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THE IMPACT OF ELECTRICITY PRICES ON SECTORAL OUTPUT IN SOUTH AFRICA

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DISSERTATION

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DEDICATION

This dissertation is dedicated to my dearest parents, Mrs. A. Magombedze Gonese, and the late Mr A. E. Gonese.

ABSTRACT

The aim of this research was to investigate the impact of electricity prices on sectoral output in South Africa from 1994 to 2015, using the three basic panel data estimators. The contribution of this study is unique in three aspects. First, it explicitly tests for the impact of electricity prices on sectoral output. Secondly, the research uses the panel data analysis which allows for control of unobserved heterogeneity and variables in the model. More so, the study shows that, besides electricity prices, there are other factors which affect sectoral output in South Africa. The research employed the Hausman test to identify the fixed effect as the appropriate estimator to use among the three estimators (pooled, fixed and random effect). More so, the feasible generalised least of squares (FGLS) and Driscroll Kraay (SCC) estimators were employed to control for heteroscedasticity, autocorrelation and cross-sectional dependence of the model of the study. The Hausman test results indicate the fixed effect as the appropriate estimator which allows cross-sectional differences. Therefore, the seemingly unrelated regression (SUR) model was employed to analyse output response to electricity price changes at sectoral level. Electricity prices were found to be statistically significant to explain the sectoral output movements in South Africa. More so, out of eight sectors employed in the study, six sectors (agriculture, manufacturing, communication, finance, trade and general government service) were found to be sensitive to electricity prices. However, electricity prices have an insignificant relationship with the mining sector output. More so, the construction sector output moves in tandem with the electricity prices. In doing so, the policy implications and recommendations were prepared using these results.

Keywords: Electricity prices, sectoral output, panel data, fixed effect, feasible generalised least of squares, seemingly unrelated regression FGLS, SUR, South Africa.

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller test
ARDL	auto-regressive distribution lag
ASGISA	Accelerated and Share Growth Initiative of South Africa
BP/LM	Breusch Pagan/Lagrange Multiplier
CD	cross-sectional dependence
CGE	computable general equilibrium
DME	Department of Energy and Minerals
DMR	Department of Minerals
DoE	Department of Energy
Eskom	Electricity Supply Commission
FBE	free basic electricity
FE	fixed effect
FGLS	feasible generalised least squares
GDP	gross domestic product
GEAR	Growth Employment and Redistribution
IPP	independent power producer
INEP	integrated national electrification programme
IPS	Im Pesaran test
JB	Jarque-Bera
KLEC	Kummel Capital-Labor-Energy and Creativity

LLC	Levin, Lin and Chin test
LSDV	least square dummy variables
MYPD	multiyear price determination
NER	National Electricity Regulator
NERSA	National Energy Regulator of South Africa
NGP	National Growth Path
OECD	Organisation for Economic Co-operation Development
OLS	ordinary least of squares
PCSE	panel corrected standard errors
RDP	Reconstruction and Development Plan
RE	random effect
SARB	South African Reserve Bank
SCC	Driscroll Kraay
SUR	seemingly unrelated regression
TIC	Trade and Industry Chamber
UK	United Kingdom
USA	United States of America
VAR	vector-autoregressive
VECM	vector error correction model

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CHAPTER ONE
INTRODUCTION AND RATIONALE OF THE STUDY

1.1 INTRODUCTION AND BACKGROUND

Output is one of the integral economic indicators that policymakers, analysts and the economic sectors should take into consideration when forecasting on the sustainable economic development goals of the country. Most analysts and economists are mainly concerned with the overall analysis when examining factors that affect the gross domestic product (GDP) of an economy. However, such analysis may lead to misinterpretations of economic and econometric inference, thereby implementing inefficient and unreliable economic policies. The GDP analysis at sectoral levels is better for policy implementation since it allows analysis for sectors separately. From 1994 to 2015, the output levels in South Africa have been fluctuating due to various factors including electricity prices (Boonzaaier, Goliger, Makrelov & McMillan, 2012). According to Inglesi-Lotz and Blignaut (2011), electricity is a low priced hitherto essential good within any economy and is one of the substantial factors of economic growth.

The Local Government Budget and Expendirure Review (2011) confirms that economic sectors (such as mining, agriculture, manufacturing, trade and communication) need electricity to undertake production, communication and a host of other uses. However, its price should not be ignored since it affects the consumption and output of the end users. Boonzaaier *et al.* (2012) suggested that if electricity prices go up, economic sectors may decide to generate their own electricity to maintain their output levels. Some sectors are likely to invest elsewhere in the region or outside the county. More so, other sectors may decide to retrench workers or shut down one or more parts of their business operations. In doing so, these decisions or reactions by economic sectors may lead to capital flight, drop in exports, output decline and high unemployment. Therefore, analysis on output response with regards to electricity at sectoral level will assist policymakers and government, to identify sectors which are vulnerable to electricity price changes. This results in implementing better, efficient and reliable policies for both economic development, as well as environmental energy demand and supply goals.

