima, maxima, skewness, and kurtosis	To examine the basin features of the variables.
2	Unit root	Augmented Dickey Fuller (ADF), Phillips Perron (PP), and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)	To test for the order of integration of the variables so as to avoid spurious regression result.
3	Lag length	Akaike information criterion.	To determine the best or correctly specified equation
4	Diagnostic checking	Normality test, heteroscedasticity test, and Breuch-Godfrey serial correlation test, CUSUM and CUSUMQ test	To check for the robustness as well as if structural break has occurred.
5	Stability	AR root graph, CUSUM and CUSUMQ test	To check for the appropriateness of the model.
6	Cointegration	Johansen-Juselius cointegration test	To check for the presence of long run relationship among the variables in the model.
7	Causality/ VECM	Vector error correction model	To distinguish between the long run and short run causality.
8	Innovation accounting	Impulse response function and variance decomposition.	To trace the effects of shocks in the system.

4.2.1. Unit Root Test

In the empirical time series analysis, the properties of the variables need to be examined to avoid the possibility of spurious regression. The first step is to ascertain the order of integration of the series. To achieve this and in order to provide an analysis of sensitivity and robustness, this study performs two different unit root tests, namely, the Augmented Dickey and Fuller (ADF) 1979, and the Phillips and Perron (PP) 1988 to check the presence of a unit root, implying non-stationarity as the null hypothesis, and the absence of the unit root (stationarity) as the alternative hypothesis, i.e.:

H_0: Series is non-stationary, i.e. unit root exists.

H_1: Series is stationary, i.e. unit root does not exist.

If the variables are found to be non-stationary then successive differencing has to be applied so that the series becomes stationary. According to Gujarati and Porter (2009), in general if a time series has to be differenced "d" times to make it stationary, that time series is said to be integrated in the order of "d".

The ADF test takes into account cases where the error terms, μ_t are correlated. That is to say, with this test the assumption is that the error term is independently distributed. According to Gujarati and Porter (2009), the ADF test involves estimating the following regression:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t \tag{4.17}$$

$$\Delta Y_t = \beta_0 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t \tag{4.18}$$

$$\Delta Y_t = \beta_0 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t \tag{4.19}$$

where μ_t = pure white house noise error term.

The major difference between the three equations is the presence of deterministic elements β_0 and $\beta_2 t$. Donald, Jenkinson and Sosvilla-Rivero (as cited in Dimitrios and Stephen, 2007) suggest a procedure which starts from the estimation of the most general model given by Equation (4.14) and checking for the appropriateness of the model before moving to the next model. We recall that the ADF test adjusts the Dickey Fuller test to take care of possible serial correlation in the error term by adding the lagged difference terms of the regressand. Phillips and Perron (1988) developed a generalization of the ADF test and use non-parametric statistical methods to take care of the serial correlation in the error terms without adding lagged difference term (Gujarati, 2004). This will be applied as an alternate test for unit root.

The test regression for the Phillips –Perron (PP) test is the AR (1) process:

$$\Delta Y_t = \beta_0 + \delta Y_{t-1} + \mu_t \qquad (4.20)$$

This corrects for any autocorrelation and heteroscedasticity in the errors and as such it gives robust estimates when the series has serial correlation and time-dependent heteroscedasticity (Odhiambo, 2009a).

4.2.2. Lag Length Determination

The choice of optimal lag length is essential in order to determine the best or correctly specified equation. There are several methods for selecting the optimal lag length. The most common are the Akaike Information Criterion (1974) and Schwarz's (1978) Information Criterion. The step in choosing the optimal lag length is to estimate the Vector Auto Regression (VAR) model with all the variables in levels after, which we estimate the VAR model with a large number of lags and then reduce it down by re-estimating the model for one lag less up to zero.

The Akaike (1974) information criterion, $AIC\ (\rho)$:

$$AIC(p) = In\frac{e\prime e}{T} + \frac{2P}{T} \qquad (4.21)$$

and Schwarz's (1978) information criterion, $SIC\ (\rho)$:

$$SIC(p) = AIC(p) + \frac{p}{T}(in\, T - 2) \qquad (4.22).$$

Conventionally, the model that minimizes AIC and SIC is selected as the one with the optimal lag length and therefore used for the estimation. The study employs the AIC to select the optimal lag length. The selected model should also well pass all the diagnostic checking such as the normality test, autocorrelation, and heteroscedasticity.

4.2.3. Diagnostic Test

Diagnostic testing is applied to check for the stability and robustness of the models. The diagnostic test employed in this study includes autocorrelation, normality, heteroscedasticity and stability tests. The presence of serial correlation and heteroscedasticity violates the classical assumptions of the OLS and hence invalidates the statistical validity of parameter estimates.

4.2.3.1. Autocorrelation Test

The study conducts diagnostics tests such as the Breusch-Godfrey (1978) test to check the null hypothesis of no autocorrelation, instead of the Durbin Watson test, which loses its power in the presence of a lagged dependent variable. It also does not take into account higher order serial correlation (Dimitrios and Stephen, 2007). A common problem in regression analysis involving time series analysis is autocorrelation. It must be noted that one of the assumptions of the classical linear regression model is that the error term μ_t is uncorrelated- that is to say the error term at time t is not correlated with the error at time $t-1$ and any other term in the past. If the error terms are correlated, the estimator becomes inefficient and may lead to a spurious regression result. Considering the model in Equation (4.23) below:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_k X_{kt} + \mu_t \qquad (4.23)$$

where

$$\mu_t = \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \cdots + \rho_n \mu_{t-n} + \varepsilon_t \qquad (4.24)$$

the Breusch-Godfrey LM test combines the two equations:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_k X_{kt} + \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \cdots + \rho_n \mu_{t-n} + \varepsilon_t \qquad (4.25)$$

Therefore the null and alternative hypotheses are:

H_0: $\rho_1 = \rho_2 = \cdots \rho_n = 0$ no serial correlation

H_1: At least one of the ρs is not zero, which implies that there is serial correlation.

4.2.3.2. Normality Test

According to Gujarati (2011), normality assumption ($\mu_t \sim N(0, \sigma^2)$) is required in order to conduct single or joint hypothesis testing about model parameters. The Jarque and Bera (1981) test of normality is an asymptotic test based on the OLS residuals. This test formalises the idea of joint hypothesis by testing if the coefficient of kurtosis and coefficient of skewness are jointly zero. It is a weighted average of the squared sample moments corresponding to skewness and excess kurtosis. Skewness is the extent to which the distribution is asymmetric: that is one side of the distribution is not a mirror image of the other (Ken Stewart, 2005). It is estimated by the coefficient of skewness:

$$S = \frac{\sum(Y_i - \bar{Y})^3/n-1}{S^3} \quad (4.26)$$

where, the denominator s is the standard deviation. Kurtosis on the other hand refers to the peakedness of the distribution. It is estimated by the coefficient of kurtosis:

$$K = \frac{\sum(Y_i - \bar{Y})^4/n-1}{S^3} \quad (4.27).$$

The JB test first computes the skewness and kurtosis measures of the residuals and uses the following test statistics:

$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right] \quad (4.28)$$

where n=sample size, s=skewness coefficient, and k=kurtosis. For a normally distributed variable, s=0, and k=3.

Under the null hypothesis of a normally distributed error, the residuals are normally distributed and the JB statistic has a Chi-Squared distribution with two degrees of freedom (Verbeek, 2004). The histogram should be bell-shaped and the Bera-Jarque should not be significant i.e. the p-value should be larger than 0.05.

4.2.3.3. Heteroscedasticity Test

We recall the assumption of the classical linear regression model of a constant (equal) variance and independent of i, which is illustrated in Equation 4.29 below:

$$var(u_i) = \sigma^2 \tag{4.29}$$

Therefore, having equal variance means that the disturbances are homoscedastic. But it is quite common for this assumption to be violated in regression analysis. In such cases where the homoscedasticity assumption is violated, the variance of the error depends on each of the observation in the sample, i.e.:

$$var(u_i) = \sigma_i^2 \tag{4.30}$$

$$i = 1,2,3,4, \dots n$$

4.2.3.4. Stability Test

In testing for the stability of the models and appropriateness of the autoregressive model (AR), the AR Root table or graph is used. If all roots have absolute values less than one and lie inside the unit circle, we can conclude that the model is stable. This study also utilised the stability test proposed by Brown, Durbin and Evans (1975) based on the recursive residuals. The technique is suitable for time series data and when one is uncertain when the structural change might have occurred. The null hypothesis is that the coefficient vector β is the same in every period, while the alternative is simply that it is not. The CUSUM and CUSUMSQ statistics are updated recursively and plotted against the model's break points. Thus, the coefficients of a given regression are stable if the plots of the statistics fall within critical bounds of 5 percent significance. Generally, CUSUM and CUSUMSQ tests are conducted through graphical representation.

The study selects CUSUM and CUSUMSQ tests ahead of other forms of stability tests because CUSUM and CUSUMSQ tests overcome the shortcomings of the other stability tests.

4.2.4. Cointegration Test

The next step is to test for the cointegration relationship among the variables. It is crucial to investigate if cointegration exists amongst the variables because the cointegration results determine if a causality test should be conducted using the Vector Autoregressive (VAR) or Vector Error Correction Model (VECM) approach. The concepts of cointegration and vector error correction (VECM) were formalised by Engle and Granger (1987) by introducing a simple test procedure to analyse the existence of long-run relationships. However, there are major setbacks with this procedure. For example, when there are more than two variables there may be more than one cointegrating relationship which, cannot be handled by the Engle-Granger procedure using residuals from a single relationship. Consequently, it is impossible for such an approach to give the number of cointegrating vectors (Dimitrios and Stephen, 2007).

According to Pindyck and Rubinfeld (1998), stated that if a linear combination of I (1) variable is a stationary process of I(0) the variables will be cointegrated. The two methods commonly used to test for cointegration are the Engle-Granger and the Johansen maximum likelihood test. According to Sindano and Kaakunga (2011) even if Engel Granger tests for the possibility of cointegration in bivariate models, the limitation of this model is that it assumes uniqueness of the co-integrating vector and the approach does not provide an adequate framework when more than two variables are used. Some of the advantages of Johansen's procedure are that it allows the testing of cointegration as a system of equations in one step and it does not carry over an error from one step into the rest (Abubakar and Gani, 2013). The Johansen maximum likelihood test corrects for autocorrelation and endogeneity parametrically using a vector error correction mechanism (Eita and Jordan, 2007).

According to Engle and Granger (1987), if two series are both non-stationary but integrated of the same order, and there is a linear combination of them which is stationary, then the two series are cointegrated, and the relationship between them is defined as cointegration. Only when two series are integrated of the same order, can we proceed to test for cointegration.

According to the two-step method developed by Engle and Granger (1987), if two series, x and y, have been tested to be non-stationary, but both of them are integrated of the same order, the regression equation can be set up as

$$x_t = \alpha + \beta y_t + \varepsilon_t \tag{4.31}$$

and taking the residuals

$$\widehat{\varepsilon_t} = x_t - \alpha - \beta y_t \tag{4.32}$$

the cointegration between x_t and y_t can be tested by examining the stationarity of the residual $\widehat{\varepsilon_t}$. If x_t and y_t are not cointegrated, any of their linear combinations will be non-stationary. On the other hand if the $\widehat{\varepsilon_t}$ is tested to be stationary, we can reliably conclude that there exists cointegration between the variables. Just as it has been stated above that when we have non-stationary variables in a regression model (see Equation 4.31), we may get results that are spurious (Dimitrios and Stephen, 2007: 309). One way of resolving this problem is to differentiate the variables. Therefore, after differencing we will have $\Delta x_t \sim I(0)$ and $\Delta y_t \sim I(0)$, and the regression equation will be:

$$\Delta x_t = a_1 + a_2 \Delta y_t + \Delta \varepsilon_t \tag{4.33}$$

In this case the regression model gives the correct estimate of $\widehat{a_1}$ and $\widehat{a_2}$ parameters and the spurious regression problem has been resolved. It must be noted that Equation (4.33) only gives us the short run relationship between the variables. But as economist we are more interested in the long run relationship. In order to resolve this, the error correction model (ECM) will be very useful. Considering a linear combination of x_t and y_t, that is I(0), then x_t and y_t are cointegrated. Thus the regression Equation in (4.31) is no longer spurious (Dimitrios and Stephen, 2007: 309), and it also provides us with the linear combination:

$$\widehat{\varepsilon_t} = x_t - \hat{\alpha} - \hat{\beta} y_t \tag{4.34}$$

that connects x_t and y_t in the long run.

Thus if x_t and y_t are cointegrated, that is $\widehat{\varepsilon_t} \sim I(0)$, we can express the relationship between x_t and y_t with an ECM specification as

$$\Delta x_t = a_0 + \beta \Delta y_t - \pi \widehat{\varepsilon_{t-1}} + x_t \tag{4.35}$$

This will now include both long run and short run information. In the Equation (4.23) β is the impact multiplier (short run effect) that measures the immediate impact that a change in y_t will have on a change in x_t. On the other hand, π measures the feedback effect, or the adjustment effect. It shows how dis-equilibrium in the previous period will be corrected.

In this study, the cointegration test was conducted using the Johansen maximum likelihood test. Since we have more than two variables in the model, it is possible to have more than one cointegrating vector. This means that there might be several equilibrium relationships among the variables in the model. Conventionally, for n number of variables we can have only up to n-1 cointegrating vectors. By extending the single equation error correction model in Equation (4.31) to a multivariate equation, and assuming that we have three variables, Y_t, X_t, and V_t which can all be endogenous, we have

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \cdots + A_k Z_{t-k} + u_t \qquad (4.36)$$

This can be reformulated in a vector error correction model (VECM) as follows:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \cdots + \Gamma_{k-1} \Delta Z_{t-k-1} + \prod Z_{t-1} + u_t \qquad (4.37)$$

where $\Gamma_i = \ (I - A_1 - A_2 - \cdots - A_k)\ (i = 1, 2, \ldots, k-1)\ \prod = -(A_1 - A_2 - \cdots - A_k)$ (4.38).

Carefully examining a $3x3$ $\prod$ matrix, since the study assumed three variables in Z_t =(Y_t, X_t, V_t), the $\prod$ matrix contains information on the long run relationship. By decomposing $\prod = \alpha\beta'$ where α is the speed of adjustment to equilibrium coefficients and β' is the long run matrix of coefficients, the $\beta' Z_{t-1}$ term is therefore equivalent to the error correction term ($Y_{t-1} - \beta_0 - \beta_1 X_{t-1}$) in the single equation case, except that now $\beta' Z_{t-1}$ contains up to $n-1$ vector in a multivariate framework.

Assuming $k = 2$, so that we have only two lagged terms, the model is given below:

$$\begin{pmatrix} \Delta Y_t \\ \Delta X_t \\ \Delta V_t \end{pmatrix} = \Gamma_1 \begin{pmatrix} \Delta Y_{t-1} \\ \Delta X_{t-1} \\ \Delta V_{t-1} \end{pmatrix} + \prod \begin{pmatrix} \Delta Y_t \\ \Delta X_t \\ \Delta V_t \end{pmatrix} + e_t \qquad (4.39)$$

Alternatively, it can be expressed as:

$$\begin{pmatrix}\Delta Y_t\\ \Delta X_t\\ \Delta V_t\end{pmatrix} = \Gamma_1\begin{pmatrix}\Delta Y_{t-1}\\ \Delta X_{t-1}\\ \Delta V_{t-1}\end{pmatrix} + \begin{pmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\\ a_{31} & a_{32}\end{pmatrix}\begin{pmatrix}\beta_{11} & \beta_{21} & \beta_{31}\\ \beta_{12} & \beta_{22} & \beta_{23}\end{pmatrix}\begin{pmatrix}\Delta Y_t\\ \Delta X_t\\ \Delta V_t\end{pmatrix} + e_t \qquad (4.40)$$

Analysing only the error correction part of the first equation (i.e. ΔY_t on the left-hand side) gives

$$\prod_1 \Delta Z_{t-1} = ([a_{11}\beta_{11} + a_{12}\beta_{12}]\ [a_{11}\beta_{21} + a_{12}\beta_{22}][a_{11}\beta_{31} + a_{12}\beta_{32}])\begin{pmatrix}\Delta Y_t\\ \Delta X_t\\ \Delta V_t\end{pmatrix} \qquad (4.41)$$

where $\prod_1$ is the first row of the $\prod$ matrix.

Rewriting Equation (4.43) we have:

$$\prod_1 \Delta Z_{t-1} = a_{11}(\beta_{11}Y_{t-1} + \beta_{21}X_{t-1} + \beta_{31}V_{t-1}) + a_{12}(\beta_{12}Y_{t-1} + \beta_{22}X_{t-1} + \beta_{32}V_{t-1}) \qquad (4.42)$$

which shows that there are two cointegrating vectors with their respective speed of adjustment terms a_{11} and a_{12}.

The hypotheses are as follows:

H_0: no cointegration

H_1: cointegration exists

The Johansen maximum likelihood test involves two test statistics for testing the number of cointegrating relations. These are the trace statistic (λ_{trace}) and the Maximum Eigen value statistic (λ_{max}). According to Adamopoulos (2010) and Pradhan (2010), the trace is the likelihood ratio test statistic of the null hypothesis that there are at most r cointegrating vectors and is computed using the following formula:

$$\Lambda\ \text{trace}(r) = -T\sum_{i=r+1}^{n} In(1-\hat{\lambda}_l) \qquad (4.43)$$

$r = 0,1,2, \ldots\ldots, n-1$

$H0{:}\ r = 0, H1{:}\ r > 1;\ H0{:}\ r \le 1, H1{:}\ r > 1;\ H0{:}\ r \le 2, H1{:}\ r > 2$

where t=number of observations.

$\hat{\lambda}_l =$ the ith Eigen value.

According to Adamopoulos (2010) and Pradhan (2010), the maximum Eigen value test is the likelihood ratio test for the null hypothesis of r cointegrating vectors against the alternative r+1 cointegrating vectors and is computed using the following formula:

$$\Lambda \max(\mathrm{r}, \mathrm{r}+1) = -\mathrm{T}\, In(1 - \hat{\lambda}_{r+1}) \tag{4.44}$$

$\mathrm{r} = 0, 1, 2, \dots, \mathrm{n}-2, \mathrm{n}-1$

$\mathrm{H0}: \mathrm{r} = 0, \mathrm{H1}: \mathrm{r} = 1;\ \mathrm{H0}: \mathrm{r} = 1, \mathrm{H0}: \mathrm{r} = 2$

The Johansen cointegration test allows us to estimate cointegrating vectors between the non-stationary variables of the model using the maximum likelihood technique which tests for the cointegrating rank. Having established the presence of cointegration among the variables, we proceed by specifying the vector error correction model (VECM). Our primary interest is the error correction model for the variables used in order to capture their dynamic interaction. The ECM represents the change in one variable as a linear function of its past changes, changes of other variables and an error correction term. For a cointegration equation, the error correction term represents the deviation from equilibrium relationship.

Thus the ECM provides two alternative channels of interaction among the variables: short run causality through past changes in the variable, and long run causality through adjustment in equilibrium error. According to the Granger representation theorem, if two or more variables are cointegrated they can always be transformed into an error correction mechanism (ECM). A vector error correction model (VECM) is very useful in time series analysis since it investigates long run and short run properties of the system variables. The variables in their differentiated form reflect the short run dynamics of the model, while the long run relationship is incorporated into the estimation procedure by including the lagged cointegrating vector.