In South Africa, electricity prices have historically been low and declining as noted in Deloitte (2012), Eskom (2011), Inglesi-Lotz and Blignaut (2011). In doing so, many researchers have been devoted to electricity consumption, demand and output nexus. Thus, the literature on electricity prices and output seems rare and trivial in the energy and economics literature of South Africa. However, following a sudden price increase in 2007/8 by 10.6% per year, economists, policymakers, energy regulators and analysts wondered how these electricity prices affect economic output and the sectoral output in particular. Nonetheless, studies such as Inglesi-Lotz (2014) predicted electricity prices as a limiting factor in both the economy and the South African economic sectors' (manufacturing, mining, construction, transport and communication, agriculture trade and finance) output. Electricity as a form of energy is one of the substantial factors of industrialisation and development in any economy (Ciarreta & Zarraga, 2010; Polemis & Dagoumas, 2013; Altman, Davies, Mather, Flemming & Harris, 2008). According to Musango and Brent (2011), electricity as an energy form is of key importance for economic growth. In South Africa, electricity is consumed depending on the nature of activities which dominate the economy (Department of Energy, 2005).

In addition to that Winkler (2006) posited that an energy carrier (electricity) plays an essential role in the day-to-day operations of the South African economy, bringing benefits and progress in different sectors including mining, manufacturing, agriculture, construction, communication, trade and finance. Consequently, none of these sectors can survive or operate without consuming energy or electricity in particular (Chen, Kuo, & Chen, 2007; Adebola, 2011). In a global sense, electricity, as noted by Chontanawat, Hunt and Pierse (2006), is considered as a lifeblood or backbone of every economy since lack of it holds back industrialisation, leading to decline in the GDP.

The Electricity Supply Commission (Eskom) (2011) noted that the South African economic sectors, particularly the sectors selected for this study, are highly energy intensive. Therefore, the wholesale, finance, agriculture, manufacturing, communication, mining, construction and government services have recorded relatively high levels of electricity use as inputs of production. Given this, the impact of electricity prices on those sectors cannot be ignored because usage and consumption are obviously affected by prices.

Starting with the seminal work of Kraft and Kraft (1978), several authors have utilised causality tests to investigate the relationship between energy and economic growth in developed, as well as developing countries such as South Africa in particular. Numerous studies (Inglesi-Lotz, 2012; Inglesi-Lotz, 2014; Inglesi-Lotz & Blignaut, 2011) have been devoted to sensitivity of industrial sector electricity consumption or demand to electricity tariff changes. However, the discussions pertaining to this relationship have been concerned with aggregated levels. For instance, various researchers (Inglesi-Lotz & Blignaut, 2011; Ciarreta & Zarraga, 2010; Ghosh, 2002) put more emphasis on energy consumption, price and economic growth than output at sectoral levels.

There is limited literature concerning the relationship between electricity prices and economic growth in developing countries and specifically in South Africa at sectoral levels. While it can be assumed that output is the main driver of electricity consumption, the impact of electricity tariffs on disaggregated sector output has not been taken into enough consideration. Therefore, the prices of energy and electricity in particular, as noted in Dunkerley (1982) and Hoa (1993) should not be ignored since they affect output and electricity demand by end users. Jorgenson (1984), Rosenberg (1983) and Schurr and Netschert (1960) suggested that output or output price of a sector is determined by the input (capital, labour, electricity, non-electric and material) prices. Literature has discussed how economic sectors' electricity consumption responds to electricity prices. Even so, the price impact on sectoral output has rarely been discussed. Yes, the prices may affect consumption, usage and demand for electricity across economic sectors, but these prices not give a real picture of how the sectoral output is affected. Therefore, the need arose for this kind of study to assess the real impact of electricity prices on the output of selected sectors in South Africa.

Again, several works (such as Adebola, 2011; Polemis & Dagoumas, 2013; Inglesi-Lotz, 2014) adopted the time series and cross-sectional methods in examining electricity consumption, prices and output. However, the use of time series data as posited in Torres-Reyna (2010) does not control heterogeneity bias within different economic sectors. Hence, it became difficult to determine the real effect of electricity prices on sectoral output. The period of study used by various authors has provided an important contribution towards electricity prices' effectiveness on economic and sectoral output in particular. Studies such as Blignaut, Inglesi-Lotz, and Weideman (2015), Inglesi-Lotz (2014) and Inglesi-Lotz and Blignaut (2011) examined the relationship between electricity consumption and prices and economic output over the periods 2002-2011, 1970-2007 and 1993-2006 respectively. This implies that these stated dates had low electricity trend records which also led to a weak and insignificant impact of electricity prices on output of the country.

In other words, the main economic contributors such as manufacturing, trade and financial services sectors are electricity intensive and they make a major contribution to gross national product in developed countries (Polemis & Dagoumas, 2013). In South Africa, the agriculture, mining, manufacturing, construction, wholesale, transport and communication, finance and general government sectors contribute 2.4%, 8%, 13%, 4%, 15%, 10%, 20% and 23.1% to GDP (Deloitte, 2012). Hence, electricity is considered among other forms of energy as one of the essential factors which operates almost all economic resources and considered as operating expenditure (Tang & Tan, 2013). This is because its crisis or shortage directly shakes all sectors of the economy (such as agriculture, mining, trade, general government among others) as it promotes poverty, lowers economic growth and increases inflation (Kohler, 2013).