Considering three variables Y, X, and V, the VECM for variables is specified as follows:

$$\Delta Y_t = \alpha_1 + \delta_1 t + \vartheta_{11}\Delta Y_{t-1} + \cdots + \vartheta_{1p}\Delta Y_{t-p} + \gamma_{11}\Delta X_{t-1} + \cdots + \gamma_{1p}\Delta X_{t-p} + \beta_{11}\Delta V_{t-1} + \cdots + \beta_{1p}\Delta V_{t-p} + \varphi_1\epsilon_{t-1} + \varepsilon_{1t} \tag{4.45}$$

$$\Delta X_t = \alpha_2 + \delta_2 t + \vartheta_{21}\Delta Y_{t-1} + \cdots + \vartheta_{2p}\Delta Y_{t-p} + \gamma_{21}\Delta X_{t-1} + \cdots + \gamma_{2p}\Delta X_{t-p} + \beta_{21}\Delta V_{t-1} + \cdots + \beta_{2p}\Delta V_{t-p} + \varphi_2\epsilon_{t-1} + \varepsilon_{2t} \tag{4.46}$$

$$\Delta V_t = \alpha_3 + \delta_3 t + \vartheta_{31}\Delta Y_{t-1} + \cdots + \vartheta_{3p}\Delta Y_{t-p} + \gamma_{31}\Delta X_{t-1} + \cdots + \gamma_{3p}\Delta X_{t-p} + \beta_{31}\Delta V_{t-1} + \cdots + \beta_{3p}\Delta V_{t-p} + \varphi_3\epsilon_{t-1} + \varepsilon_{3t} \tag{4.47}$$

where p is the lag length, the error term is given as:

$$\epsilon_{t-1} = Y_{t-1} - \alpha - \beta X_{t-1} - \pi V_{t-1},$$

while φ is the coefficient of the error term.

4.2.5. Impulse Response Function and Variance Decomposition

In order to get additional insight into the causality between economic growth and energy consumption both at the aggregate and dis-aggregate levels, we analyse the impulse response and variance decomposition with the VECM framework. The impulse response function (IRF) traces the response of the endogenous variable to its own shocks and to shocks in every other endogenous variable. In other words, it is the path whereby the variables return to equilibrium after any shock in the system (William, 2000).

Since a VECM involves a number of variables, it is of interest to know the response of one variable to an impulse in another, that is, to ascertain how shock spreads over time. Variance decomposition is regarded as an alternative method to the IRF. The distinction between this method and the IRF is that variance decomposition gives information about the relative importance of each random variable in affecting the variation of the variables in the VAR (Sunde, 2013). This Variance decomposition (VDC) helps in examining the effect of the impulses on the explained variables. According to Abu-Bader and Abu-Qarn (2006) variance decomposition can provide an indication of Granger causality beyond the sample period.

4.3. Data Sources and Software

The study used annual time series data for the period 1980 to 2012 to investigate the relationship and direction of causality between energy consumption and economic growth in South Africa. The variables used in the model are: GDPGR- gross domestic product growth rate; PRYGR- gross value added of the primary sector (growth rate); SEYGR-gross value added of the secondary sector (growth rate); TEYGR- gross value added of the tertiary sector (growth rate); LABGR- labour (total employment growth rate); CAPGR- capital (gross fixed capital formation growth rate); ENYGR- total energy consumption growth rate; COLGR- coal consumption growth rate; ELCGR- electricity consumption growth rate; OILGR- oil consumption growth rate.

The data energy consumption both at aggregate and dis-aggregated level were obtained from BP Statistics, (2013) while that of Gross Domestic Product were obtained from the South African Reserve Bank (SARB, 2014). The energy consumption series are expressed in Million Tons of Oil Equivalent (MTOE), except crude oil which is measured in Million Tons and Electricity consumption which is measured in Billion Kilowatthours, while that of economic output is measured in Million Rands. A summary description of the data is provided in Table 4.2. The study used Eviews 9 software for the estimation of the models.

Table 4.2: Summary Description of Data and Sources

Variables	Description	Data Sources
Real GDP (GDPGR).	The study used real GDP growth rate at current prices. The GDP is the sum of gross value added by all resident producers in the economy plus product taxes minus subsidies.	Annual data on Real GDP between 1980 and 2012 was obtained from the South Africa Reserve Bank 2014 and measured in Million Rands.
Labour (LABGR)	The study used data on aggregate employment (growth rate) as a proxy for labour. Aggregate employment includes both private sector and public sector employment.	The data on aggregate employment was retrieved from the South Africa Reserve Bank 2014 and measured in Million Rands
Capital (CAPGR)	The study used growth rate of total gross fixed capital formation (investment) as a proxy for capital.	The data on gross fixed capital formation between 1980 and 2012 was sourced from the South Africa Reserve Bank 2014 and measured in Million Rands
Primary sector output (PRYGR)	The study used the growth rate of gross value added at basic prices of primary sector (GVA). Gross value added at basic prices is output valued at basic prices less intermediate consumption valued at purchasers' prices	The data on gross value added of the primary sector was sourced from the South African Reserve Bank online database 2014 and measured in Million Rands.
Secondary sector output (SEYGR).	The study used the growth rate of the gross value added at basic prices of the secondary sector. Gross value added at basic prices of secondary sector (GVA) was used in the study.	Annual data on gross value added of the secondary sector was obtained from the South African Reserve Bank online database 2014 and measured in Million Rands
Tertiary sector output (TEYGR)	Annual data on the gross value added (growth rate) at basic prices of tertiary sector (GVA) was used by the study.	The data on gross value added of the tertiary sector was obtained from the South African Reserve Bank online database 2014 and measured in Million Rands
Total primary energy consumption (ENYGR).	The study used the total primary energy consumption (natural logarithms) to capture the aggregate energy consumption. Total primary energy comprises commercially traded fuels including modern renewables used to generate electricity	Annual data on total primary energy consumption between 1980 and 2012 was obtained from the BP Statistical Review of World Energy 2013 and measured in Million Tons of Oil Equivalents.
Coal consumption (COLGR).	The study used commercial solid fuels only to capture the total coal consumption (natural logarithms). Commercial solid fuels include: bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal. It excludes coal converted to liquid or gaseous fuels, but includes coal consumed in transformation processes.	The data on coal consumption between 1980 and 2012 was obtained from the BP Statistical Review of World Energy 2013 and measured in Million Tons of Oil Equivalents.
Crude Oil consumption (OILGR).	Annual data on crude oil consumption (natural logarithms) was used in this study. Crude oil consumption used in the study includes: Inland demand, international aviation and marine bunkers and refinery fuel, and loss. Consumption of bio-gasoline (such as ethanol), biodiesel and derivatives of coal and natural gas are also included.	Annual data on crude oil consumption between 1980 and 2012 was obtained from the BP Statistical Review of World Energy 2013 and measured in m Million Tons.
Electricity consumption (ELCGR).	Annual data on the Total Electricity Consumption (natural logarithms) was used as a proxy for electricity consumption.	The data on total electricity net consumption was sourced from the International Energy Agency 2014 and measured in Billion Kilowatthours.

Natural gas consumption (GASGR)	The natural gas consumption values used in the study excludes natural gas converted to liquid fuels but includes derivatives of coal as well as natural gas consumed in Gas-to-Liquids transformation.	The data on natural gas consumption was obtained from the BP Statistical Review of World Energy 2013 and measured in Million Tons of Oil Equivalents.

4.4. Summary

This chapter focused on the methodologies, variables and the estimation techniques used for the estimation of the impact of energy consumption on economic growth in South Africa. The Augmented Dickey Fuller (ADF) tests and Phillip Perron (PP) tests tests were highlighted to test for the order of the integration of the variables. This was followed by discussions of the diagnostic and stability tests. The Johansen cointegration and vector error correction model (VECM) framework were presented as the estimation technique used in the study. This was followed by a discussion of the impulse response function (IRF) and the variance decomposition (VDC) analysis. Chapter five presents the empirical results and discussion of the quantitative analysis of the impact of energy demand on the South African economy.

CHAPTER 5

RESULTS AND DISCUSSION

This chapter presents and discusses the results of the quantitative analysis of the impact of energy consumption on economic growth. It thus accomplishes the major objectives that were discussed in Chapter one: (1) To examine and estimate the causal relationship between energy consumption as a whole and economic growth in South Africa; (2) To examine the impact of different energy components (coal, crude oil, natural gas and electricity) on the overall economic growth; and (3) To examine the impact of energy components on each of the primary, secondary and tertiary sectors of the economy. To facilitate the smooth presentation and discussion of results, the chapter is arranged under nine sections. Section one presents the results of the descriptive statistics. Section two shows the results of the unit root test. Section three provides the order of arrangement of the tests performed. Section four gives the result of the impact of aggregate energy consumption on economic growth. The impact of the energy structure on economic growth is presented in section five while that of the impact of energy structure on the sub sectors (primary, secondary and tertiary) of the economy are presented in sections six, seven and eight respectively. Finally, section nine provides a summary of the entire chapter.

5.1. Results of Descriptive Statistics

The study commenced its empirical analysis by first carrying out a preliminary examination of the data series so as to describe the basic features of the variables used in the study. The estimate of the various summary statistics such as mean, median, maximum, minimum, standard deviation, skewness, and kurtosis are presented in Table 5.1 below.

Table 5.1: Descriptive Statistics of the variables (Aggregate)

Main statistics	GDPGR	ENYGR	LABGR	CAPGR	PRYGR	SEYGR	TEYGR	COLGR	ELCGR	NAGGR	OILGR
Mean	9.506991	4.549273	5.912559	11.52615	11.80004	12.5317	13.4648	4.2723	5.070591	-0.28993	5.999131
Median	9.640043	4.605179	5.843834	11.57068	11.79813	12.45232	13.39873	2.298645	5.108204	-0.01536	6.063785
Maximum	11.00391	4.862908	6.235391	13.31973	11.87335	12.87772	14.01054	4.57368	5.395798	1.280934	6.357842
Minimum	7.698483	4.00915	5.686636	9.826661	11.68383	12.33848	13.03802	3.754199	4.448739	-1.60944	5.513429
Std Dev.	1.002594	0.214353	0.171919	1.116767	0.048029	0.181422	0.294388	0.187773	0.255952	1.102644	0.257305
Skewness	-0.24487	-0.48228	0.880468	0.096466	-0.58222	0.811458	0.463126	-0.57529	-0.63249	0.010328	-0.29168
Kurtosis	1.893991	2.623	2.347704	1.744899	2.916275	2.14166	1.930252	3.173766	2.592966	1.579759	1.778036
Jarque Bera	2.011754	1.474673	4.848776	2.217187	1.874057	4.634583	2.75317	1.861789	2.428011	2.774076	2.521058
Probability	0.365724	0.478386	0.088532	0.330023	0.39179	0.09854	0.252439	0.394201	0.297005	0.249814	0.283504
Sum	313.7307	152.126	195.1144	380.3628	389.4014	413.546	444.3385	140.9859	167.3259	-9.56757	197.9713
Sum Sq. Dev.	32.1662	1.47031	0.945765	39.9094	0.073816	1.053248	2.773259	1.128282	2.096361	38.90636	2.118595
Observations	33	33	33	33	33	33	33	33	33	33	33

Source: Estimation

Where GDPGR is the growth rate of GDP, ENYGR growth rate of aggregate energy consumption, LABGR is the growth rate of labour, CAPGR is the growth rate of capital, COLGR is the growth rate of coal consumption, ELCGR is the growth rate of electricity consumption, OILGR is the growth rate of oil consumption, NAGGR is the growth rate of natural gas consumption, PRYGR is the growth rate of primary sector output, SEYGR is the growth rate of secondary sector output and TEYGR is the growth rate of tertiary sector output.

Table 5.1 indicates that the mean observation for GDPGR, ENYGR, LABGR and CAPGR were 9.51, 4.55, 5.91 and 11.52 respectively while the median for the entire sample were 9.64, 4.61, 5.84 and 11.57 in that order. The mean and median can be used to determine the skewness of the set. A distribution is said to be symmetrical or has zero skewness if the mean and median are equal. From Table 5.1 we can see that the mean and median values for GDPGR, ENYGR, LABGR and CAPGR are almost equal. This implies that the distribution is symmetrical. This is also confirmed by the skewness values for all the variables which are close to zero. The Jarque Bera test of normality is an asymptotic test used based on the OLS residuals. It is a test of the joint hypothesis that skewness and kurtosis are 0 and 3 respectively (Gujarati 2004). Kurtosis measures the degree of flatness of a symmetry distribution compared with a normal distribution of the same variance. A more flat-topped distribution ($\pi < 0$) it is described as "platykurtic", a less flat-topped distribution ($\pi > 0$) as "leptokurtic" while that of an equally flat-topped distribution ($\pi = 0$) is referred to as "mesokurtic". Also, we can see that the mean and median values for PRYGR, SEYGR, TEYGR, ELCGR and OILGR are almost equal. This implies that the distribution is symmetrical. This is also confirmed by the skewness values for all the variables which are close to zero. The JB test follows the chi-square distribution with 2 degrees of freedom with the null hypothesis that the residuals are normally distributed. If the JB statistic is greater than the value of the chi-square of 5.99 at 5 percent level, we reject the null hypothesis that the residuals are normally distributed. The result of the JB test in Table 5.1 shows that all the variables used in the model are normally distributed since they are all less than the chi-square critical value at 5 percent significance level.

5.2. Results of Unit Root Test

Empirical procedure in time series regression analysis requires that we test for the stationarity of the variables and the order of integration. This will prevent spurious regression results. If the variables are found to be non-stationary, successive differencing will be applied so that the series become stationary. This study employed the Augmented Dickey Fuller (ADF) and Philip Peron (PP) to test stationarity of the variables. The tests were conducted with intercept only, intercept and trend and none.

The study applied the Donaldo, Jenjinson and Sosvilla-Rivero 1990 (see Dimitrios and Stephen, 2007) procedure to choose the appropriate model. For example, for GDP the model with constant and trend showed that the inclusion of trend was not appropriate because the coefficient was not statistically significant. We therefore use the model that includes only constant to test for the presence of unit root in the variable. Since the p-value of the constant term is significant, the model is therefore used to check the presence of unit in the series. The same procedure is applied to other series and the results are presented in Appendix A.

5.2.1. Augmented Dickey Fuller (ADF) Test Result

The ADF test with and without time trend indicates that the variables GDPGR, ENYGR, LABGR, CAPGR, COLGR, NAGGR, OILGR, PRYGR, SEYGR and TEYGR exhibit a unit root problem which means that they are not stationary at levels. This is because their estimated test statistic values are not more negative than their critical values at the 5 percent level. For stationary of the series to be accomplished, the test for the series is carried out at first difference. The result of the test at first difference shows that all the series are stationary, that is, they are integrated of order one I(1) (see Appendix A-1)

5.2.2. Philip Peron (PP) Test Result

The PP test result shown in Appendix A-2 indicates that the variables GDPGR, ENYGR, LABGR, CAPGR, COLGR, NAGGR, OILGR, PRYGR, SEYGR and TEYGR exhibit a unit root problem which means that they are not stationary at levels. This is because their estimated test statistic values are not more negative than their critical values at the 5 percent level. . We therefore fail to reject the null hypothesis that the series are non-stationary. For stationary of the series to be accomplished, the test for the series is carried out at first difference. The result of the test at first difference shows that all the series are stationary, that is, they are integrated of order one I(1) (see Appendix A-1).

5.3. Order of Estimation

The sequential arrangement of the tests performed to achieve the first objective (to examine and estimate the causal relationship between energy consumption as a whole and economic growth in South Africa), the second objective (to examine the impact of different energy components (coal, crude oil, natural gas and electricity) on the overall economic growth) and the third objective (to examine the impact of energy components on each of the primary, secondary and tertiary sectors of the economy) is given below: (1) The Johansen Cointegration test is performed to determine if there exists long run equilibrium relationship among the variables in the models. (2) After a long run relationship has been established by the cointegration test, a vector error correction estimate is performed to distinguish the short run and long run causal relationship among the variables in the models and also to determine the direction of causality. (3) A stability test is performed to check for the stability of the residuals. (4) A diagnostic test is employed to test for the reliability of the vector error correction model. (5) The impulse response function traces the effect of one standard deviation shock to one innovation on the current and future values of the endogenous variables. (6) Variance decomposition shows the fraction of the forecast error for each variable that is attributed to its own innovation and innovations of other variables in the system.

5.4. Results and Discussion of Analysis of the Aggregate Energy Consumption Model

This section examines the impact of energy composition (coal, electricity and oil) consumption on economic growth. Natural gas was also used for the estimation but since its inclusion was not yielding the desired result, it was removed and the model was re-estimated. The results of the cointegration are presented in section 5.4.1, while the vector error correction model result and speed of adjustment are presented in sections 5.4.2 and 5.4.3 respectively, followed by the diagnostic, stability, impulse response and variance decomposition tests which are presented in sections 5.4.4, 5.4.5, 5.4.6, and 5.4.7 respectively.

5.4.1. Cointegration Test Result for the Aggregate Energy Consumption Model

According to Engle and Granger (1987), if two time series with the same order of integration are cointegrated, the vector error correction model (VECM) can better capture their joint dynamics than VAR. Due to this consideration, we should examine whether there are cointegration relationships among the variables. Having established the order of the integration of the variables, the next step is to determine the number of lag length that will be appropriate for the estimation. To select the lag order of the VAR, the information criteria approach is applied. For this study, the AIC was used to determine the lag length as it generate more reliable estimate. The appropriate model is chosen by applying the general to specific method of lag length selection for the best model identification. Recall that the lower the in AIC value the better the model. The AIC determined the order of the VAR as 1 annual periods (see Appendix B-1).

The result of the Maximum Eigenvalue statistics and trace statistics of Johansen's cointegration test for the aggregate energy consumption model using assumption three of ‘no intercept no trend in cointegration equation’ is reported in Appendix C-1. Other deterministic assumptions were explored but did not yield interpretable results. The null hypothesis states that there is no cointegration as opposed to the alternative hypothesis which states that cointegration is present. The decision rule is that we reject the null hypothesis that there is no cointegration if at least one of the maximum eigenvalue or trace statistics is greater than the critical value at the 5 percent level of significance. From the cointegration test result presented in Appendix C-1, the maximum eigenvalue statistics and the trace statistics shows that there is one cointegrating equation in the model. The null hypothesis of no cointegrating vector is rejected since the trace (test) and maximum eigenvalue statistic of 57.45095 and 27.85797 is greater than the 5 percent critical value of approximately 47.85613 and 27.58434 respectively.

Therefore it can be concluded that there is one significant long run equilibrium relationship between the dependent variable economic growth (GDPGR) and the independent variables of total energy consumption (ENYGR), capital (CAPGR) and labour (LABGR) using the trace test and the maximum eigenvalue statistic. It must be noted however that the cointegration test only indicates the presence of long run equilibrium between the variables, that is, there is a causal relationship between the dependent variable GDPGR and the independent variables ENYGR, LABGR, and CAPGR but does not indicate the direction of causality.

According to Bahmani-Oskooee and Alse (1993), if the variables are cointegrated, then the standard Granger causality test result will be invalid. In this case, the VECM should be appropriate for examining the direction of causality among the variables. Also since the variables can either have a long or short run effect, a vector error correction model was used to disaggregate this effect and also to examine the direction of causality.

5.4.2. The Vector Error Correction Model Result for the Aggregate Energy Consumption Model

Since the presence of a long run cointegrating relationship has been established using the Johansen test, the direction of causality is estimated within the VECM framework. The advantage of using the VECM to test for causality is that it allows testing for short run causality through the lagged differenced explanatory variables and also tests for the long run causality through the lagged error correction term (ECM_{t-1}). This enables us to establish the effects of energy consumption on economic growth. The inclusion of a dummy is to account for the electricity crisis experienced in 2007 since the initial estimation did not yield a good result. A summary of the long run parameters in the aggregate energy model is presented in Table 5.2 below.

Table 5.2: Results of the Long Run Cointegration Equation for the Aggregate Energy Consumption Model

Variables	Coefficient	Standard Error	t-statistic
GDPGR	1.00000	-	-
CONSTANT	-18.0018	-	-
ENYGR	75.12750	25.3768	2.96048*
LABGR	0.045851	0.02086	2.19797**
CAPGR	28.72206	8.30374	3.45893*
Dummy	-8.72486	3.19383	-2.73179*
'*', '**' means significant at the 1 & 5 percent level of significance respectively			

Source: Estimation

The long run impact of the explanatory variables on economic growth (GDPGR) as shown in Table 5.2 indicates that all the explanatory variables (ENYGR, LABGR and CAPGR) have a positive and significant long run relationship with GDPGR since they have an absolute t-value greater than 2.

A one percent increase in energy consumption (ENYGR) causes an increase in economic growth (GDPGR) by 75.13 percent. The positive and significant relationship is in line with *a priori* expectation. Theoretically, an increase in energy consumption is expected to lead to an increase in economic growth. However, the magnitude of the change is counter intuition and as such should be treated with caution. This may be as a result of the small sample size used in the estimation. South Africa is an energy intensive economy, so the availability of energy resources is critical to economic growth.

Labour (LABGR) and capital (CAPGR) also exhibited a positive relationship with economic growth. A unit increase in labour and capital will lead to 0.05 and 28.72 unit increase in economic growth. This is also in consonance with *a priori* expectation. Labour and capital investment are major factor input in production, therefore they are expected to cause an increase in economic growth ceteris paribus.

5.4.3. Speed of Adjustment and Short Run Terms for the Aggregate Energy Model

The error correction term coefficients indicate the speed of adjustment towards the long run equilibrium after a shock in the system. It shows how quickly variables adjust to the equilibrium and it must be significant with a negative sign. The significance of the error correction term also determines the long run causality running from all independent variables towards the dependent variable. Results from the error correction model are presented in Table 5.3 below:

Table 5.3: Speed of Adjustment for the Aggregate Energy Consumption Model

Variable	Coefficient	Standard Error	t-statistic
GDPGR	-0.014	0.09639	-0.14524
ENYGR	-0.00646	0.00175	-3.68991*
LABGR	0.737357	0.41806	1.76375
CAPGR	-0.0217	0.00724	-2.99656*
DUMMY	0.035263	0.01724	2.04538**
*, ** Significant at the 1 and 5 percent level of significance respectively			

Source: Estimation

As can be seen in Table 5.3; the coefficient of the error correction term of energy consumption (ENYGR) and capital (CAPGR) possesses the correct sign but not statistically significant at the 1 percent level with the speed of adjustment back to equilibrium of 0.6 percent and 2.2 percent respectively. This result implies that in the short run, energy consumption will converge back to equilibrium by 0.6 percent and 2.2 percent of the past year’s deviation from equilibrium. This confirms the stability of the system, though the speed of adjustment for energy consumption and capital investment is slow as it will take up to 167 years and 45 years to fully restore back to equilibrium respectively. The result also indicates that there is a long run causality running from energy consumption (GDPGR), labour (LABGR) and capital (CAPGR) to energy consumption

(ENYGR) and also from economic growth (GDPGR), energy consumption (ENYGR) and labour (LABGR) to capital (CAPGR). However, in the short run, there exists unidirectional causal relationship between economic growth (GDPGR) and capital (CAPGR), energy consumption (ENYGR) and economic growth (GDPGR) and also between capital (CAPGR) and energy consumption (GDPGR).

In summary, the results show that there exists a long run bidirectional causal relationship from between energy consumption (ENYGR) and capital (CAPGR) and long-run unidirectional causal relationship from economic growth (GDPGR) and labour (LABGR) to energy consumption (ENYGR). The long run unidirectional causality from economic growth to energy consumption is similar to the findings of Herrerias et al., (2013) and Onuonga (2012) in the case of China and Kenya respectively. This long run unidirectional causality from economic growth to energy consumption implies that economic growth tends to drive energy consumption in the long run and implementation of energy conservation policy may not hamper economic growth in the long run. The bidirectional causal relationship between energy consumption and capital implies that they are compliments; increase in energy consumption drives investment (especially in the electricity sector) upward, vice versa.

5.4.4. Result of Diagnostic Test for the Aggregate Energy Consumption Model

The diagnostic tests for the short-run estimation to examine the reliability of the result of the error correction model are shown in Table 5.4. From the table we fail to reject the null hypothesis of normality since the p-value (0.71895) of the Jarque Bera test statistics is greater than 5 percent. The probability value of the LM Version (0.0892) and F Version (0.2214) of the Breusch-Godfrey Serial Correlation LM test shows that there is no problem of serial correlation in the model; therefore we fail to reject the null hypothesis of no serial correlation in the model. The study also found no presence of heteroscedasticity since the p-value of both the LM test and the F-Version is statistically not significant at the 5 percent level (See Table 5.4).

Table 5.4: Diagnostic Test for the Aggregate Energy Consumption Model

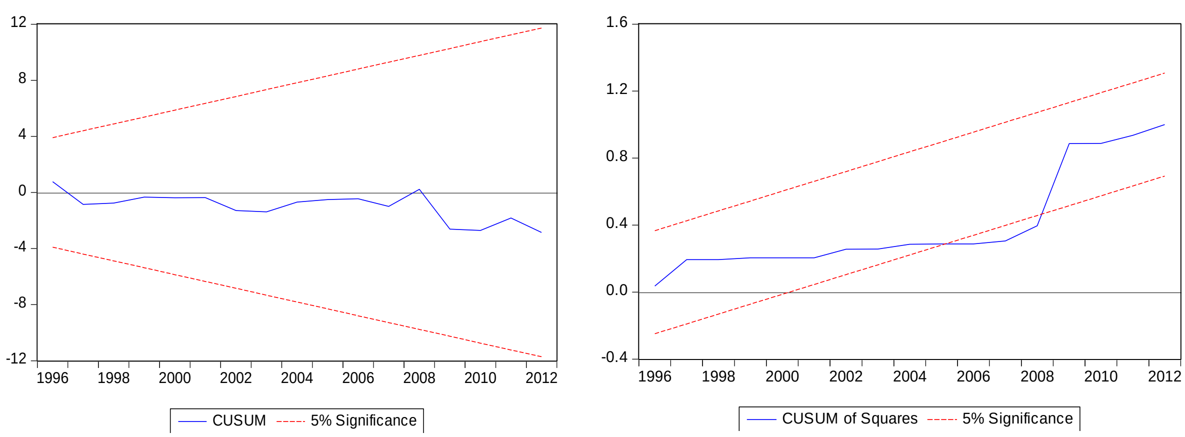
Test statistics	LM Version	F Version
A: serial correlation	CHSQ(16)=24.01442 [0.0892]	F(2, 16)= 1.718858 [0.2214]
B: Normality	JB= 0.659923* [0.71895]	Not applicable
C: Heteroscedasticity	CHSQ(10)=14.49319 [0.1517]	F(10, 20)= 1.756026 [0.1362]
Breusch-Godfrey Serial Correlation LM Test *Jarque-Bera test Statistics Heteroskedasticity Test: Breusch-Pagan-Godfrey Note: Probability value in parenthesis [ ]		

Source: Estimation

5.4.5. Stability Test for the Aggregate Energy Consumption Model

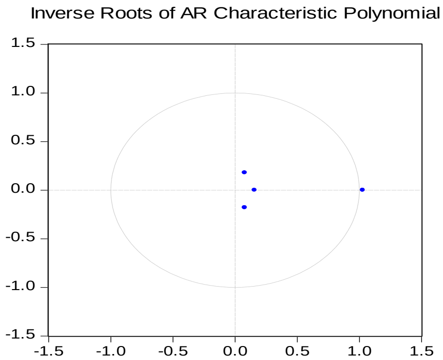
The study employed the cumulative sum of recursive residuals (CUSUM) and CUSUMQ test to check the stability of the residuals, that is, to check if the residuals persistently stray outside the error bounds -2 and +2. The result of the stability test shown in Figure 5.1a and 5.1b below indicate that the model passes the stability test; both tests reveal that the estimate and the variance were stable since the residuals and the squared residuals fell within the 5 percent critical boundaries. Thus we fail to reject the null hypothesis. The result of the AR Root in Figure 5.1c shows that the VAR model satisfies the stability condition since all roots have a modulus less than one and lie within the unit circle.

Figure 5.1: Stability Plots for Aggregate Energy Consumption Model



(a) (b)

Plot of Cumulative Sum of Recursive Residuals . Plot of Cumulative Sum of Squares Recursive Residuals for aggregate energy model



(b) Plot of Inverse AR Root

5.4.6. Impulse Response Function for the Aggregate Energy Consumption Model

In order to analyse the impact of energy consumption on economic growth, the study employed two analytical techniques, namely impulse response function and variance decomposition. The impulse response function shows the effect of shocks on the adjustment path of the variables. That is, it traces the effect of one standard deviation shock to one of the innovations on the current and future values of the endogenous variables. For the four variables in the model we want to see how far into the future, that is, for the next ten years, one variable will react to a change in the other. For the purpose of this study we restrict our analysis to the impulse of all the variables to economic growth (GDPGR). The result of the IRF as shown in Appendix D-1 indicates that economic growth responds positively to its own one standard deviation shocks. In the case of energy consumption (ENYGR), a unit shock in the system will result in a positive value of economic for the first two years after which it will converge back towards equilibrium i.e. close to zero but will continue to be positive in the future. As indicated in Appendix D-1, a one standard deviation shock to labour (LABGR) will affect economic positively for the first three and half years, after which the effect becomes negative up to the tenth year. Also a one standard deviation shock to capital (CAPGR) will only have a marginal positive effect on economic growth for the first two and half years, after which it becomes negative.

5.4.7. Variance Decomposition for the Aggregate Energy Consumption Model

The variance decomposition shows the fraction of the forecast error variable for each variable that is attributed to its own innovations and the innovations of other variables in the system. The result of the variance decomposition indicates the economic growth (GDPGR) accounts for 100 percent of its own forecast error variance in the first year with no other variable explaining it. This however decreased to 79.76 percent in the fifth year and later increase to 84.00 percent in the tenth year. Apart from its past values, energy consumption (ENYGR), labour (LABGR), and capital (CAPGR) also accounted for variation in economic growth. For example, in the fifth year, energy consumption accounts for 12.20 percent of the forecast error variance in economic growth while the share of labour and capital stood at 1.16 percent and 2.52 percent respectively. But in the next five year period energy consumption and capital account for a percentage of about 7.92 percent and 1.90 percent respectively while labour accounts for about 1.48 percent (See Appendix E-1). This result implies that labour is a major variable that influences economic growth in South Africa.

5.5. Results and Discussion of Analysis of the Disaggregated Energy Consumption Model

This section examines the impact of the energy composition (coal, electricity and oil) consumption on economic growth. Natural gas was also used for the estimation but since its inclusion was not yielding the desired result, it was removed and the model was re-estimated. The results of the cointegration are presented in section 5.5.1; vector error correction model and speed of adjustment are presented in sections 5.5.2 and 5.5.3 respectively; sections 5.5.4 and 5.5.5 report the results of the diagnostic and stability test, respectively, while the impulse response and variance decomposition tests are presented in section 5.5.6, and 5.5.7 in that order.

5.5.1. Cointegration Test Result for the Disaggregated Energy Consumption Model

The test for cointegration is preceded by the selection of the lag value of the multivariate model. The maximum lag length was determined by the application of the AIC and SBC as shown in Appendix B-2. However, since the study is interested in obtaining the best feasible outcome, the criterion is selected based on theoretical implication and *a priori* information on the relationship in question. The criterion that produces the minimum information is conventionally accepted as the most suitable. Lag 1 was selected based on the AIC.

The result of the Johansen-Juselius cointegration test for the disaggregated energy consumption model is presented in the Appendix C-2. The result shows that the maximum likelihood statistics (λ_{max}) which indicate there is one cointegrating equation in the model since we cannot reject the null hypothesis of "at most 1" cointegrating equation at the 5 percent level of significance. The trace statistic (λ_{trace}) on the other hand, indicates the presence of two cointegrating equations since the null hypothesis of "at most 2" cointegrating equation cannot be rejected at the 5 percent level of significance. In situations where the trace test and the maximum eigenvalue test indicate conflicting results, Johansen and Juselius (1990) advises the examination of the cointegrating vector and base the decision on the interpretability of the cointegrating relations (Mazenza, 2012). Batchelor (2000) on the other hand suggests that, in the presence of two cointegrating equations, there is a need for normalization of the cointegrating coefficients. The normalization process yields one cointegration equation and one cointegration vector. The Johansen and Juselius approach is adopted in the study.

5.5.2. Vector Error Correction Model Result for the Disaggregated Energy Consumption Model

Since the presence of long run relationship has been established using the Johansen test, we proceed to estimate the vector error correction model in order to distinguish between the long run and short run relationships in the dis-aggregated energy consumption model. The results of the long run relationship between economic output (GDPGR) and energy components are presented in Table 5.5.

Table 5.5: Results of Long Run Cointegration Equation for the Disaggregated Energy Consumption Model

Variables	Coefficient	Standard error	t-statistic
GDPGR	1.000000	-	-
CONSTANT	-3.591510	-	-
LABGR	0.091956	0.08670	1.06060
CAPGR	-0.29069	0.05560	-5.22849*
COLGR	-0.4802	0.12304	-3.90277*
ELCGR	0.675210	0.16928	3.98883*
OILGR	1.277355	0.16001	7.98310*
DUMMY	3.166372	1.21252	2.61139*
*Significant at the 1 percent level of significance			

Source: Estimation

The long run coefficient in Table 5.5 reveals the significant positive effect of electricity consumption (ELCGR) and oil consumption (OILGR) on economic growth (GDPGR). It is noted that a 1 percent increase in electricity and oil consumption will stimulate economic growth by 0.68 and 1.28 percent respectively. This is in line with *a priori* expectation as South Africa is an energy intensive economy. The coefficient of labour is also positive but statistically insignificant. This may be ascribed to the fact that South African economy is more or less capital intensive in nature. Frost and Sullivan (2011) stated that energy intensive industries tend to be more capital intensive. On the other hand there exists a negative relationship between capital and coal consumption on economic growth. It is noted that in the long run, a 1 percent increase in capital and coal consumption will result in a decline in economic growth by 0.29 and 0.48 percent respectively. This is contrary to expectation. The negative impact of coal on economic growth may be ascribed to the prolonged strike in the mining sector which is believed to have contributed to a decline in economic growth. The strike often disrupt production thereby depriving households of wage income and retailers of customers, damaging export, and ultimately compromising investment and employment (SARB, 2014). The significance of the variable implies that all the independent variables are important factors of production in South Africa.

5.5.3. Speed of Adjustment and Short Run Terms for the Disaggregated Energy Consumption Model

The error correction term coefficients indicate the speed of adjustment towards the long run equilibrium after a shock in the system. The sign of the error correction term is expected to be negative and significant. The significance of the error correction term also determines the long run causality running from all independent variables towards the dependent variable. The results from the error correction model are presented in Table 5.6 below.

Table 5.6: Speed of Adjustment for the Disaggregated Energy Consumption Model

Variables	Coefficient	Standard error	t-statistic
GDPGR	-0.25407	0.14305	-1.77600***
LABGR	0.057602	0.26858	0.21447
CAPGR	0.623199	0.44236	1.40881
COLGR	0.196900	0.31212	0.63084
ELCGR	-0.52396	0.23623	-2.21797**
OILGR	-0.93087	0.18230	-5.10631*
DUMMY	-0.00789	0.02236	-0.35311
*, **, *** Significant at the 1, 5 and 10 percent level of significance respectively			

Source: Estimation

The coefficient of the error correction term of economic growth (GDPGR), electricity consumption (ELCGR) and oil consumption (OILGR) indicates the correct sign and are statistically significant at the 10 percent, 5 percent and 1 percent significance level respectively. The coefficients of the error correction terms (0.25, 0.52 and 0.93) imply that in the occurrence of any misalignment in the equilibrium level of economic growth, electricity consumption and oil consumption, all the explanatory variables in the VECM will act together to restore long run equilibrium. These coefficients suggests that any deviation in the economic growth model, electricity consumption model, and oil consumption model will be corrected by 25, 52 and 93 percent respectively in the following year. This shows that the system is stable and it will take up to 4, 1.92 and 1.08 years for economic growth, electricity consumption and oil consumption to restore back to equilibrium. This significance of the estimate means that (1). labour, capital, coal consumption, electricity consumption and oil consumption granger cause economic growth in the long run. (2). There is a long run causal relationship running from economic growth, labour, capital, coal consumption and oil consumption to electricity consumption. (3). There is also a long run causal relationship from economic growth, labour, capital, coal consumption, electricity consumption to oil consumption.

In summary, the result revealed that there is a long run bidirectional causal relationship between economic growth and electricity consumption, economic growth and oil consumption, as well as between electricity consumption and oil consumption. The bidirectional relationship implies that these variables are compliments as they tend to drive one another. The result further revealed that there is a unidirectional causal relationship running from labour, capital and coal consumption to economic growth. This implies that labour, capital and coal consumption have great influence on economic growth and that an increase in labour, capital and coal consumption tends to drive economic growth upward. The unidirectional causality from coal consumption to economic growth is contrary to findings of Bildirici and Barkitas (2014). Their findings revealed absence of causality between coal consumption and economic growth in the case of South Africa.

The long run bidirectional relationship between electricity consumption and economic growth validates the findings of Odhiambo (2009) who employed error correction mechanism to investigate the relationship between electricity consumption and economic growth in South Africa. His result revealed a bidirectional causal relationship between electricity consumption and economic growth in the case of South Africa. The long run bidirectional causal relationship between oil consumption and economic growth is also similar to the findings of Bildirici and Barkitas (2014) in the case of South Africa. The policy implication of these is that, there should be increased investment in terms of electricity generating capacity in order to cope with the ever increasing electricity demand as well as oil consumption exerted by the country's economic growth and continuous industrialization.

5.5.4. Short Run Causality Tests for the Disaggregated Energy Consumption Model

The result as presented in Appendix F-2 indicates that there exists short run unidirectional causality from oil consumption to economic growth. The result of causality from oil consumption to economic growth means that in the short run, energy, particularly oil consumption acts as an engine of economic growth. The result further revealed that there is a short run causality running from oil consumption to capital and electricity consumption, coal consumption to oil consumption (see Appendix F-2). Effort should be made to increase oil supply though it is highly capital intensive.

5.5.5. Diagnostic Test for the Disaggregated Energy Consumption Model

The stability and reliability of the model is examined with the application of the test for serial correlation, normality, heteroscedasticity, cumulative sums (CUSUM) and cumulative sums of squares (CUSUMQ). These diagnostic statistics are presented in Table 5.7.

Table 5.7: Diagnostic Test for the Disaggregated Energy Consumption Model

Test statistics	LM Version	F Version
A: serial correlation	CHSQ(2)=4.482530 [0.1063]	F(2, 19)= -1.668819 [0.2149]
B: Normality	JB= 0.559729* [0.755886]	Not applicable
C: Heteroscedasticity	CHSQ(14)=15.49112 [0.3454]	F(14, 15)= 1.143964 [0.3983]
Breusch-Godfrey Serial Correlation LM Test Jarque-Bera test Statistics (*) Heteroscedasticity Test: Breusch-Pagan-Godfrey Note: Probability value in parenthesis [ ]		

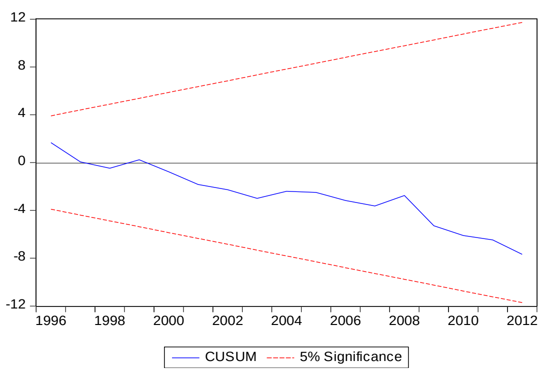
Source: Estimation

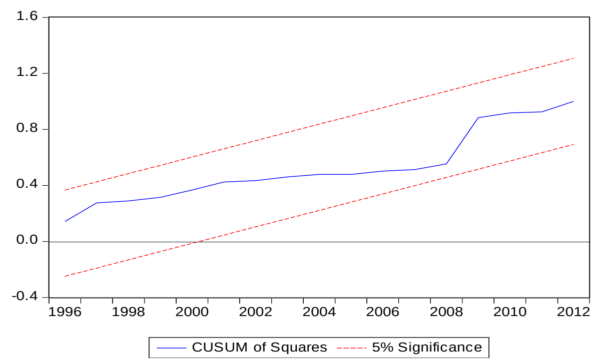
The study shows the absence of serial correlation since the p-value of the Lagrange Multiplier LM (0.1063) and F-version (0.2149) was statistically insignificant at 5 percent. We therefore fail to reject the null hypothesis that there is no serial correlation in the model. The normality test based on Jarque-Bera test statistics with p-value of 0.7559 indicates that the errors were normally distributed. The study also found no presence of heteroscedasticity since the p-value of both the LM test and the F-Version is statistically not significant at the 5 percent level (see Table 5.7).