According to Deloitte (2012), the agriculture, mining, manufacturing, banking, trade and construction sectors remain the largest contributors to GDP, generating almost 60% of overall national output. These sectors provide a locus for stimulating growth as the main food providers and earners of foreign exchange. The sectors are employment source providers, a source of capital as noted by the Department of Agriculture Forestry and Fisheries (2014). In addition to that, Eskom (2011) suggests that these sectors are also buyers of goods and providers of inputs to other sectors and among themselves. Thus, the information processes and day-to-day operations of these sectors are mostly activated by electricity such that the electricity price becomes an input (Stresing, Lindenberger & Kummel, 2008) and a constraint to these sectors (Soytas & Sari, 2007; Soytas & Sari, 2003). Indeed, the importance of any individual sector suggested by Eskom Holdings Ltd (2017) should be measured in relation to its employment and production growth. Therefore, examining the impact of electricity prices on each sector will help the government, policy makers, regulators and electricity suppliers to easily identify the root of electricity bearing on the aggregate GDP.

The South African economy has been facing the challenge of electricity price increases since 2008. The main reason for price hikes in South Africa is that the utility company aimed to expand the industry so as to be sustainable (Pegels, 2010). Therefore, increasing the tariff is another way of raising capital for future investments; however, it is a burden to both aggregate and individual economic sectors in the country (Inglesi-Lotz & Blignaut, 2011;Inglesi-Lotz &

Blignaut, 2012; Kohler, 2013). These constraints on electricity supply have adverse effects on electricity intensive sectors (such as mining, finance, manufacturing, agriculture, communications, trade among others), which ultimately affects economic growth (Eskom, 2011). Although the electricity-growth relationship has been examined, the main focus has been on the developed countries (Chima & Freed, 2005; Tang, Shahbaz and Arouri, 2013; Polemis & Dagoumas, 2013). More so, previous studies in the South African context (Inglesi-Lotz, 2014; Odhiambo, 2010) have shown different results, with price and income as the key drivers of electricity consumption, considering a neutral hypothesis between electricity price and economic growth.

Previous studies (Inglesi-Lotz, 2014; Tang & Tan, 2013; Ciarreta & Zarraga, 2010) were much concerned with electricity consumption and GDP. Again, electricity prices are considered to be very small as a proportion of the GDP. This study will enable a clear understanding of the fact that electricity can be treated as a separate factor of production unlike the standard production theory and other works of energy economics literature, which regards electricity price as an insignificant variable. Furthermore, recent studies have focused on the effect of electricity prices on electricity consumption aggregate growth and electricity demand. Findings from mixed research techniques and methods brought no consensus on the causality between these variables (Boonzaaier, Goliger, Makrelov, & Mcmillan, 2015; Inglesi-Lotz & Blignaut, 2012).

Therefore, in light of the above discourse, the researcher identified the need to conduct a detailed study regarding the effect of electricity tariffs on real sectoral output in developing countries such as South Africa. This study estimated the likely effects of electricity prices on sectoral output in South Africa. Apart from that, this study examined the sectoral output responses with regards to electricity price changes using panel data analysis. Moreover, the use of the panel data technique in this research helps to determine the real impact of electricity prices on each and every selected economic sector in the study. Panel data controls heterogeneity and omitted variables. Again, the use of robust standard error estimators provides consistent and efficient inferences. The three basic models (pooled, fixed and random effect) were employed in the study. Again, panel data allows individual heterogeneity. Hence, to analyse the impact of electricity prices for each and every sector, the study implemented the seemingly unrelated regression (SUR) models which give the possibility of sectoral analysis separately. Panel data allows the use of robust standard error estimators of which this study utilised the feasible generalised least squares (FGLS), and Driscroll-Kraay (SCC). All estimation techniques were implemented in the Stata package. This enabled revealing the real picture on how the economic output responds to electricity price changes at sectoral level in South Africa.

1.2 STATEMENT OF PROBLEM

Electricity prices were low and declining in South Africa until 2008 when they increased by almost 10.6% per year (Inglesi-Lotz and Blignaut, 2011; Deloitte, 2012). According to Deloitte (2012), different economic sectors (mining, manufacturing, construction, communication, wholesale and trade, finance trade and catering) are vulnerable to electricity prices mostly because of their dependence on electricity as an input to production. Again high electricity prices may cause capital flight, drop in exports output decline and high unemployment (Boonzaaier *et al.,* 2012). Nonetheless, Lange (2008) proposed that the era of low electricity prices is about to change. Analysts and economists wonder how these prices will affect economic growth. However, very much attention has been devoted to electricity consumption, prices and GDP relationship and there has been little focus on how electricity prices affect output at sector level. The matter of electricity prices and sectoral real output has not been clearly discussed in South Africa since most of the studies (Odhiambo, 2009; Inglesi-Lotz, 2012; Kohler, 2013) have focused on the impact of electricity consumption on demand and aggregate economic growth.