5.5.6. Stability Test Result for Disaggregated Energy Consumption Model

The test for stability of the model using the CUSUM determines the methodical arrangement of the estimates (Bosco, 2014). The decision rule is that if the CUSUM plot lies within the critical boundaries, we fail to reject the null hypothesis which states that the coefficients are stable, the converse is true. On the other hand the CUSUMQ determines the stability of the variance (Bosco, 2014). As shown in Figures 5.2a and 5.2b, both tests reveal that the estimate and the variance were stable, since the residuals and the squared residuals fell within the 5 percent critical boundaries. Thus we fail to reject the null hypothesis. The result of the Inverse AR Root shown Figure 5.2c reveals that the VAR model satisfies the stability condition since all roots have a modulus less than one and lie within the unit circle.

Figure 5.2: Stability Plots for the Disaggregated Energy Consumption Model



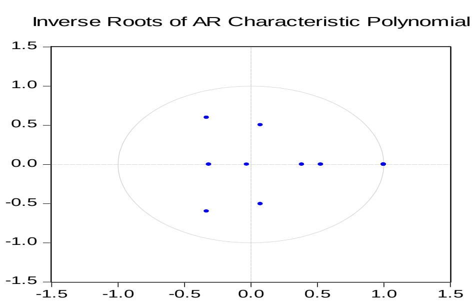


(a)

(b)

Figure 5.2: Plot of Cumulative Sum of Recursive Residuals. energy structure model

Figure 5.2: Plot of Cumulative Sum of Squares of Recursive Residuals for



(c) Plot of Inverse AR Root

5.5.7. Impulse Response Function Result for the Disaggregated Energy Consumption Model

The direction of causality can be determined via the VEC framework; however, the importance of the causal impact is also worthy of note. In order to assess how a shock to dependent variable (GDPGR) affects the independent variables (coal, electricity and oil consumption) and how long the effect lasts, the impulse response function and the variance decomposition were employed. The impulse response function tracks the impact of any variable on other variables in the system making it essential for our analysis. For the six variables in the model, we want to see how far into the future, that is, for the next ten years, one variable will react to a change in the other.

The result presented in Appendix D-2 indicates that economic (GDPGR) responds positively to a unit shock in itself. The result also indicates that for the first two and half years a unit shock in labour (LABGR) and electricity consumption (ELCGR) will be neutral, after which it will declines continuously for the next ten years. This implies that labour and electricity are major determinant of output in South Africa. On the other hand a unit shock to coal consumption (COLGR) and oil consumption (OILGR) will result in a negative value of economic growth (GDPGR) for the entire period. The impact of coal on output (GDPGR) seems to be larger than that of labour, electricity consumption and oil consumption (See Appendix D-2).

5.5.8. Variance Decomposition Result for the Disaggregated Energy Consumption Model

The result of the variance decomposition of the energy structure model is presented in Appendix E-2. The result indicates that own shock is the major source of variation in the model. Variation in economic growth (GDPGR) was explained by past growth, which accounts for 100 percent of its own forecast error variance in the first year. This, however decreased to 84.95 percent and 83.68 percent in the fifth and tenth years respectively. Apart from its past values, labour (LABGR), capital (CAPGR), coal consumption (COLGR), electricity consumption (ELCGR) and oil consumption (OILGR) also account for variation in economic growth. Unlike past growth, the other variables performed weakly in the short run as we can see that in the third year, labour, capital, coal consumption, electricity consumption, and oil consumption only accounted for 0.30 percent, 2.37 percent, 0.56 percent, 9.82 percent and 1.18 percent variation of the fluctuation in economic growth respectively, but when contribution to variation in economic growth became prominent as analysis enters the threshold of the long run and became constant thereafter. For example, electricity consumption became constant at 11 percent.

5.6. Results and Discussion of Analysis of the Primary Sector Energy Consumption Model

This section examines the impact of the energy composition (coal, electricity and oil) consumption on the primary sector economic output (PRYGR). Natural gas was also used for the estimation but since its inclusion was not yielding the desired result, it was removed and the model was re-estimated. The results of the cointegration test are presented in section 5.6.1, followed by the vector error correction model and speed of adjustment result in sections 5.6.2 and 5.6.3 respectively. Sections 5.6.4 and 5.6.5 reports the results of the diagnostic and stability test, while the impulse response function and variance decomposition tests results are presented in sections 5.6.6, and 5.6.7 in that order.

5.6.1. Cointegration Test Result for the Primary Sector Energy Consumption Model

In order to test for the presence of long run relationship between PRYGR this is the primary sector output and the various energy components (COLGR, ELCGR, and OILGR) together with labour (LABGR) and capital (CAPGR), the Johansen test of cointegration is applied and the result is presented in Appendix C-3. The Maximum eigenvalue statistic indicates that there exist two cointegrating vectors since we fail to reject the null hypothesis of “at most 2” cointegrating equations at 5 percent significance level. The trace statistic indicates that there exist three cointegrating equations. This indicates that there exists a long run equilibrium relationship among the variables. However, since the maximum eigenvalue and the trace statistic generated conflicting results, the procedure adopted in section 5.5.1 is applied. Lag length of 1 was selected based of the AIC (See Appendix B-3).

5.6.2. Vector Error Correction Model Result for the Primary Sector Energy Consumption Model

Having established the presence of cointegration among the variables, a VECM with one cointegrating equation and one lag was estimated (see Table 5.8). The VECM allows the long run behaviour of the endogenous variables to converge to their long run equilibrium relationship while allowing a wide range of short run dynamics. A dummy variable was introduced to account for the shock (labour strike) in the primary sector comprising the agricultural and mining sectors.

Table 5.8: Result of Long Run Cointegration Equation of the Primary sector Energy Consumption Model

Variables	Coefficient	Standard error	t-statistic
PRYGR	1.000000	-	-
CONSTANT	-5.904168	-	-
LABGR	0.401688	0.18597	2.15999**
CAPGR	-0.28011	0.11855	-2.36280**
COLGR	-1.1503	0.26824	-4.28832*
ELCGR	1.076084	0.36752	2.92795*
OILGR	2.342930	0.34946	6.70439*
DUMMY	11.12519	2.59364	4.28942
*, **, *** means significant at the 1, 5 and 10 percent levels of significance respectively			

Source: Estimation

The long run coefficient reported in Table 5.8 indicates that there exists a positive relationship between labour, electricity consumption, oil consumption and primary sector output in the long run. The results as presented above reveal that a 1 percent increase in labour, electricity consumption and oil consumption will stimulate growth in the primary sector by 0.40, 1.08 and 2.34 percent respectively.

On the other hand there is a negative relationship between capital, coal consumption and primary sector output. This means that a 1 percent increase in capital and coal consumption will lead to a decline in the primary sector output. The significance of the parameters indicates that all the variables are important factor inputs in the primary sector.

5.6.3 Speed of Adjustment and Short Run Terms for the Primary Sector Energy Consumption Model

The error correction term coefficients indicate the speed of adjustment towards the long run equilibrium after a shock in the system. It shows how quickly variables adjust to the equilibrium and it must be significant with a negative sign. The significance of the error correction term also determines the long run causality running from all independent variables towards the dependent variable. Results from the error correction model are presented in Table 5.9 below.

Table 5.9: Speed of Adjustment for the Primary Sector Energy Consumption Model

Variables	Coefficient	Standard error	t-statistic
PRYGR	-0.32946	0.19500	-1.68955
LABGR	-0.02859	0.15171	-0.18844
CAPGR	0.174949	0.26808	0.65259
COLGR	0.149386	0.17549	0.85126
ELCGR	-0.26545	0.13627	-1.94794**
OILGR	-0.41887	0.12115	-3.45751*
DUMMY	-0.01304	0.01178	-1.10707
*, ** means significant at the 1 and 5 percent levels of significance respectively			

Source: Estimation

The result shown in Table 5.9 indicates that electricity consumption and oil consumption possess the correct sign and are highly significant at the 5 percent and 1 percent level significance respectively, with the speed of adjustment back to equilibrium of 0.27 percent and 0.42 percent in that order. This implies that in the advent of a shock in the system in the short run, electricity consumption and oil consumption will converge back to equilibrium by 0.74 percent and 0.04 percent of the past year’s deviation from equilibrium. The significance of the error correction term indicate that there exists a long run causal relationship running from (1) primary sector output, labour, capital, coal consumption and oil consumption to electricity consumption; (2) primary sector output, labour, capital, coal consumption and electricity consumption to oil consumption.

In summary, there exists a bidirectional long run causal relationship between electricity consumption and oil consumption, while there exist, unidirectional causal relationship from primary sector output to electricity consumption and also unidirectional causality running from primary sector output to oil consumption. The unidirectional causality from the primary sector output growth rate to energy resource (electricity and oil consumption growth) implies that primary sector growth drive energy consumption and in that case energy conservation policy may not harm the economy.

5.6.4 Short Run Causality Tests for the Primary Sector Energy Consumption Model

The result presented in (See Appendix F-3) indicates that there exists a short run unidirectional causality from oil consumption to primary sector output, capital and electricity consumption, and also from coal consumption to oil consumption. The result of causality from oil consumption to economic growth means that in the short run, energy, particularly oil consumption acts as an engine of economic growth.

5.6.5. Diagnostic Test for the Primary Sector Energy Consumption Model

The diagnostic test presented in Table 5.10 indicates that there is no evidence of a diagnostic problem with the model. A number of diagnostic tests were applied to the error correction model. The study shows the absence of serial correlation since the p-value of the Lagrange Multiplier LM (0.1274) and F-version (0.4255) was statistically insignificant at the 5 percent level of significance. We therefore fail to reject the null hypothesis that there is no serial correlation in the model. The normality test base on Jarque-Bera test statistics with p-value of 0.957526 indicate that the errors were normally distributed. According to the JB test, the null hypothesis of normally distributed residuals cannot be rejected. The study also found no presence of heteroscedasticity since the p-value of both the LM test and the F-Version is statistically not significant at 5 percent level significance (see Table 5.10)

Table 5.10: Diagnostic Test for the Primary Sector Energy Consumption Model

Test statistics	LM Version	F Version
A: serial correlation	CHSQ(10)=15.12929 [0.1274]	F(10, 11)= 1.119127 [0.4255]
B: Normality	JB= 0.086805* [0.957526]	Not applicable
C: Heteroscedasticity	CHSQ(14)=12.75870 [0.5456]	F(14, 15)= 0.792865 [0.6653]
Breusch-Godfrey Serial Correlation LM Test *Jarque-Bera test Statistics Heteroskedasticity Test: Breusch-Pagan-Godfrey Note: Probability value in [ ]		

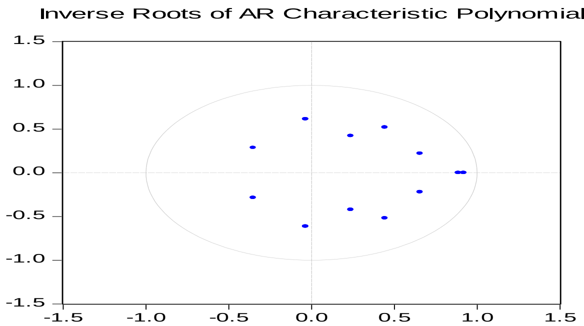
Source: Estimation

5.6.6. Stability Test for the Primary Sector Energy Consumption Model

Testing for the stability of the long run coefficient is carried out using the CUSUM, CUSUMQ and the AR Inverse Root test. The graphical representation of the test is presented in Figure 5.3. a, b and c below. The graph for the CUSUM and CUSUMQ plots does not cross the 5 percent critical bound, suggesting that the residual variance is stable. Also the modulus for the AR graph lies within the circle suggesting that the model is stable.

Figure 5.3: Stability Test for the Primary Sector Energy Consumption Model

(a)Figure 5.2: Plot of Cumulative Sum of Recursive Residuals. (b) Figure 5.2: Plot of Cumulative Sum of Squares of Recursive Residuals primary energy consumption model.



(C) Plot of Inverse AR Root

5.6.7. Impulse Response Function for the Primary Sector Energy Consumption Model

The impulse response shows the effect of a unit shock applied separately to the error of each equation of the VECM. From the results of the IRF presented in Appendix D-3 it can be seen that primary sector output responds positively to its own shock. The result also indicates that whenever there is a unit standard deviation shock in labour output will respond positively though marginally. Shocks in capital, coal consumption and electricity consumption will cause output to fall while output will remain neutral to a unit shock in oil consumption for the entire period (see Appendix D-3).

5.6.8. Variance Decomposition for the Primary Sector Energy Consumption Model

The variance decomposition shows the proportion of the movement in the dependent variables that is due to their own shocks and the shocks of other variables. Variations in economic growth were explained by past growth which accounts for 100 percent of its own forecast error variances in the first year. This however decreased to 77.98 percent and 71.80 percent in the fifth and tenth years respectively. Apart from its past values, labour, capital, coal consumption, electricity consumption as well as oil consumption also account for variation in economic growth.

Unlike past growth, the other variables performed weakly in the short run as we can see that in the fifth year, labour, capital, coal consumption, electricity consumption, and oil consumption only account for 5.97 percent, 0.21 percent, 0.56 percent, 2.39 percent, and 0.17 percent variation of the fluctuation in the primary sector output respectively. While in the long run, that is, in the tenth year, a shock to labour, capital, coal consumption, electricity consumption and iol consumption will account for 6.95 percent, 0.23 percent, 0.87 percent, 3.40 percent and 0.17 percent variation of the fluctuation in output (see Appendix E-3).

5.7. Results and Discussion of Analysis of the Secondary Sector Energy Consumption Model

This section examines the causal relationship between energy composition (COLGR, ELCGR and OILGR) consumption and the secondary sector economic output (SEYGR). Natural gas was also used for the estimation but since its inclusion was not yielding the desired result, it was removed and the model was re-estimated. The results of the cointegration, error correction model, short run causality, diagnostic, stability, impulse response and variance decomposition tests are presented in sections 5.7.1, 5.7.2, 5.7.3, 5.7.4, 5.7.5, 5.7.6, and 5.7.7 respectively.

5.7.1. Cointegration Test Result for the Secondary Sector Energy Consumption Model

The Johansen cointegration test result for the secondary sector energy consumption model with assumption three of no trend in cointegration equation is presented in Appendix C-4. The null hypothesis states that there is no cointegration, as opposed the alternative which states that cointegration is present. The decision rule is that we reject the null hypothesis that there is no cointegration if at least one of the maximum eigenvalue or trace statistics is greater than the critical value at the 5 percent level.

From the cointegration test result, the maximum eigenvalue statistic and the trace test statistics show that there is one and three cointegrating equation(s) respectively in the model. This means we reject the null hypothesis of no cointegration among the variables and conclude that there is a long run equilibrium relationship between the dependent variable secondary sector output (SEYGR) and the independent variables labour (LABGR), capital (CAPGR), coal consumption (COLGR), electricity consumption (ELCGR) and oil consumption (OILGR). The indication of at least one cointegrating equation in the model presupposes that a vector error correction model can be used to distinguish between the short run and long run effects of the variables in order to establish the effect of the energy consumption component on the secondary sector output. Applying the procedure stated in section 5.5.1, the VECM was estimated with one cointegrating equation. Lag 1 was selected based on the AIC.

5.7.2. Vector Error Correction Model Result for the Secondary Sector Energy Consumption Model

Having established the presence of a long run equilibrium relationship among the variables, the error correction representation was subsequently estimated in order to distinguish between the long run and short run effects of the secondary sector energy sector model. The inclusion of a dummy is to account for the electricity crisis of 2007. The results are presented in Table 5.11 below.

Table 5.11: Result of Long Run Cointegration Equation of the Secondary sector Energy Consumption Model

Variable	Coefficient	Standard error	t-statistic
SEYGR	1.000000	-	-
CONSTANT	-3.13645	-	-
LABGR	0.313655	0.13504	2.32276**
CAPGR	-0.52097	0.08497	-6.13121*
COLGR	-0.79169	0.19349	-4.09168*
ELCGR	1.180118	0.26841	4.39668*
OILGR	1.964226	0.24985	7.86168*
DUMMY	4.213698	1.85927	2.26632**
*, ** means significant at the 1 and 5 percent levels of significance respectively			

Source: Estimation

The long run coefficient presented in Table 5.11 reveals the positive and significant effect of labour, electricity consumption and oil consumption on secondary sector output. This implies that the long run a 1 percent increase in labour, electricity consumption and oil consumption will stimulate growth in the secondary sector by 0.31, 1.18, and 1.96 percent respectively. This is expected as the secondary sector is a major consumer of electricity and oil resources (Statistics South Africa, 2009).

On the other hand there exists a negative relationship between capital, coal consumption and economic growth. This implies that the secondary sector output will decline by 0.52, 0.79 percent respectively for every 1 percent rise in capital and coal consumption. The negative relationship can be ascribed to poor investment decision especially in the energy sector which resulted in power cuts (BBC News, 2008) and the prolonged strike in the mining sector which often disrupt production (SARB, 2014).

5.7.3. Speed of Adjustment and Short Run Terms for the Secondary Sector Energy Consumption Model

The error correction term coefficients indicate the speed of adjustment towards the long run equilibrium after a shock in the system. They show how quickly variables adjust to the equilibrium and must be significant with a negative sign. The significance of the error correction term also determines the long run causality running from all independent variables towards the dependent variable. Results from the error correction model are presented in Table 5.12 below.

Table 5.12: Speed of Adjustment for the Secondary Sector Energy Consumption Model

Variable	Coefficient	Standard error	t-statistic
SEYGR	-0.15387	0.16375	-0.93969
LABGR	0.066332	0.16486	0.40235
CAPGR	0.513203	0.27412	1.87216
COLGR	0.184091	0.18883	0.97493
ELCGR	-0.31566	0.14320	-2.20435**
OILGR	-0.53708	0.12066	-4.45099*
DUMMY	0.001703	0.01392	0.12233
*, ** means significant at the 1 and 5 percent level of significance respectively			

Source: Estimation

From the results presented in Table 5.12, the error correction term of electricity consumption and oil consumption models possess the correct sign and is statistically significant at the 5 and 1 percent significance level, with the speed of adjustment back to equilibrium of 31.6 and 53.7 percent respectively. In the case of any misalignment in the equilibrium level of electricity consumption and oil consumption, all the explanatory variables in the VECM will act together to re-establish long run equilibrium. The coefficients suggest that any deviation in the electricity consumption model and oil consumption model will be corrected by about 31.6 and 53.7 percents respectively in the following year. Thus it will take approximately 31.6 and 0.54 years for the deviation in the electricity consumption and oil consumption to completely disappear. The significance of the t-statistic imply that there is a long run causality running from secondary sector output, labour, capital, coal consumption and oil consumption to electricity consumption as well as from secondary sector output, labour, capital, coal consumption and electricity consumption to oil consumption. The results also suggest that as the industrial sector expands, there will also be an expansion in the demand for electricity and oil resources in the long run. Therefore policy makers should take adequate steps to increase electricity generating and oil production capacities in the long run in order to meet the future increase in demand.

5.7.4. Short Run Causality Tests for the Secondary Sector Energy Consumption Model

The short run causality estimate as presented in Appendix E-4 indicates that there exist a short run unidirectional causality from oil consumption to secondary sector output, capital investment and electricity consumption (See Appendix F-4). This confirms the fact that the South African manufacturing sector depends to a large extent on oil resources for its output and is highly capital intensive.