In addition, Inglesi and Pouris (2010) hypothesised that one of the causes of the electricity demand and supply crisis was the lack of research on energy and output in general. This confirms that there is still lack of research on electricity prices and sectoral output in South Africa. Generalising electricity prices on overall GDP may be challenging for policymakers and government to identify the degree of electricity price influence across sectors, and this may lead to futile policy implementations. Also, most methods that evaluated the electricity-growth relationship (Eskom, 2011; Khanna & Rao, 2009; Soytas & Sari, 2007) fell into the omitted variable trap as they used time series and cross sectional system (Masuduzzaman ,2013), with some researchers using surveys and other techniques which suffered data availability, especially in developing countries (Boonzaaier *et al.*, 2015).

Therefore, this persisting limitation induced some researchers to recommend the need for quantitative analysis on the impact of pricing, privatisation and distribution of electricity on output in developing countries (Khanna *et al.,* 2009). Furthermore, analysis of the effect of electricity price on real sector output is scant, especially using panel data which allows control of individual heterogeneity (Schmidheiny, 2015; Torres-Reyna, 2010). This study therefore aimed to test the findings from the developed countries with regards to the electricity price-growth relationship (that economic growth decline is associated with sectoral productivity rate rather than other factors and strongly associated with increased energy prices) (Ciarreta & Zarraga,2010; Chima and Freed, 2005), using panel data analysis in South Africa.

As stated, various studies adopted the standard model where electricity consumption is a function of income/output and electricity prices. This study adopted the production function where electricity is considered as an additional input in the economic sectors. Usually, electricity in any sector is recorded as an operating expenditure; therefore in this study, electricity price is the main regressor.

1.3 RESEARCH OBJECTIVES

The broader objective of this study was to examine the impact of electricity prices on sectoral output in South Africa from 1994 to 2015.

Specific objectives included the following:

- To review trends in electricity prices and sectoral output over the period 1994-2015.
- To econometrically examine the impact of electricity prices on sectoral real output over the same period.
- To make policy recommendations based on the findings.

1.4 RESEARCH HYPOTHESIS

H_0: The impact of electricity prices on real output does not vary across different sectors in South Africa.

H_1: The impact of electricity prices on real output varies across different sectors in South Africa.

1.5 SIGNIFICANCE OF THE STUDY

Studies that reviewed the link between electricity prices and output used qualitative research methods such as surveys and the standard model where electricity consumption is the function of output and electricity prices. More so, the mainstream growth models consider only output as a function of labour and capital where energy is regarded as a less effective input of production.

The impact of electricity prices on output and sectoral output has been analysed at aggregate levels. Hence, this study provides an analysis of how the selected real sector output responds to electricity price changes in South Africa. Empirical literature on electricity prices and output considered the period when electricity prices were low and declining between 1970 and 2006. This research combined a period when electricity prices were low and hiking and thus the study covers 22 years from 1994 to 2015. Economic sectors regard electricity prices as input cost. Therefore, cost is considered an important economic indicator. In doing so, electricity prices become useful in understanding the impact of the entire power sector on sectoral output. This study sought to bring an understanding of the effect of electricity prices on sectoral output as opposed to aggregate analysis. In doing so, the electricity price was the main independent variable with an investigation of its impact on the South African economic sectors such as agriculture, manufacturing, trade, mining, construction and banking.

The panel data analysis was employed with fixed coefficients as betas (β) to categorise the variances of electricity prices on sectoral output, since this estimation technique accounts for differences across economic sectors (individual heterogeneity). More so, unlike other estimation techniques, the panel data system offers an alternative to estimate if unobserved individual specific effects are assumed (Cameron, Pravid & Trivedi, 2005). Panel data offers a means of determining the extent of econometric problems that frequently arise in the empirical studies such as the presence of omitted (unobserved) variables that are correlated with explanatory variables (Sibanda, Mishi & Tsegaye, 2015). More so, Lockwood and McCaffrey (2007) found that panel data leads to less biased and more precise estimates of the effects of substantive variables on individual outcomes than is generally possible with purely cross-sectional observational data. The panel data methods offer optional robust standard error estimators in case of violations (presence of heteroscedasticity, serial and cross sectional correlation) of the assumptions of the linear regression model (Hoechle, 2010). In addition, another benefit of panel data is the improved correctness in estimation. This is due to an increase in the number of observations emanating from the combination of several time periods of data for each individual (Cameron *et al.,* 2005).

This study aimed to provide policymakers with more information on the behaviour of different sectors with regards to electricity price changes, and hence assisting regulators and policymakers in future decisions on electricity price changes in relation to output at sectoral levels. Better knowledge of the link between electricity prices and the real sector output should permit better regulatory decisions to facilitate economic efficiency. Furthermore, it helps the government to identify sectors in need of power subsidies to enhance economic development.

1.6 ORGANISATION OF THE STUDY

The study is divided into six chapters as follows:

The first chapter covers the introduction and background of the study (current chapter). The second chapter gives an overview of the South African economy with respect to the trends in sectorial output, electricity price and other macroeconomic variables that have been included in the study model. Chapter Three reviews both theoretical and empirical literature on the subject area. The fourth chapter presents the research methodology as well as a description of variables and the expected a priori of each. Chapter Five presents the estimates and discusses the results. Policy recommendations, limitations of the research and possible areas for further research are discussed in the last chapter of the dissertation.

CHAPTER TWO

SOUTH AFRICAN ELECTRICITY PRICES AND SECTORAL REAL OUTPUT: AN OVERVIEW

2.1 INTRODUCTION

The main aim of this chapter is to present the synopsis of electricity prices and sectoral output and other macroeconomic variables in South Africa over the period 1994-2015. This chapter also provides an overview of the electricity sector in terms of its generation, transmission and distribution in South Africa. Further, the chapter reviews growth and energy policy changes between 1994 and 2015. In addition, the trends on overall electricity price, sectoral output and other macroeconomic indicators (such as inflation and interest rate) from 1994-2015 are reviewed in this chapter. This will give a clue on the correlation between sectoral output performance and electricity prices in South Africa.

2.2 AN OVERVIEW OF THE SOUTH AFRICAN ELECTRICITY SECTOR

According to Inglesi-Lotz and Blignaut (2011) and Marquard (2006), the period from 1920 till today has marked the third phase of the electricity sector when the state utility, Eskom, was established and became the generator, transmitter and distributor of electricity. Eskom as the state entity has the responsibility of managing the demand and supply of electricity. The sector plans to maintain and expand the current industry in the long term. Kohler (2006) posited that electricity production costs have been cheaper in South Africa due to large coal reserves. In addition to that, Inglesi-Lotz (2010) reasoned that the exemption of Eskom from taxation and dividend payments, exclusion of eternality costs and the maximising economies of scale through technology use were some of the reasons for low and declining electricity prices in the early 1990s. In doing so, the analysis of electricity prices on output was of less concern due to low and declining electricity prices. However, numerous studies were much devoted to electricity consumption and GDP.

According to Thopil and Pouris (2013) and Odhiambo (2010), the electricity sector is regulated by the National Energy Regulator of South Africa (NERSA) which was established in terms of the National Energy Regulator Act of 2004. NERSA is mandated to regulate electricity and other forms of energy through issuing licences, setting and approving tariffs and charges, meditating disputes, gathering information and promoting competition and optimal use of resources (Department of Energy, 2014). More so, the electricity pricing scheme employed by

NERSA is grounded on the multi-year pricing determination (MYPD). Likewise, the MYPD was implemented, based on Eskom's cost recovery requirements to ensure that the utility remains functioning and sustains itself economically. South Africa has an above average energy intensity in the sense that more electricity is used per unit of economic output (Hedden, 2015). Therefore, if the prices of the energy and particularly electricity rise, then the economic output is likely to be affected. For this reason, an analysis on output response to electricity prices at sectoral levels shall assist the NERSA to set an efficient electricity price tag that will enhance South African economic and environmental goals.

One other reason for low and declining electricity prices in the 1990s and late 2000 is that since the democratic transition in 1994, the government rolled out the integrated national electricity programme (INEP). The main aim of the programme, as noted in Kohler (2006), has been to ensure universal access to basic electricity in order to maintain a macroeconomic balance right, attract investors, reduce the budget deficit and fight inflation through high interest rates. This was desirable for investors and business sectors since it increases competitiveness with economic sectors (such as mining, manufacturing, agriculture and trade). However, Eskom Holdings Ltd (2017) opined that the low and subsidised electricity prices lead to wasteful use of energy.

Kenny (2015) posited that South Africa is blessed by abundant coal. Therefore, a cheap source of energy may have been the main cause of declining electricity prices which seems to have less of an impact on sector output performance in South Africa. However, coal is a non-renewable resource which can exhaust in time. Therefore the price hikes in 2008 may have been caused by dilapidating and aging coal reservoirs (Dames, 2012). Apart from that, the increasing demand for electricity from both households and firms forced the power sector to plan to build new generation plants (Kusile and Medupi) in order to cover the electricity demand and supply imbalances (Inglesi-Lotz & Blignaut ,2011). Indeed, the power sector in combination with NERSA also imposed a cost reflective electricity price in order to increase revenue for refurbishment maintenance and expansion of the power sector.

Eskom retails electricity to a range of customers such as the municipalities who also distribute electricity to end users (Steele, Schultz, & Musana, 2012). This implies that the selected sectors in this study are end users of electricity. More so, numerous operations in various sectors are done using electricity. This reveals that electricity price changes are expected to have a negative effect on sectoral output (agriculture, mining, manufacturing, construction, communication, general government, banking and trade) in South Africa. Eskom's overall impact on South Africa is fundamental concerning electricity as the driver of the country's development in economic growth and job creation. Likewise, the government has to set economic objectives to achieve economic growth to create employment, and in that way lessen inequality and poverty, assuming that long-term sustainable economic growth is tied to sufficient, reliable and affordable energy (electricity) availability. An examination of electricity prices on sectoral output will therefore help NERSA, Eskom, the government and the policymakers to impose efficient electricity pricing policies which maintain both the power industry and the economic development of South Africa. The following section presents the generation, transmission and distribution of electricity in South Africa between 1994 and 2015.