5.7.5. Diagnostic Test for the Secondary Sector Energy Consumption Model

The study shows the absence of serial correlation since the p-value of the Lagrange Multiplier LM (0.6218) and F-version (0.7365) was statistically insignificant at 5 percent level of significance. We therefore fail to reject the null hypothesis that there is no serial correlation in the model. The normality test based on Jarque-Bera test statistics with a p-value of 0.771640 indicates that the errors were normally distributed at the 5 percent level of significance. The study also found no presence of heteroscedasticity since the p-value of both the LM test and the F-Version is statistically not significant at the 5 percent level of significance (see Table 5.13)**.**

Table 5.13: Diagnostic Test for the Secondary Sector Energy Consumption Model

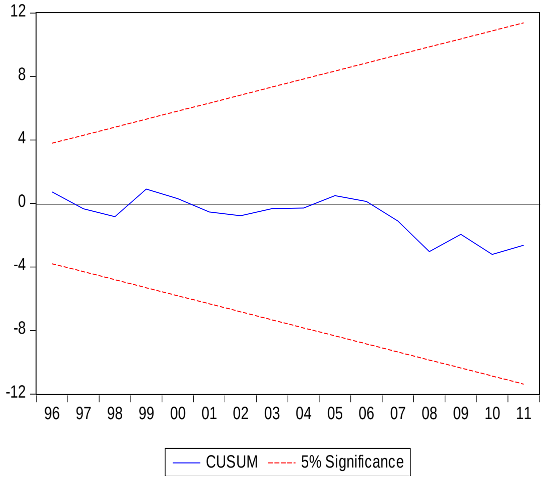
Test statistics	LM Version	F Version
A: serial correlation	CHSQ(2)= 0.950433 [0.6218]	F(2, 19)= 0.310818 [0.7365]
B: Normality	JB= 0.518473* [0.771640]	Not applicable
C: Heteroscedasticity	CHSQ(14)=11.81890 [0.6208]	F(14, 15)= 0.696499 [0.7477]
Breusch-Godfrey Serial Correlation LM Test *Jarque-Bera test Statistics Heteroskedasticity Test: Breusch-Pagan-Godfrey Note: Probability value in [ ]		

Source: Estimation

5.7.6. Stability Test for the Secondary Sector Energy Consumption Model

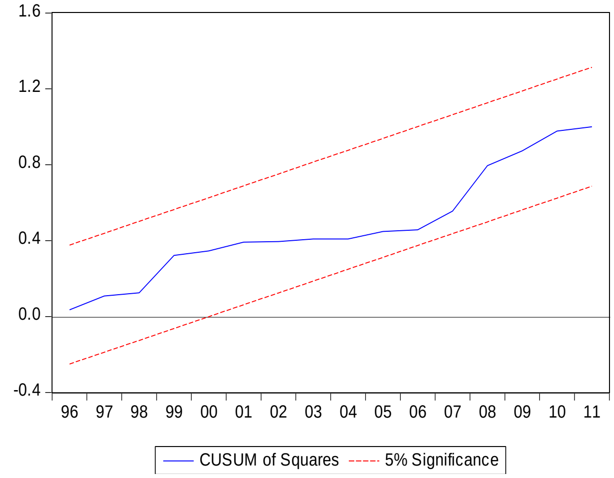
Testing for the stability of the long run coefficient is carried out using the CUSUM, CUSUMQ and the AR Inverse Root test. The graphical representation of the test is presented in Figure 5.4 a, b and c below. The graph for the CUSUM and CUSUMQ plots does not cross the 5 percent critical bounds, suggesting that the residual variance is stable. Also, the modulus for the AR graph lies within the circle suggesting that the model is stable.

Figure: 5.4: Stability Test for the Secondary Sector Energy Consumption Model



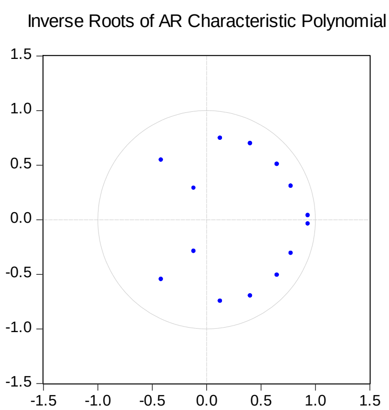
(a)

Figure 5.2: Plot of Cumulative Sum of Recursive Residuals. secondary sector energy consumption model



(b)

Figure 5.2: Plot of Cumulative Sum of Squares of Recursive Residuals for



(c)Plot of Inverse AR Root

5.7.7. Impulse Response Function for the Secondary Sector Energy Consumption Model

Since the causality test may not tell us the entire story about the causal relationship among the variables in the model, it is essential to use the impulse response function to analyze the dynamic effects of the entire system when it experiences shocks in the future. The results presented in Appendix D-4 indicate that whenever there is a standard deviation shock in labour, secondary sector output will be negative for the next ten years although it converged back to equilibrium in the third and six year. In the case of capital and coal consumption, one unit standard deviation shock in the system will result in a fluctuation in growth. For electricity consumption, a standard deviation shock in the system will result in a negative value of secondary sector output. The result also indicates that whenever there is a shock in oil consumption, secondary sector output will always be negative (see Appendix D-4).

5.7.8. Variance Decomposition for the Secondary Sector Energy Consumption Model

Variance decomposition tells us how much of a change in a variable is due to its own shock and how much is due to the shocks of other variables. Appendix E-4 presents the variance decomposition of the variables used in the model. The result indicates that own shock is the major source of variation in the model. Variation in economic output of the secondary sector was explained by past growth, accounting for 100 percent of its own forecast error variances in the first year. This however decreased to 94.73 percent and 94.68 percent in the fifth and tenth years respectively.

Apart from its past values, labour, capital, coal consumption, electricity consumption and oil consumption also account for variation in secondary sector output. Unlike past growth, the other variables performed weakly in the short run as we can see that in the fifth year, labour, capital, coal consumption, electricity consumption, and oil consumption only accounted for 1.51 percent, 0.96 percent, 0.35 percent, 0.82 percent and 1.09 percent variation of the fluctuation in secondary sector output respectively, but when their contribution to variation in economic growth became prominent as analysis enters threshold of the long run they became constant thereafter. For example electricity consumption became constant at 0.9 percent (see Appendix E-4).

5.8. Results and Discussion for the Tertiary Sector Energy Consumption Model

This section examines the impact of the energy composition (coal, electricity and oil) consumption on the tertiary sector economic output. Natural gas was also used for the estimation but since its inclusion was not yielding the desired result, it was removed and the model re-estimated. The results of the cointegration, error correction model, short run causality, diagnostic, stability, impulse response and variance decomposition tests are presented in sections 5.8.1, 5.8.2, 5.8.3, 5.8.4, 5.8.5, 5.8.6, and 5.8.7 respectively.

5.8.1. Cointegration Test Result for Tertiary Sector Energy Consumption Model

In order to test for the presence of a long run relationship between TEYGR, which is the tertiary sector output and the various energy components (COLGR, ELCGR and OILGR) together with labour and capital, the Johansen test of cointegration is applied. The results are presented in Appendix C-5. The maximum eigenvalue statistic indicates that there exists one cointegrating vector since we fail to reject the null hypothesis that there is at most 1 cointegrating equations at k percent significant level. The trace statistic on the other hand indicates that there exist two cointegrating equations. This indicates that there exists a long run equilibrium relationship among the variables. However, applying the procedure in section 5.5.1 the VECM is estimated with one cointegrating equation. Lag 1 was selected based on AIC (see Appendix B-5).

5.8.2. Vector Error Correction Model Result for the Tertiary Sector Energy Consumption Model

Having established the presence of a long run equilibrium relationship among the variables, the error correction representation was subsequently estimated in order to distinguish between the long run and short run effects of the tertiary sector energy consumption model. A dummy variable was also introduced but did not yield a desired result. It was however removed.

Table 5.14: Result of Long Run Cointegration Equation for the Tertiary Sector Energy Consumption Model

Variable	Coefficient	Standard error	t-statistic
TEYGR	1.000000	-	-
CONSTANT	-4.42857	-	-
LABGR	0.093055	0.07735	1.20307
CAPGR	-0.26122	0.04872	-5.36125*
COLGR	-0.44181	0.10896	-4.05463*
ELCGR	0.465271	0.15081	3.08512*
OILGR	1.404992	0.14305	9.82184*
DUMMY	2.212143	1.07354	2.06062**
*, **, *** means significant at the 1, 5 and 10 percent levels of significance respectively			

Source: Estimation

The long run coefficient reported in Table 5.14 indicates that there is a significant positive relationship between electricity consumption, oil consumption and tertiary sector output. The long run coefficient of the electricity consumption and oil consumption are 0.47 and 1.40 respectively. Thus a 1 percent increase electricity consumption and oil consumption will raise tertiary sector output in the long run by 0.47 and 1.40 percent respectively. This may be true as the service sector depends on electricity and oil resources for its activities. Labour also exhibited a positive relationship with output though not statistically significant. The service sector is a major employer of labour in South Africa though the contribution of labour to the overall output is minimal. It is noted that a 1 percent increase in labour will stimulate growth in the long run by 0.09 percent.

On the other hand capital and coal consumption are seen to have negative impact on the service sector. It is noted also from Table 5.16 that a 1 percent change in capital and coal consumption will cause a decline in the tertiary sector by 0.26 and 0.44 percent respectively. The significance of the parameters indicates that all the variables are important factor inputs in the tertiary sector.

5.8.3. Speed of Adjustment and Short Run Terms for the Tertiary Sector Energy Consumption Model

The coefficients error correction term indicate the speed of adjustment towards the long run equilibrium after a shock in the system. They show how quickly variables adjust to the equilibrium and must be significant with a negative sign. The significance of the error correction term also determines the long run causality running from all independent variables towards the dependent variable. Results from the coefficient of the error correction model are presented in Table 5.15 below.

Table 5.15: Speed of Adjustment for the Tertiary Sector Energy Consumption Model

Variable	Coefficient	Standard error	t-statistic
TEYGR	-0.20437	0.11490	-1.77874***
LABGR	0.034012	0.28036	0.12132
CAPGR	0.635918	0.47761	1.33145
COLGR	0.172949	0.31390	0.55097
ELCGR	-0.43486	0.25625	-1.69699
OILGR	-1.02407	0.17633	-5.80768*
DUMMY	-0.00209	0.02350	-0.08876
*, **, *** means significant at the 1, 5 and 10 percent levels of significance respectively			

Source: Estimation

From the results presented in Table 5.15 the error correction term of tertiary sector output and oil consumption possess the correct sign, which is negative and statistically significant at the 10 percent and 1 percent level of significance respectively. This implies that there is long run bidirectional causality between tertiary sector output and oil consumption. The long run bidirectional causality indicates that they are compliments and that oil conservation policy may be implemented without necessarily affecting output in the tertiary sector. The result further indicates that there is a long run unidirectional causality from coal consumption, electricity consumption to tertiary sector output. This means growth in the tertiary sector drives energy consumption thereby supporting the growth hypothesis with regards to coal consumption and electricity consumption.

5.8.4. Short Run Causality Tests for the Tertiary Sector Energy Consumption Model

The short run causality results indicate there is a short run bi-directional causal relationship between electricity consumption and tertiary sector output on one hand and a unidirectional causality from coal consumption to oil consumption and from oil consumption to electricity consumption on the other hand (see Appendix F-5).

5.8.5. Diagnostic Test for Tertiary Sector Energy Consumption Model

The study shows the absence of serial correlation since the p-value of the Lagrange Multiplier LM (0.3792) and F-version (0.5300) was statistically insignificant at 5 percent level of significance. We therefore fail to reject the null hypothesis that there is no serial correlation in the model. The normality test based on Jarque Bera test statistics with p-value of 0.098284 indicates that there is no evidence of a diagnostic problem in the model at 5 percent level of significance, which implies that the errors were normally distributed. The study also found no presence of heteroscedasticity since the p-value of both the LM test and the F-Version is statistically not significant at the 5 percent level of significance (see Table 5.16).

Table 5.16: Diagnostic Test for Tertiary Sector Energy Consumption Model

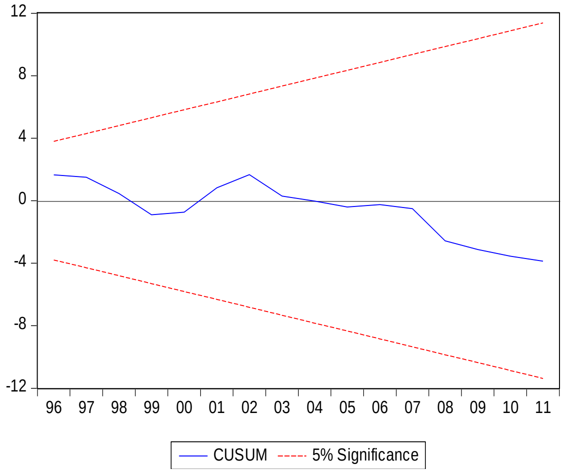
Test statistics	LM Version	F Version
A: serial correlation	CHSQ(2)=1.939528 [0.3792]	F(2, 19)= 0.656636 [0.5300]
B: Normality	JB= 4.639782* [0.098284]	Not applicable
C: Heteroscedasticity	CHSQ(16)=12.12312 [0.5964]	F(14, 15)= 0.726584 [0.7221]
Breusch-Godfrey Serial Correlation LM Test *Jarque-Bera test Statistics Heteroskedasticity Test: Breusch-Pagan-Godfrey Note: Probability value in [ ]		

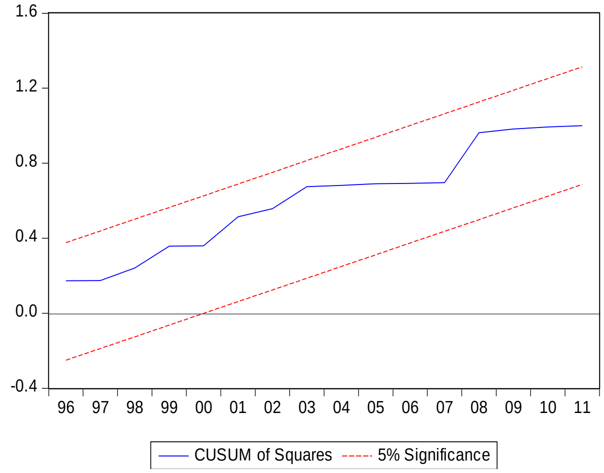
Source: Estimation

5.8.6. Stability Test for Tertiary Sector Energy Consumption Model

Testing for the stability of the long run coefficient is carried out using the CUSUM, CUSUMQ and the AR Inverse Root test. The graphical representation of the test is presented in Figure 5.6. a, b and c below. The graph for the CUSUM and CUSUMQ plots does not cross the 5 percent critical bounds, suggesting that the residual variance is stable. Also the modulus for the AR graph lies within the circle suggesting that the model is stable.

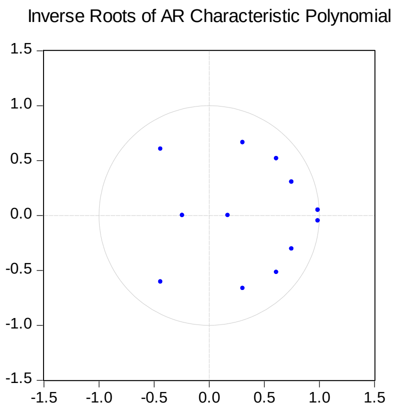
Figure 5.5: Stability Test for Tertiary Sector Energy Consumption Model





(a) (b)

Plot of Cumulative Sum of Recursive Residuals. Plot of Cumulative Sum of Squares of Recursive Residuals for tertiary energy consumption model.



(b) Plot of Inverse AR Root

5.8.7. Impulse Response Function for Tertiary Sector Energy Consumption Model

The impulse response permits us to examine the response of endogenous variable to one standard deviation shock in the system of innovation for a period of ten years. The results presented in Appendix D-5 indicate that whenever there is a shock in labour and capital, the tertiary sector output remains positive though marginally, but for other variables such as coal consumption, electricity consumption and oil consumption, a standard deviation shock in the system will result in a negative value of tertiary sector output.

5.8.8. Variance Decomposition for the Tertiary Sector Energy Consumption Model

Variance decomposition tells us how much of a change in a variable is due to its own shock and how much is due to the shocks of other variables. The results of the variance decomposition for the tertiary sector energy consumption model presented in Appendix E-5 indicate that own (tertiary sector output) shock is the major source of variation in the model. Variation in economic output of the tertiary sector was explained by past growth. It accounts for 100 percent of its own forecast error variances in the first year; this however decreased to 88.50 percent and 87.83 percent in the fifth and tenth year respectively. Apart from its past values, labour, capital, coal consumption, electricity consumption and oil consumption also account for variation in economic growth.

Unlike past growth, the other variables performed weakly in the short run as we can see that in the fifth year, labour, capital, coal consumption, electricity consumption, and oil consumption only accounted for 0.25 percent, 1.44 percent, 1.04 percent, 7.97 percent and 0.44 percent variation of the fluctuation in secondary sector economic growth respectively, but their contribution to variation in economic growth became prominent as analysis enters the threshold of the long run and became constant thereafter. For example, electricity consumption became constant at 8.9 percent (see Appendix B-5).

5.9. Chapter Summary

This chapter focused on the presentation and discussion of the estimated results for the energy consumption models in South Africa between 1980 and 2012. It employed the unit root test in order to determine the order of integration of the variables after which the Johansen cointegration test was employed to determine if there exists a long run relationship among the variables. VECM was applied to distinguish between the long run and short run dynamics and also to determine the direction of causality. Dummy variables were included to account for the shocks in the electricity sector and strikes experienced in the country. Diagnostic and stability tests were performed on all models and the lag length was selected based on the AIC. The general assessment of the models indicates that there exists a long run causal relationship among the variables the models, although the direction of causality differs. There is also evidence that electricity is a major energy resource for economic growth in South Africa. A summary of the study’s findings, conclusions and policy recommendations are presented in chapter six.

CHAPTER 6

SUMMARY, CONCLUSION AND POLICY RECOMMENDATION

The chapter provides an overall summation of the entire study and the result which answered the research objectives as well as giving policy recommendation based on the result obtained in the study. The chapter also links the results of major findings to the general and specific objectives outlined by the study. The summary of the study is presented in section one. Section two outlines the study's discussion of findings and conclusion. The study's policy implications and recommendation are presented in section three while limitations of the study and recommendations for future research are presented in section four.

6.1. Summary of the Study

The study investigated the dynamic interaction between energy consumption and economic growth in South Africa for the period 1908 and 2012. Aggregate as well as several disaggregated categories of energy consumption, including coal, oil, gas and electricity were used in the study. The impact of the energy components on the primary, secondary and tertiary sectors of the economy was also examined.

The overall object of this study was to examine and discuss the implication of energy consumption on economic growth in South Africa. Specifically the study aimed at achieving the following objectives:

1. To examine the causal relationship between energy consumption as a whole and economic growth in South Africa,
2. To examine the impact of different energy components (coal, crude oil, natural gas and electricity) on the overall economic growth (dis-aggregated analysis),
3. To examine the impact of dis-aggregated energy consumption on each of the primary, secondary and tertiary sectors of the economy,
4. To suggest policy recommendations with respect to energy use in the South African economy.

South Africa's economy is energy intensive and dominated by coal. The other energy resources are oil, natural gas, nuclear power, hydropower and renewable energy. Due to limited availability of crude oil and natural gas, most of the country's gas and crude oil needs are met through importation and coal to liquid transformation. South Africa's renewable energy sources have not been optimally exploited except biomass. Energy efficiency and energy intensity in South Africa were also examined together with their impact on economic growth.

The neoclassical and ecological theory approaches to the role of energy resources in economic growth were examined. The neoclassical growth theory is based on the argument that labour and capital are the primary factors of production. Energy resources are regarded as an intermediate input in the factors of production. The argument is based on the following assumptions: the productivity of the different production factors should be equal to their respective cost shares; technological progress can effectively decouple energy use for economic growth; energy is regarded as an intermediate factor of production.

However, the ecological theory ascribes a primary role to energy in production. As noted earlier, Moroney (1992) argues: though it may be true that energy has a small cost share in GNP, but it will be an error to conclude that energy plays a secondary role. Its role is primary, coequal with capital formation. Empirical literature on the causal relationship between energy consumption and economic growth was summarised into four testable hypotheses namely: the growth hypothesis, the conservation hypothesis, the neutrality hypothesis and the feedback hypothesis.

The study employed the use of both descriptive and econometric tools to estimate the results. Descriptive analysis includes the use of graphs and tables while econometric analysis includes the stationarity test, the Johansen cointegration technique and the vector error correction model (VECM).

6.2. Discussion of Findings and Conclusions

The Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root tests were conducted to test the presence of unit root among the variables. All variables were non-stationary at levels, but they became stationary at first difference. The Johansen cointegration test revealed the presence of long run relationship in the entire models. Causality test was performed through the vector error correction model (VECM) for the non-stationary and cointegrated variables. The causality test results were further justified with the use of the impulse response function and variance decomposition. Diagnostic tests were also performed and evidence from the study revealed that all the model passed the tests.

For the first objective, which was aimed at examining the impact of energy consumption on economic growth, the coefficient of the long run estimate for the independent variables exhibited significantly positive signs. This is in line with a priori expectation. South Africa is an energy intensive economy and the availability of energy resources is critical for economic growth. The coefficient of the error correction term for the energy consumption function is negative and statistically significant at the 5 percent level of significance. This implies that there is a long run causal relationship running from all the independent variables (GDPGR, LABGR and CAPGR) to energy consumption respectively. That is, there is a unidirectional causal relationship from economic growth to energy consumption, which supports the conservation hypothesis. However, in the short run, there exists unidirectional causal relationship running from energy consumption to economic growth. In that case, energy conservation policies may be implemented in the long run without hampering growth but will hamper growth in the short run. The results further revealed that there exists bidirectional causality between energy consumption and capital investment both in the short and long run. This is not surprising as South Africa is a highly capital as well as energy intensive economy.

For the second objective, which was aimed examining the impact of the disaggregated energy consumption on economic growth, the coefficients of the long run estimate indicate that labour, electricity consumption and oil consumption exhibited a positive influence on economic growth, while capital and coal consumption have negative impact on economic growth. The negative impact of coal on economic growth is contrary to expectation. This phenomenon may be ascribed to the prolonged strike in the mining sector which is believed to have contributed to a decline in economic growth. The findings also revealed that there exists bidirectional causal relationship between economic growth and electricity consumption, economic growth and oil consumption, as well as between electricity consumption and oil consumption. The bidirectional relationship implies that these variables are compliments as they tend to drive one another. The results further revealed that there is a unidirectional causal relationship running from labour, capital and coal consumption to economic growth. This implies that labour, capital and coal consumption have great influence on economic growth and that an increase in labour, capital and coal consumption tends to drive economic growth upward. The long run bidirectional causal relationship between electricity consumption and economic growth validates the findings of Odhiambo (2009) who employed the error correction mechanism to investigate the relationship between electricity consumption and economic growth in South Africa. The policy implication of these is that, there should be increased investment in the electricity sector to boost the electricity generating capacity in order to cope with the ever increasing demand exerted by the country's economic growth and continuous industrialization. Effort should also be made to increase oil supply, though it is highly capital intensive.

For the third objective, which was aimed at examining the impact of the disaggregated energy consumption (COLGR, ELCGR, OILGR with LABGR and CAPGR) on the primary (PRYGR), secondary (SEYGR) and tertiary (TEYGR) sectors of the South African economy, the long run coefficients of the primary sector model indicate that all the explanatory variables except capital and coal consumption have positive impact on the primary sector output. The results further revealed that there exists long run unidirectional causality from primary sector output to electricity consumption and oil consumption. That is to say, primary sector output drives both electricity consumption and oil consumption in the long run thereby supporting conservation hypothesis. In that case, the implementation of energy conservation policy may not hamper growth in the primary sector. In the short run there exists unidirectional causality from oil consumption to primary sector output, capital and electricity consumption, and also from electricity consumption to capital. This implies that oil consumption acts as an engine of economic growth in the short run.

For the secondary sector, the long run coefficients show that labour, electricity consumption and oil consumption have positive relationship with output. The results also indicated that there exists bidirectional causality between electricity consumption and oil consumption. There is also evidence of a long run unidirectional from secondary sector output, capital, coal consumption, electricity consumption and oil consumption to electricity consumption, as well as from all the explanatory variables to oil consumption. This means that secondary sector growth drives energy consumption and that the implementation of energy conservation policy may not hamper growth in the secondary sector. In the short run, there exist a short run unidirectional causality from oil consumption to secondary sector output, capital investment and electricity consumption. This is in line with *a priori* expectation as South Africa is an energy as well as capital intensive country especially in the secondary sector (Statistics South Africa, 2009). The results also suggest that as the industrial sector expands, there will also be an expansion in the demand for electricity and oil resources in the long run. Therefore policy makers should take adequate steps to increase electricity generation and oil production capacity in the long run in order to meet the future increase in demand.

The findings of the tertiary sector model show that the coefficients of labour and electricity consumption are statistically significant and positively related to the tertiary sector output. The results further reveal that there is a long run bidirectional causal relationship between the tertiary sector output and oil consumption thereby supporting the feedback hypothesis. There is also evidence of a long run unidirectional causality from coal consumption, electricity consumption to tertiary sector output. This means growth in the tertiary sector drives energy consumption thereby supporting the growth hypothesis with regards to coal and electricity consumption.

6.3. Policy Implications and Recommendation

The divergent causality results revealed in this study have a major implication for energy and environmental policy with regards to economic growth and environmental sustainability. The unidirectional causality from energy consumption to economic growth implies that reducing (increasing) energy consumption might lead to a decline (growth) in output respectively. In that case, any energy conservation measures undertaken might have adverse effects on economic growth. However, there is possibility that increase in energy use might not lead to a corresponding increase in growth especially in relatively less productive sectors or inefficient energy use.

Where there is unidirectional causality from economic growth to energy consumption, reducing energy consumption may be implemented with little or no adverse effect on growth. However, it must be noted that reducing energy may not be a realistic option in the case of South Africa especially in the secondary and tertiary sectors given the structure of the economy and the fact that the current energy infrastructure is being overstretched to meet the growing energy demand. The bidirectional causality found between energy consumption and economic growth implies that they are complimentary. Increase in economic growth may lead to demand for more energy on the one hand while more energy may induce economic growth on the other. While evidence of no causal relationship in the case of the tertiary sector implies that energy saving policy can be followed without affect output.

It is established that South Africa is an energy dependent economy and that energy (especially electricity and oil) is a limiting factor of growth. This implies that implementation of energy conservation policies may hamper economic growth. There is therefore need to increase investment, especially in the electricity sector as well as to take strategic steps to increase oil production. In the long run, there should be increased generating capacity to meet future demands. There will also be a need to explore more renewable sources in order to meet the growing energy demand without compromising growth and environmental sustainability. Apart from increasing the electricity generating capacity to meet future demands, policy makers should also pursue energy conservation policies both at the aggregated and disaggregated level.

Also, improving energy efficiency will have a significant impact on the provision of energy to meet sustainable development goals. South Africa needs to pursue energy efficiency policies more diligently in the long term, in the same manner as renewable energy policies, as they both have similar benefits in terms of energy security and climate change mitigation.

6.4. Limitations of the Study and Recommendations for Future Research

Although the results of the study were consistent with the a priori theoretical expectation, the study suffered certain limitations. Firstly, the study was limited to fossil energy consumption; it did not conduct any empirical analysis on the impact of renewable energy especially on the sub sectors of the South African economy. Secondly, energy efficiency improvement in the various subsectors of the South African economy is a major policy option for meeting the country's growing energy demand. However, this was not covered in the study. These caveats are considered open questions for further research, and it is hoped that the findings of this study will spark other researchers’ interest in extending their research along these lines.

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APPENDICES

APPENDIX A: Stationarity Test (Unit Root) Result

Table A-1: ADF Stationarity Test Result

Variables	T statistic	Critical value (5%)	Lag length	Integrated order	Restriction
GDP	-1.384535	-3.562882	1	I(0)	Constant and trend
D(GDP)	-4.548317	-3.562882	0	I(1)*	Constant and trend
ENY	-1.981241	-2.957110	0	I(0)	Constant
D(ENY)	-5.229000	-2.960411	0	I(1)*	Constant
KAP	-0.849517	-3.562882	1	I(0)	Constant and trend
D(KAP)	-3.844668	-3.562882	0	I(1)*	Constant and trend
LAB	0.790603	-1.952066	1	I(0)	None
D(LAB)	-2.561431	-1.952066	0	I(1)*	None
COL	-3.155497	-3.562882	1	I(0)	Constant and trend
D(COL)	-4.776846	-3.562882	0	I(1)*	Constant and trend
ELC	-2.487314	-3.557759	0	I(0)	Constant and trend
D(ELC)	-5.065980	-3.568379	1	I(1)*	Constant and trend
NAG	-2.053214	-3.562882	1	I(0)	Constant and trend
D(NAG)	-4.233449	-3.562882	0	I(1)*	Constant and trend
OIL	0.055936	-2.971853	4	I(0)	Constant
D(OIL)	-4.524109	-2.971853	3	I(1)*	Constant
PRY	-2.904936	-2.957110	0	I(0)	Constant
D(PRY)	-7.194858	-2.963972	1	I(1)*	Constant
SEY	-1.179721	-3.557759	0	I(0)	Constant and trend
SEY	-5.370753	-3.562882	0	I(1)*	Constant and trend
TEY	-0.465147	-3.568379	2	I(0)	Constant and trend
D(TEY)	-6.083840	-3.574244	1	I(2)*	Constant and trend

Source: Estimation * means significant at 5 percent level

Table A-2: PP Stationarity Test Result

Variables	T statistic	Critical value (5%)	Bandwidth	Integrated order	Restriction
GDP	-0.692660	-3.557759	1	I(0)	Constant and Trend
D(GDP)	-4.505098	-3.562882	4	I(1)	Constant and trend
ENY	-3.211604	-3.557759	1	I(0)	Constant and trend
D(ENY)	-5.226070	-3.562882	3	I(1)	Constant and trend
KAP	-0.366002	-3.557759	4	I(0)	Constant and trend
D(KAP)	-3.626088	-3.562882	11	I(1)*	Constant and trend
LAB	1.503567	-1.951687	3	I(0)	None
D(LAB)	-2.537981	-1.952066	2	1(1)*	None
COL	-3.260572	-3.557759	1	I(0)	Constant and trend
D(COL)	-4.812255	-3.562882	5	I(1)	Constant and trend
ELC	-2.537565	-3.557759	1	I(0)	Constant and trend
D(ELC)	-5.767457	-3.562882	3	I(1)*	Constant and trend
NAG	-1.737175	-3.557759	3	I(0)	Constant and trend
D(NAG)	-4.065593	-3.562882	7	I(1)*	Constant and trend
OIL	-0.898142	-2.957110	31	30	Constant
D(OIL)	-11.47784	-2.960411	30	I(1)*	Constant
PRY	-2.808226	-2.957110	3	I(0)	Constant
D(PRY)	-11.52286	-2.960411	8	I(1)	Constant
SEY	-1.067382	-3.557759	4	I(0)	Constant and trend
D(SEY)	-5.665098	-3.562882	6	I(1)*	Constant and trend
TEY	0.465147	-3.568379	2	I(0)	Constant and trend
D(TEY)	-6.083840	-3.574244	1	I(1)	Constant and trend

Source: Estimation * means significant at 5 percent level

APPENDIX B: Lag Length Selection Result

Table B-1: Lag Length Selection for Aggregate Energy Consumption Model

VAR Lag Order Selection Criteria

Endogenous variables: GDPGR LABGR CAPGR ENYGR

Exogenous variables: C

Date: 05/20/15 Time: 09:03

Sample: 1980 2012

Included observations: 30

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-327.1681	NA	45545.46	22.07788	22.26470*	22.13764
1	-304.2570	38.18517*	29090.96*	21.61714*	22.55127	21.91597*
2	-297.9938	8.768463	59332.04	22.26626	23.94769	22.80416

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table B-2: Lag Length Selection for Disaggregated Energy Consumption Model

VAR Lag Order Selection Criteria

Endogenous variables: GDPGR LABGR CAPGR COLGR ELCGR OILGR

Exogenous variables: DUMMY

Date: 05/17/15 Time: 06:28

Sample: 1980 2012

Included observations: 30

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-486.7923	NA	7464788.	32.85282	33.13306*	32.94247
1	-437.1275	76.15269*	3163264.*	31.94184*	33.90351	32.56939*
2	-413.7085	26.54160	10031318	32.78056	36.42368	33.94603

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table B-3: Lag Length Selection for Primary Sector Energy Consumption Model

VAR Lag Order Selection Criteria

Endogenous variables: PRYGR LABGR CAPGR COLGR ELCGR OILGR DUMMY

Exogenous variables:

Date: 05/13/15 Time: 14:28

Sample: 1980 2012

Included observations: 29

Lag	LogL	LR	FPE	AIC	SC	HQ
1	-460.7078	NA	4662907.	32.35804*	37.46252*	35.87581
2	-414.6916	47.60304	9883009.	35.15226	39.97856	36.80513
3	-321.8105	51.24470	3823820.*	35.33176	39.26254	34.50239*

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table B-4: Lag Length Selection for Secondary Sector Energy Consumption Model

VAR Lag Order Selection Criteria

Endogenous variables: SEYGR LABGR CAPGR COLGR
ELCGR OILGR

Exogenous variables: C

Date: 05/20/15 Time: 09:06

Sample: 1980 2012

Included observations: 30

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-493.2270	NA	11463575	33.28180	33.56204*	33.37145*
1	-449.9383	66.37605*	7430947.*	32.79588*	34.75756	33.42344
2	-422.7945	30.76292	18383407	33.38630	37.02941	34.55176

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5%
level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table B-5: Lag Length Selection for Tertiary Sector Energy Consumption Model

VAR Lag Order Selection Criteria

Endogenous variables: TEYGR LABGR CAPGR COLGR
ELCGR OILGR

Exogenous variables: C

Date: 05/20/15 Time: 09:04

Sample: 1980 2012

Included observations: 30

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-472.5073	NA	2880199.*	31.90048	32.18072*	31.99014*
1	-435.9675	56.02761*	2927856.	31.86450*	33.82618	32.49206
2	-408.2087	31.45994	6952243.	32.41392	36.05703	33.57938

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5%level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

APPENDIX C: Cointegration Test Result

Table F-1: Cointegration Result for Aggregate Energy Consumption Model

Hypothesized No. of CE(s)	Max-Eigen statistic	5% critical values	P value**	Conclusion
None *	27.85797	27.58434	0.0461	Reject null hypothesis
At most 1	18.48252	21.13162	0.1128	Do not reject null hypothesis
At most 2	10.98889	14.26460	0.1548	Do not reject null hypothesis
At most 3	0.121573	3.841466	0.7273	Do not reject null hypothesis
Max-eigenvalue test indicates 1 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values				
Hypothesized No. of CE(s)	**Trace test statistic**	**5% critical values**	**P value****	**Conclusion**
None *	57.45095	47.85613	0.0049	Reject null hypothesis
At most 1	29.59298	29.79707	0.0528	Do not reject null hypothesis
At most 2	11.11046	15.49471	0.2048	Do not reject null hypothesis
At most 3	0.121573	3.841466	0.7273	Do not reject null hypothesis
Trace test indicates 1 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values.				

Source: Estimation

Table C-2: Cointegration Test Result for Disaggregated Energy Consumption Model

Hypothesized No. of CE(s)	Max-Eigen statistic	5% critical values	P value**	Conclusion
None*	60.88626	46.23142	0.0008	Reject null hypothesis
At most 1	34.94120	40.07757	0.1693	Do not reject null hypothesis
At most 2	20.37634	33.87687	0.7301	Do not reject null hypothesis
At most 3	18.96066	27.58434	0.4175	Do not reject null hypothesis
At most 4	11.91286	21.13162	0.5563	Do not reject null hypothesis
At most 5	10.01591	14.26460	0.2109	Do not reject null hypothesis
At most 6	2.536768	3.841466	0.1112	
Max-eigenvalue test indicates 1 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values				
Hypothesized No. of CE(s)	**Trace test statistic**	**5% critical values**	**P value****	**Conclusion**
None*	159.6300	125.6154	0.0001	Reject null hypothesis
At most 1*	98.74373	95.75366	0.0306	Reject null hypothesis
At most 2	63.80254	69.81889	0.1375	Do not reject null hypothesis
At most 3	43.42619	47.85613	0.1225	Do not reject null hypothesis
At most 4	24.46554	29.79707	0.1814	Do not reject null hypothesis
At most 5	12.55267	15.49471	0.1323	Do not reject null hypothesis
At most 6	2.536768	3.841466	0.1112	
Trace test indicates 2 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values.				

Source: Estimation

Table C-3: Cointegration Test Result for the Primary Sector Energy Consumption Model

Hypothesized No. of CE(s)	Max-Eigen statistic	5% critical values	P value**	Conclusion
None*	51.11635	46.23142	0.0139	Reject null hypothesis
At most 1*	47.03417	40.07757	0.0071	Reject null hypothesis
At most 2	27.68750	33.87687	0.2283	Do not reject null hypothesis
At most 3	18.38765	27.58434	0.4632	Do not reject null hypothesis
At most 4	10.51941	21.13162	0.6949	Do not reject null hypothesis
At most 5	8.230333	14.26460	0.3558	Do not reject null hypothesis
Max-eigenvalue test indicates 2 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values				
Hypothesized No. of CE(s)	**Trace test statistic**	**5% critical values**	**P value****	**Conclusion**
None*	169.1751	125.6154	0.0000	Reject null hypothesis
At most 1*	118.0587	95.75366	0.0006	Reject null hypothesis
At most 2*	71.02457	69.81889	0.0400	Reject null hypothesis
At most 3	43.33707	47.85613	0.1246	Do not reject null hypothesis
At most 4	24.94942	29.79707	0.1633	Do not reject null hypothesis
At most 5	14.43000	15.49471	0.0719	Do not reject null hypothesis
Trace test indicates 3 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values.				

Source: Estimation

Table C-4: Cointegration Test Result for Secondary Sector Energy Consumption Model

Hypothesized No. of CE(s)	Max-Eigen statistic	5% critical values	P value**	Conclusion
None*	63.05404	46.23142	0.0004	Reject null hypothesis
At most 1	31.77262	40.07757	0.3156	Do not reject null hypothesis
At most 2	25.91144	33.87687	0.3262	Do not reject null hypothesis
At most 3	21.67468	27.58434	0.2375	Do not reject null hypothesis
At most 4	12.51876	21.13162	0.4974	Do not reject null hypothesis
At most 5	10.07689	14.26460	0.2069	Do not reject null hypothesis
Max-eigenvalue test indicates 1 cointegrating equations at the 5% level. * denotes rejection of ull hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values				
Hypothesized No. of CE(s)	**Trace test statistic**	**5% critical values**	**P value****	**Conclusion**
None*	167.1280	125.6154	0.0000	Reject null hypothesis
At most 1*	104.0739	95.75366	0.0118	Reject null hypothesis
At most 2*	72.30132	69.81889	0.0313	Reject null hypothesis
At most 3	46.38988	47.85613	0.0682	Do not reject null hypothesis
At most 4	24.71520	29.79707	0.1719	Do not reject null hypothesis
At most 5	12.19644	15.49471	0.1478	Do not reject null hypothesis
Trace test indicates 3 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values.				