2.2.1 An outline of electricity generation, transmission and distribution

According to Newbery and Eberhard (2008), the South African electricity sector is dominated by the state-owned and vertically integrated utility. The Eskom Company generates 95% of the country's electricity, whereas the private generators contribute about 3% of national output (mostly for their own consumption) and municipalities contribute less than 2%. In general terms, the South African power sector is comprised of three components, namely generation, transmission and distribution (Kenny, 2015). The first function is the generation of electricity that is the production of electricity at the utility industry. The Eskom industry as shown in Figure 2.1 produces approximately 95% of the power consumed in the economy from more than 20 power stations (Lange, 2008). Naidoo and Tyre (2006) added that the remaining 5% is generated by the municipality and the private sector which are called the independent power producers (IPPs) Department of Minerals and Energy (Polity), (2008). The monopoly sector reports to the Department of Public Enterprise and it is responsible for all the transmitted electricity in the country (Eberhard, 2001).

Since Eskom is a state-owned enterprise, the government established a group of experts called regulators with statutory powers to set prices charged by utilities. One of the main objectives of the NERSA is to establish an investment-friendly environment capable of attracting capital at reasonable cost (Musango & Brent, 2011). It is of uttermost importance for these institutions to be aware of how the electricity prices affect sectoral output. The NERSA and Eskom aim to expand the power industry. Therefore, a better understanding of the impact of electricity prices on each sector output will assist these power bodies to impose consistent and efficient prices. For instance, if the electricity prices do not affect some sectors then surcharging the prices on those sectors will have less impact. Eskom can use that as a gateway to raise funds for power industry expansion without adversely affecting the sectoral output.

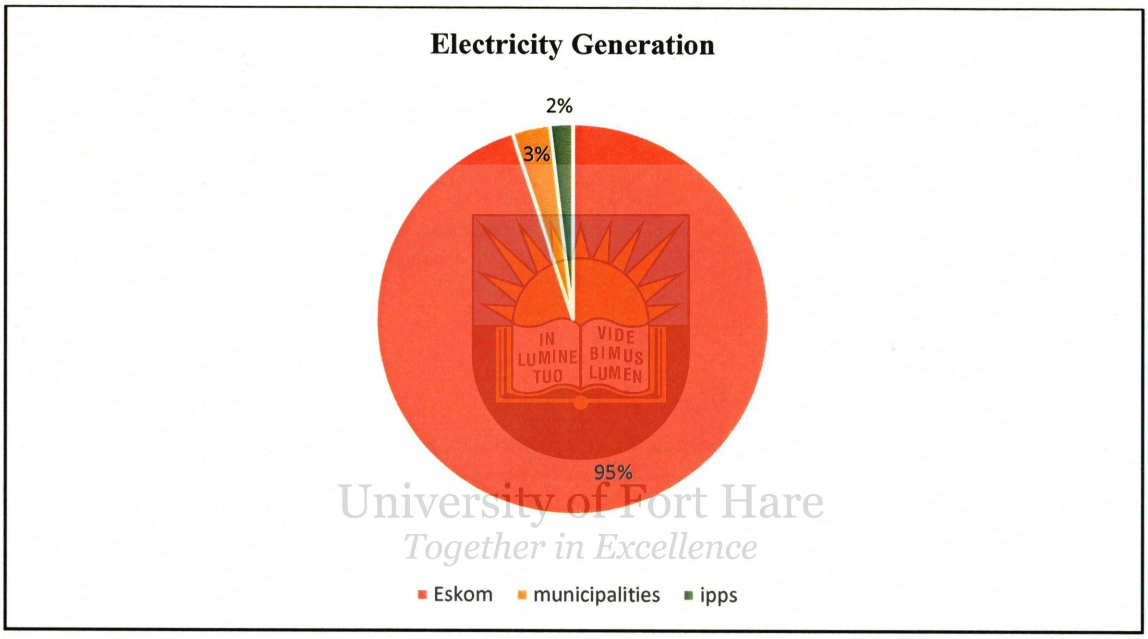

Figure 2.1 Electricity generation in South Africa 1994-2015

*Source: **Author's own** drawing. Data from Department of Energy (2016)*

Furthermore, Eskom is responsible for all transmitted electricity in South Africa (Amra, 2013; Nair, 2014). This implies that the power industry owns the transmission licence. Kenny (2015) suggested that the transmission of electricity involves the bulk transfer of electricity from the power station to the centres of demand. Since Eskom is the generator of last resort, it transmits 100% of the South African transmission (Kenny, 2005). The utility industry uses high voltage on transmission lines, which are more than 1500km, to reduce the cost of supply. The electricity transmission lines are utilised from Eskom and run by an independent state-owned operator who purchases electricity from generators and then sells it to the distributors (Eberhard, 2001). This process is based on commercial consideration whilst political and ideological consideration are not considered. Transmission of electricity from the power industry to the distributors has a certain cost. Therefore when the electricity industry charges its price to the economic sectors, the cost of transmission is included. Thus if the transmission process is expensive, the electricity prices may rise to cover the cost of transmission.

Electricity in South Africa is distributed directly by Eskom and the municipalities which purchase from Eskom and sell it to their end users (Newbery & Eberhard, 2008). Figure 2.2 shows that the Eskom distribution system is responsible for about 60% of electricity directly to its customers while the municipalities purchase the balance (they buy electricity from Eskom and distribute it with an additional mark-up subject to approval by NERSA) and retail it to the consumers (Thopil & Pouris, 2013). The remaining 40% is undertaken by 187 municipalities (Mzini & Lukamba-Muhiya, 2014). The municipality may add onto the total cost incurred when buying electricity from Eskom and surcharge to their customer, which in turn is the municipality's source of revenue.

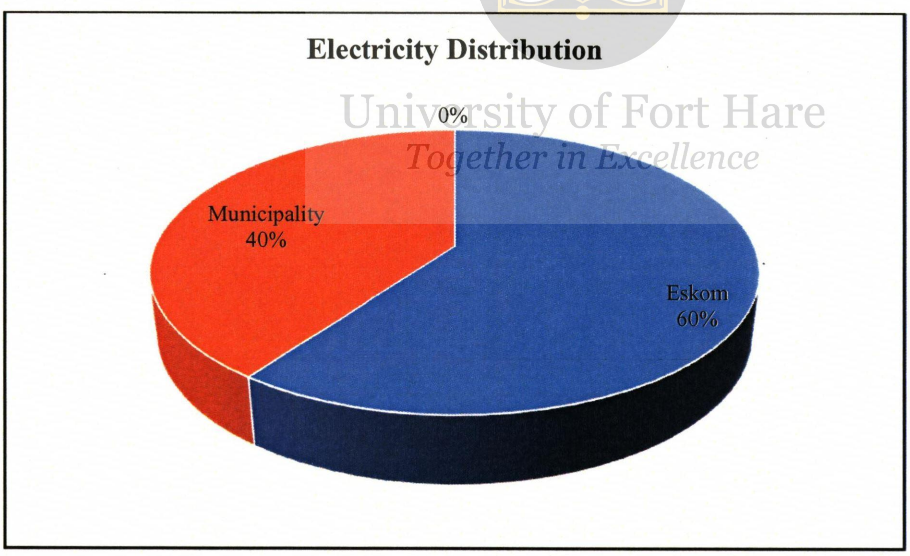

Figure 2.2 Electricity distribution sources

Source: Author's own graph created with figures from Mzini and Lukamba-Muhiya (2014)

Figure 2.2 shows that the responsibility for distribution is shared between Eskom and the municipalities. About 180 municipalities distribute 40% of electricity whilst Eskom distributes to 60% of the customer base. The end use of electricity in South Africa is currently divided between different sectors of the economy which include domestic, agriculture, mining, industrial (which includes manufacturing and construction), transport, general government services and commercial sectors (such as banking, wholesale and trade). This study selected different sectors in terms of their contribution to economic performance. Overall, the selected sectors (agriculture, mining, manufacturing, communication, wholesale and trade, construction, banking and trade) in this study consume almost 68% of electricity distributed in South Africa. This usage is illustrated in Figure 2.3 below.

2.2.2 Usage of electricity by sectors in South Africa (2015)

Figure 2.3 shows the flow of electricity production through distribution to end use customers. It clarifies that the largest proportion of electricity is consumed by the manufacturing sector (38%), followed by the mining sector. Large differences within each sector are due to variations in products, raw material and process.

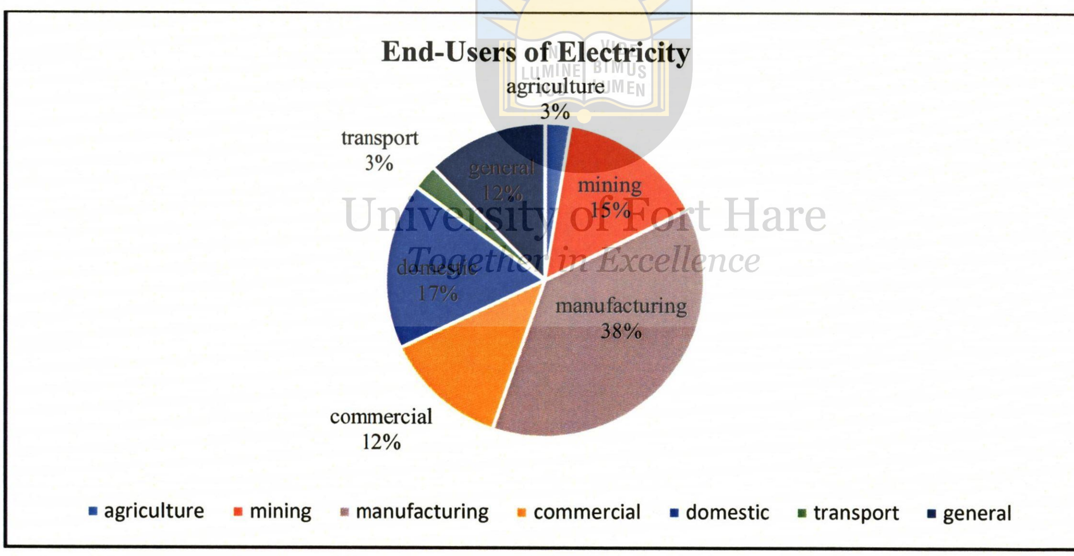

Figure 2.3 Sectoral usage of electricity, 1994-2015

Source: Author's own graph created with figures from Mzini and Lukamba-Muhiya (2014)