Source: Estimation

Table C-5: Cointegration Test Result for Tertiary Sector Energy Consumption Model

Hypothesized No. of CE(s)	Max-Eigen statistic	5% critical values	P value**	Conclusion
None*	64.64034	46.23142	0.0002	Reject null hypothesis
At most 1	35.43867	40.07757	0.1520	Fail to reject null hypothesis
At most 2	19.05414	33.87687	0.8186	Fail to reject null hypothesis
At most 3	17.45915	27.58434	0.5407	Fail to reject null hypothesis
At most 4	12.94247	21.13162	0.4575	Fail to reject null hypothesis
At most 5	9.091451	14.26460	0.2786	Fail to reject null hypothesis
Max-eigenvalue test indicates 1 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values				
Hypothesized No. of CE(s)	**Trace test statistic**	**5% critical values**	**P value****	**Conclusion**
None*	161.5872	125.6154	0.0001	Reject null hypothesis
At most 1*	96.94683	95.75366	0.0413	Reject null hypothesis
At most 2	61.50816	69.81889	0.1920	Fail reject null hypothesis
At most 3	42.45402	47.85613	0.1464	Fail to reject null hypothesis
At most 4	24.99488	29.79707	0.1616	Fail to reject null hypothesis
At most 5	12.05241	15.49471	0.1544	Fail to reject null hypothesis
Trace test indicates 2 cointegrating equations at the 5% level. * denotes rejection of null hypothesis at the 5% level. ** denotes MacKinnon-Haug-Michelis (1999) P-values.				

Source: Estimation

APPENDIX D: Impulse Response Function Result

Figure D-1: Impulse Response Function for Aggregate Energy Consumption Model

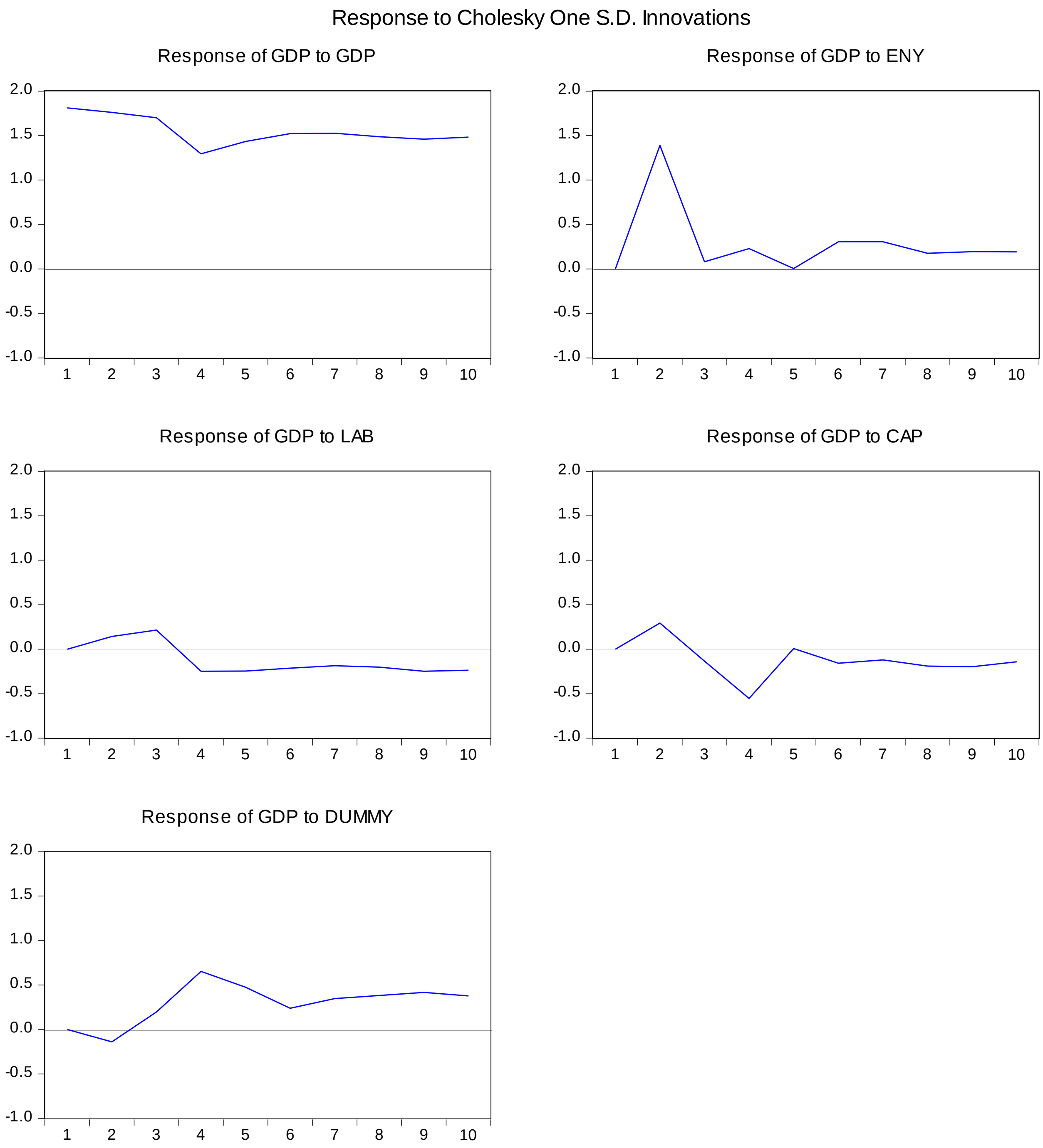


Figure D-2: Impulse Response Function Result for Disaggregated Energy Consumption Model

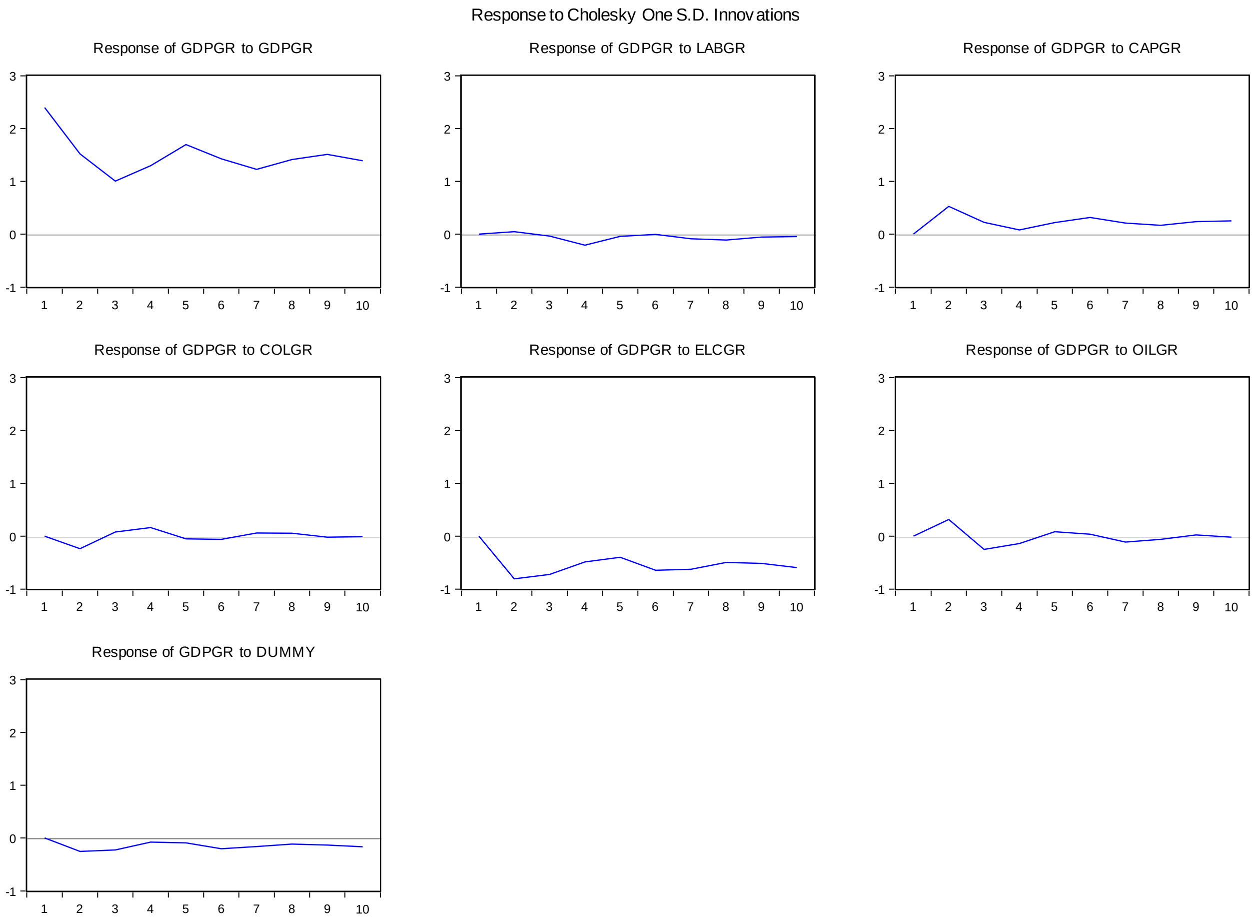


Figure D-3: Impulse Response Function for Primary Sector Energy Consumption Model

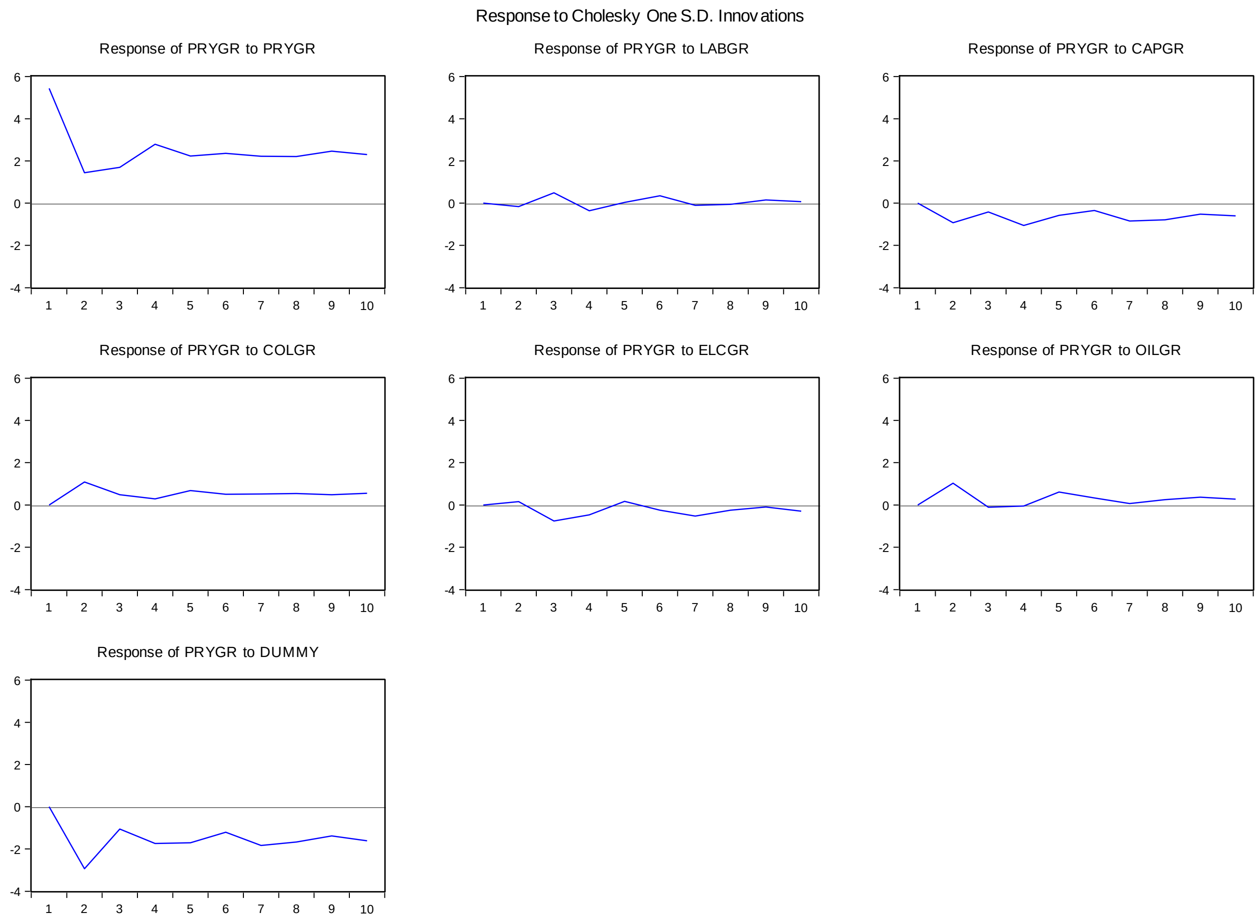


Figure D-4: Impulse Response Function for Secondary Sector Energy Consumption Model

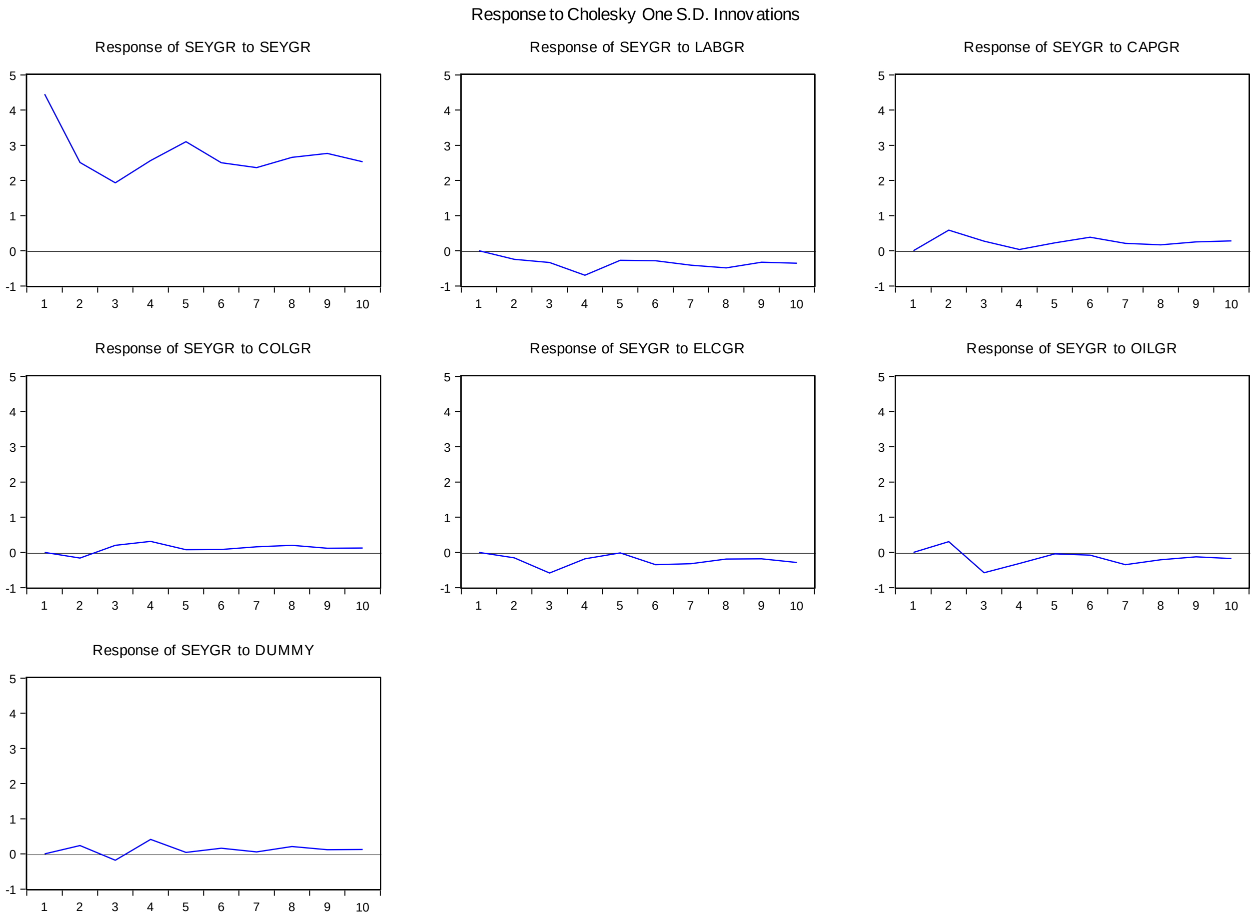
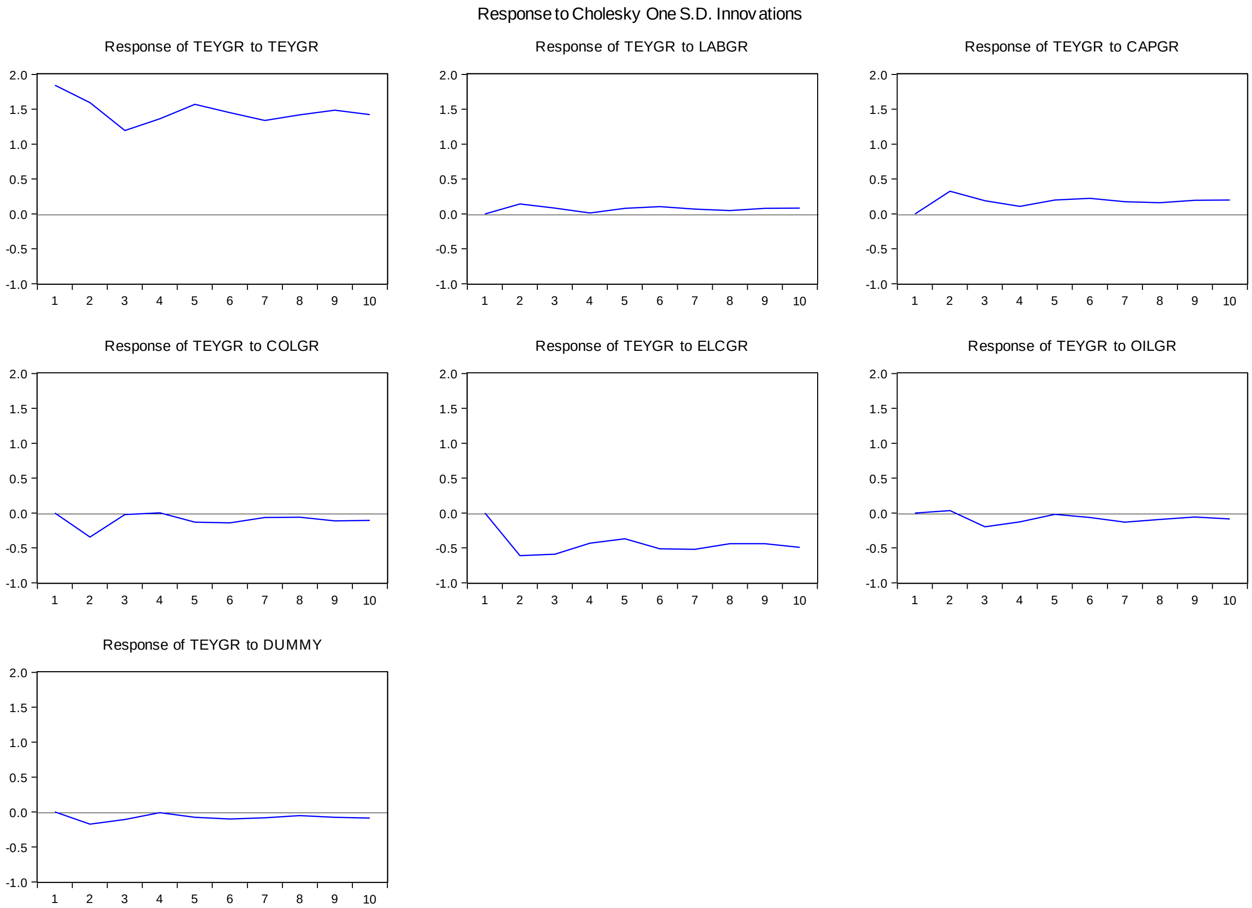


Figure D-5: Impulse response function For Tertiary Sector Energy Consumption Model



APPENDIX E: Variance Decomposition Test Result

Table E-1: Variance Decomposition Result for Aggregate Energy Consumption Model

Period	S.E.	GDPGR	ENYGR	CAPGR	LAB
1	1.785646	100.0000	0.000000	0.000000	0.000000
2	2.978094	71.93869	27.32441	0.734937	0.001965
3	3.457134	76.90929	21.63929	1.391228	0.060196
4	3.831566	73.52808	20.22154	6.115950	0.134430
5	4.108286	73.87220	18.80894	6.343463	0.975399
6	4.430398	74.35531	17.77362	6.420526	1.450537
7	4.735735	74.43028	17.40588	6.387913	1.775929
8	5.010744	74.55946	16.71877	6.704097	2.017673
9	5.267585	74.38542	16.27490	7.054145	2.285533
10	5.511701	74.38211	15.85541	7.207198	2.555281

Cholesky Ordering: GDPGR ENYGR CAPGR LAB

Table E-2: Variance Decomposition Result for Disaggregated Energy Consumption Model

Period	S.E.	GDPGR	LABGR	CAPGR	COLGR	ELCGR	OILGR	DUMMY
1	2.397880	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	3.035408	87.49327	0.025975	2.987045	0.600297	7.111912	1.089751	0.691751
3	3.304153	83.06010	0.032800	2.974439	0.564101	10.82564	1.495112	1.047802
4	3.597010	83.10498	0.365145	2.559274	0.676830	10.95293	1.410883	0.929961
5	4.005976	84.95935	0.304125	2.366826	0.562479	9.823967	1.181855	0.801394
6	4.318674	84.03657	0.261728	2.571500	0.503726	10.69412	1.024326	0.908027
7	4.543725	83.22883	0.272581	2.535155	0.472303	11.56076	0.985813	0.944558
8	4.790919	83.58017	0.297250	2.402045	0.438257	11.47341	0.902383	0.906482
9	5.058166	83.92442	0.277443	2.372511	0.394478	11.33790	0.811885	0.881356
10	5.288508	83.68603	0.261083	2.400916	0.361089	11.64049	0.743915	0.906474
Cholesky Ordering: GDPGR LABGR CAPGR COLGR ELCGR OILGR DUMMY								

Table E-3: Variance Decomposition for Primary Sector Energy Consumption Model

Period	S.E.	PRYGR	LABGR	CAPGR	COLGR	ELCGR	OILGR	DUMMY
1	5.432323	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	6.586615	72.82256	0.062482	1.992081	2.728025	0.059427	2.419144	19.91629
3	6.971158	70.92882	0.547289	2.140404	2.912748	1.234850	2.184550	20.05134
4	7.808914	69.30736	0.649158	3.552898	2.455028	1.335718	1.745403	20.95444
5	8.368300	67.42689	0.567027	3.567801	2.801147	1.202483	2.058172	22.37648
6	8.817201	67.90926	0.667463	3.368178	2.849437	1.164287	1.999121	22.04225
7	9.345091	66.11555	0.605882	3.820974	2.838509	1.346449	1.784334	23.48830
8	9.798370	65.20172	0.554395	4.114752	2.890547	1.288446	1.690702	24.25944
9	10.23001	65.59774	0.530017	4.033736	2.877635	1.191284	1.680383	24.08920
10	10.64743	65.21111	0.494180	4.045407	2.924983	1.175647	1.618125	24.53054

Cholesky
Ordering:
PRYGR
LABGR
CAPGR
COLGR
ELCGR
OILGR
DUMMY

Table E-4: Variance decomposition for Secondary Sector Energy Consumption Model

Period	S.E.	SEYGR	LABGR	CAPGR	COLGR	ELCGR	OILGR	DUMMY
1	4.452832	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	5.168218	97.75397	0.228038	1.278868	0.101133	0.091734	0.342040	0.204215
3	5.601131	95.10061	0.552217	1.329436	0.217351	1.165155	1.356880	0.278348
4	6.232248	93.74289	1.700992	1.076552	0.429778	1.026735	1.356011	0.667044
5	6.972122	94.72683	1.508097	0.964481	0.355725	0.821005	1.086979	0.536881
6	7.434107	94.66672	1.473988	1.109551	0.325808	0.940125	0.966425	0.517382
7	7.830787	94.43570	1.606356	1.069457	0.334432	1.013802	1.068447	0.471808
8	8.295506	94.41710	1.775111	0.994729	0.356579	0.955990	1.017051	0.483443
9	8.758111	94.67003	1.731312	0.976206	0.336841	0.901319	0.933141	0.451154
10	9.136142	94.68442	1.743531	0.991204	0.327712	0.925256	0.894882	0.432996

Cholesky Ordering:
SEYGR LABGR
CAPGR COLGR
ELCGR OILGR
DUMMY

Table E-5: Variance Decomposition for Tertiary Sector Energy Consumption Model

Period	S.E.	TEYGR	LABGR	CAPGR	COLGR	ELCGR	OILGR	DUMMY
1	1.843671	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	2.567449	90.12689	0.304632	1.581605	1.810591	5.700795	0.015589	0.459903
3	2.909363	87.06171	0.316714	1.651144	1.415780	8.578808	0.482849	0.492994
4	3.246079	87.55075	0.255668	1.437367	1.137358	8.678169	0.543786	0.396900
5	3.634405	88.50157	0.250892	1.442796	1.040452	7.967349	0.436673	0.360264
6	3.959745	88.01396	0.277935	1.531780	1.005458	8.406172	0.395927	0.368766
7	4.219667	87.56164	0.271922	1.518787	0.909604	8.927209	0.447871	0.362967
8	4.478209	87.78289	0.253261	1.475896	0.826020	8.885727	0.440413	0.335794
9	4.745642	87.96955	0.252828	1.480062	0.792153	8.772662	0.407502	0.325241
10	4.986661	87.82802	0.257060	1.497479	0.764530	8.928689	0.398712	0.325509

Cholesky Ordering: TEYGR LABGR CAPGR COLGR ELCGR OILGR DUMMY

APPENDIX F: Short run Causality Test Result

Table F-1: Result of Short Run Causality of the Aggregate Energy Consumption Model

VARIABLES:	D(GDPGR)	D(ENYGR)	D(LABGR)	D(CAPGR)	D(DUMMY)
D(GDPGR(-1))	0.066591	0.003658	-0.344202	0.021960	-0.009248
	(0.15931)	(0.00289)	(0.69092)	(0.01197)	(0.02849)
	[0.41800]	[1.26422]	[-0.49818]	[1.83509]	[-0.32456]
D(ENYGR(-1))	41.77832	-0.379441	7.700184	0.048104	-2.140756
	(9.03600)	(0.16412)	(39.1892)	(0.67874)	(1.61612)
	[4.62354]	[-2.31191]	[0.19649]	[0.07087]	[-1.32463]
D(LABGR(-1))	0.005122	0.000828	0.473021	0.004801	-0.000777
	(0.04394)	(0.00080)	(0.19057)	(0.00330)	(0.00786)
	[0.11657]	[1.03741]	[2.48219]	[1.45473]	[-0.09889]
D(CAPGR(-1))	2.960577	0.148166	-2.488418	-0.021545	0.330189
	(2.45816)	(0.04465)	(10.6611)	(0.18465)	(0.43965)
	[1.20439]	[3.31850]	[-0.23341]	[-0.11668]	[0.75103]
D(DUMMY(-1))	-0.597356	-0.034313	-0.199416	-0.221886	-0.231780
	(1.01996)	(0.01853)	(4.42359)	(0.07661)	(0.18242)
	[-0.58567]	[-1.85217]	[-0.04508]	[-2.89613]	[-1.27056]
C	0.143875	-0.003946	1.939248	-0.008087	-0.006234
	(0.36152)	(0.00657)	(1.56793)	(0.02716)	(0.06466)
	[0.39797]	[-0.60095]	[1.23682]	[-0.29780]	[-0.09642]

Source: Estimation

Table F-2: Short Run Causality Test for Disaggregated Energy Consumption Model

Error Correction:	D(GDPGR)	D(LABGR)	D(CAPGR)	D(COLGR)	D(ELCGR)	D(OILGR)
D(GDPGR(-1))	0.086793	-0.090788	1.023190	0.155320	0.503574	0.733067
	(0.34412)	(0.64608)	(1.06410)	(0.75082)	(0.56826)	(0.43852)
	[0.25222]	[-0.14052]	[0.96156]	[0.20687]	[0.88616]	[1.67169]
D(LABGR(-1))	0.087261	-0.006198	0.436355	0.539037	0.216149	0.435009
	(0.12383)	(0.23250)	(0.38293)	(0.27019)	(0.20450)	(0.15781)
	[0.70466]	[-0.02666]	[1.13952]	[1.99503]	[1.05698]	[2.75662]
D(CAPGR(-1))	-0.025664	-0.009749	-0.329560	-0.091458	-0.070110	-0.111377
	(0.05378)	(0.10096)	(0.16629)	(0.11733)	(0.08880)	(0.06853)
	[-0.47724]	[-0.09656]	[-1.98188]	[-0.77949]	[-0.78951]	[-1.62530]
D(COLGR(-1))	-0.148876	-0.129347	0.065382	-0.533429	-0.222373	-0.406154
	(0.09905)	(0.18596)	(0.30628)	(0.21611)	(0.16357)	(0.12622)
	[-1.50305]	[-0.69555]	[0.21347]	[-2.46832]	[-1.35954]	[-3.21782]
D(ELCGR(-1))	-0.135148	-0.113542	-0.957233	-0.348183	-0.420420	0.039952
	(0.17856)	(0.33524)	(0.55214)	(0.38958)	(0.29486)	(0.22754)
	[-0.75689]	[-0.33869]	[-1.73368]	[-0.89373]	[-1.42583]	[0.17558]
D(OILGR(-1))	0.411872	0.166930	0.913605	0.346829	0.618775	0.617998
	(0.15143)	(0.28431)	(0.46827)	(0.33040)	(0.25007)	(0.19297)
	[2.71984]	[0.58714]	[1.95104]	[1.04971]	[2.47441]	[3.20250]
D(DUMMY(-1))	-0.136815	-1.753157	5.174908	2.980427	0.623841	2.240004
	(1.26502)	(2.37506)	(3.91176)	(2.76010)	(2.08901)	(1.61204)
	[-0.10815]	[-0.73815]	[1.32291]	[1.07983]	[0.29863]	[1.38954]
C	-0.009079	-0.155571	-0.445158	-0.809293	-0.463155	-0.228722
	(0.44880)	(0.84262)	(1.38780)	(0.97922)	(0.74113)	(0.57192)
	[-0.02023]	[-0.18463]	[-0.32077]	[-0.82647]	[-0.62493]	[-0.39992]

Source: Estimation

Table F-3: Short Run Causality Test for Primary Sector Energy Consumption Model

Error Correction:	D(PRYGR)	D(LABGR)	D(CAPGR)	D(COLGR)	D(ELCGR)	D(OILGR)	D(DUMMY)
D(PRYGR(-1))	-0.324716	0.046795	0.073368	-0.126321	0.183154	0.104851	0.022965
	(0.19820)	(0.15421)	(0.27249)	(0.17837)	(0.13851)	(0.12314)	(0.01197)
	[-1.63832]	[0.30346]	[0.26925]	[-0.70819]	[1.32230]	[0.85149]	[1.91810]
D(LABGR(-1))	0.061874	0.004518	0.464196	0.529084	0.215249	0.415404	0.001667
	(0.29876)	(0.23245)	(0.41074)	(0.26887)	(0.20879)	(0.18561)	(0.01805)
	[0.20710]	[0.01944]	[1.13015]	[1.96780]	[1.03094]	[2.23800]	[0.09237]
D(CAPGR(-1))	-0.029597	0.003282	-0.222471	-0.094665	-0.051869	-0.105471	0.011417
	(0.12806)	(0.09963)	(0.17605)	(0.11524)	(0.08949)	(0.07956)	(0.00774)
	[-0.23113]	[0.03294]	[-1.26367]	[-0.82143]	[-0.57960]	[-1.32571]	[1.47592]
D(COLGR(-1))	-0.044122	-0.162103	0.109843	-0.467999	-0.249517	-0.394413	0.015062
	(0.24169)	(0.18804)	(0.33228)	(0.21751)	(0.16890)	(0.15016)	(0.01460)
	[-0.18256]	[-0.86205]	[0.33058]	[-2.15162]	[-1.47727]	[-2.62667]	[1.03166]
D(ELCGR(-1))	0.034751	-0.106773	-0.527094	-0.275895	-0.370421	0.170569	-0.001048
	(0.38755)	(0.30152)	(0.53280)	(0.34878)	(0.27084)	(0.24078)	(0.02341)
	[0.08967]	[-0.35411]	[-0.98928]	[-0.79104]	[-1.36769]	[0.70841]	[-0.04478]
D(OILGR(-1))	0.803530	0.225800	1.325327	0.341922	0.606410	0.468992	0.002109
	(0.35086)	(0.27298)	(0.48236)	(0.31576)	(0.24520)	(0.21798)	(0.02119)
	[2.29019]	[0.82717]	[2.74759]	[1.08287]	[2.47317]	[2.15154]	[0.09951]
D(DUMMY(-1))	-3.948803	-1.592206	4.612116	2.318502	1.785133	4.034400	-0.278263
	(3.20317)	(2.49217)	(4.40373)	(2.88271)	(2.23853)	(1.99006)	(0.19350)
	[-1.23278]	[-0.63888]	[1.04732]	[0.80428]	[0.79746]	[2.02727]	[-1.43808]
C	0.118899	-0.149344	-0.148969	-0.748299	-0.479558	-0.232144	0.017719
	(1.07404)	(0.83563)	(1.47659)	(0.96658)	(0.75059)	(0.66728)	(0.06488)
	[0.11070]	[-0.17872]	[-0.10089]	[-0.77417]	[-0.63891]	[-0.34790]	[0.27310]

Source: Estimation

Table F-4: Short Run Causality Test for Secondary Sector Energy Consumption Model

Error Correction:	D(SEYGR)	D(LABGR)	D(CAPGR)	D(COLGR)	D(ELCGR)	D(OILGR)	D(DUMMY)
D(SEYGR(-1))	-0.333238	-0.137488	-0.026616	0.123184	-0.054727	0.372432	-0.002912
	(0.35862)	(0.36107)	(0.60036)	(0.41355)	(0.31362)	(0.26427)	(0.03049)
	[-0.92922]	[-0.38078]	[-0.04433]	[0.29787]	[-0.17450]	[1.40929]	[-0.09552]
D(LABGR(-1))	0.008624	-0.040576	0.357775	0.532661	0.237129	0.549046	-0.002042
	(0.24359)	(0.24526)	(0.40780)	(0.28090)	(0.21303)	(0.17950)	(0.02071)
	[0.03540]	[-0.16544]	[0.87734]	[1.89625]	[1.11313]	[3.05867]	[-0.09863]
D(CAPGR(-1))	-0.054745	-0.003110	-0.305728	-0.117158	-0.037494	-0.134705	0.007444
	(0.10413)	(0.10484)	(0.17433)	(0.12008)	(0.09107)	(0.07674)	(0.00885)
	[-0.52572]	[-0.02966]	[-1.75376]	[-0.97565]	[-0.41172]	[-1.75543]	[0.84089]
D(COLGR(-1))	-0.221088	-0.129569	0.187333	-0.502742	-0.195436	-0.363160	0.024925
	(0.17572)	(0.17691)	(0.29416)	(0.20263)	(0.15367)	(0.12949)	(0.01494)
	[-1.25821]	[-0.73238]	[0.63684]	[-2.48112]	[-1.27181]	[-2.80465]	[1.66853]
D(ELCGR(-1))	0.136417	-0.080759	-0.721537	-0.435282	-0.235938	-0.015781	-0.000393
	(0.34240)	(0.34473)	(0.57320)	(0.39484)	(0.29943)	(0.25231)	(0.02911)
	[0.39842]	[-0.23427]	[-1.25879]	[-1.10244]	[-0.78795]	[-0.06254]	[-0.01351]
D(OILGR(-1))	0.502706	0.148705	0.906730	0.276295	0.693543	0.618231	-0.015545
	(0.28107)	(0.28298)	(0.47053)	(0.32411)	(0.24580)	(0.20712)	(0.02389)
	[1.78856]	[0.52549]	[1.92705]	[0.85246]	[2.82158]	[2.98491]	[-0.65057]
D(DUMMY(-1))	1.479359	-1.853409	5.772986	3.319243	0.197427	2.017194	-0.345888
	(2.37807)	(2.39429)	(3.98106)	(2.74228)	(2.07967)	(1.75240)	(0.20217)
	[0.62208]	[-0.77410]	[1.45011]	[1.21039]	[0.09493]	[1.15110]	[-1.71086]
C	0.045977	-0.158061	-0.317141	-0.845288	-0.370564	-0.221052	0.018102
	(0.82986)	(0.83552)	(1.38925)	(0.95696)	(0.72573)	(0.61152)	(0.07055)
	[0.05540]	[-0.18918]	[-0.22828]	[-0.88331]	[-0.51061]	[-0.36148]	[0.25658]

Source: Estimation

Table F-5: Short Run Causality Test for Tertiary Sector Energy Consumption Model

Error Correction:	D(TEYGR)	D(LABGR)	D(CAPGR)	D(COLGR)	D(ELCGR)	D(OILGR)	D(DUMMY)
D(TEYGR(-1))	0.108259	-0.187200	0.443274	0.840567	0.588020	0.963750	0.023008
	(0.26928)	(0.65707)	(1.11937)	(0.73568)	(0.60058)	(0.41326)	(0.05508)
	[0.40203]	[-0.28490]	[0.39600]	[1.14257]	[0.97910]	[2.33206]	[0.41770]
D(LABGR(-1))	0.080474	0.008548	0.392173	0.479372	0.172243	0.385881	-0.002562
	(0.09653)	(0.23555)	(0.40128)	(0.26373)	(0.21530)	(0.14815)	(0.01975)
	[0.83365]	[0.03629]	[0.97731]	[1.81765]	[0.80002]	[2.60469]	[-0.12974]
D(CAPGR(-1))	0.009414	-0.005354	-0.275834	-0.097044	-0.081486	-0.102877	0.007189
	(0.03988)	(0.09732)	(0.16579)	(0.10896)	(0.08895)	(0.06121)	(0.00816)
	[0.23603]	[-0.05501]	[-1.66371]	[-0.89060]	[-0.91605]	[-1.68073]	[0.88116]
D(COLGR(-1))	-0.110962	-0.134962	0.147803	-0.536108	-0.190909	-0.389960	0.023954
	(0.07312)	(0.17842)	(0.30396)	(0.19977)	(0.16308)	(0.11222)	(0.01496)
	[-1.51752]	[-0.75641]	[0.48626]	[-2.68362]	[-1.17063]	[-3.47499]	[1.60148]
D(ELCGR(-1))	-0.077792	-0.103665	-0.548836	-0.331045	-0.455949	0.031568	-0.002132
	(0.11273)	(0.27508)	(0.46862)	(0.30799)	(0.25143)	(0.17301)	(0.02306)
	[-0.69006]	[-0.37686]	[-1.17118]	[-1.07486]	[-1.81345]	[0.18246]	[-0.09248]
D(OILGR(-1))	0.252658	0.199155	0.887030	0.213922	0.572353	0.711793	-0.016891
	(0.12590)	(0.30722)	(0.52338)	(0.34398)	(0.28081)	(0.19323)	(0.02575)
	[2.00674]	[0.64825]	[1.69482]	[0.62190]	[2.03824]	[3.68373]	[-0.65584]
D(DUMMY(-1))	-0.143261	-1.659268	5.288757	2.713510	0.219016	1.556788	-0.353053
	(0.97791)	(2.38623)	(4.06514)	(2.67172)	(2.18106)	(1.50081)	(0.20004)
	[-0.14650]	[-0.69535]	[1.30100]	[1.01564]	[0.10042]	[1.03730]	[-1.76493]
C	0.004368	-0.148242	-0.227088	-0.806130	-0.482204	-0.209262	0.017713
	(0.34234)	(0.83535)	(1.42309)	(0.93529)	(0.76353)	(0.52539)	(0.07003)
	[0.01276]	[-0.17746]	[-0.15957]	[-0.86190]	[-0.63155]	[-0.39830]	[0.25294]

Source: Estimation