Based on the selected sectors by the study, the manufacturing sector consumes more electricity than other sectors. However, agriculture is the lowest end user of electricity although it makes a major contribution as food provider in the South African economy. Although some sectors consume less electricity, it does not justify how they respond to electricity prices. At some point, a sector may consume more electricity without being affected by the prices. Therefore, the researcher of this study saw the need to examine the real impact of electricity prices on each economic sector regardless of their consumption levels. Such analysis may assist the government electricity regulators to charge efficient prices.

2.2.3 Electricity sources in South Africa

Electricity power is a secondary energy source obtained from conversion of energy resources such as fossil fuels (natural gases), oil and coal. Coal has been the fuel mostly used in electricity generation (Hedden, 2015).

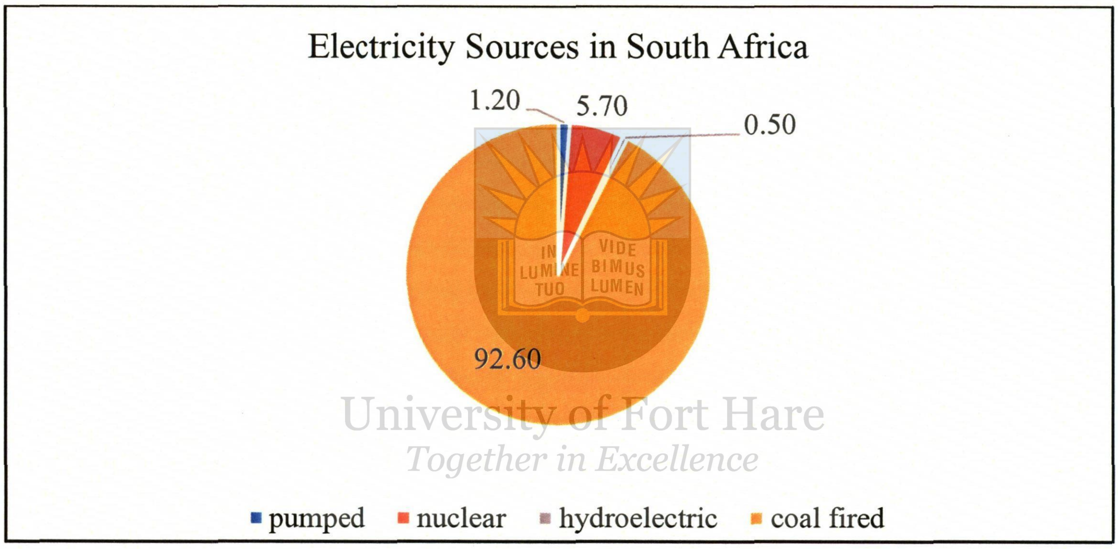

Figure 2.4 Electricity sources in South Africa

Sources: Own graph created with figures from Eskom (2016) and (Kenny, 2015)

Figure 2.4 illustrates that the electricity infrastructure in South Africa is heavily dependent on coal which accounts for 92.6% of electricity sources (Kenny, 2015). Coal accounts for 56% of the total primary energy costs. **South Africa's** electricity prices have been low since there is abundant and cheap coal in the country. Consistently, Eskom Holdings Ltd (2017) opined that the low and declining electricity prices increased consumption, encourage the ineffective use of energy and excessive pollution. Figure 2.4 also shows that the nuclear power accounts for 5.7%, while bagasse, gas fired, hydroelectric and pumped storage account for 2%. This confirms Musango and Brent (2011) who stated that the deployment of renewable energy projects is still slow in South Africa.

2.3 ENERGY POLICIES IN SOUTH AFRICA: 1994-2015

This section gives an overview of the perspectives of the government of South Africa, NERSA and Eskom concerning energy and electricity prices in regards to economic development and sectoral output in the country. Pegels (2010) suggested that the energy sector plays a vital role in the South African economy. However, Borel-Saladin and Turok (2013) argued that the said sector also contributes to environmental degradation. According to Winkler (2005), the energy policies in South Africa intend to increase access to affordable energy, improving energy governance, and inducing economic and social development whilst managing energy-related environmental impacts as well as securing electricity supply through diverse power producers. Musango and Brent (2011) added that the South African government's long-term energy policy goal is the establishment of conditions of energy security, stability and environmental protection. The policies presented in this section include the electricity price subsidy, cost reflective electricity price, renewable energy and electricity efficiency policies.

Winkler (2006) suggested that the energy policies of South Africa are divided into three different periods, namely the apartheid era from 1948 to 1994, the democratic elections 1994 to 2000 and the after-independence period from 2000 onwards. The current study does not cover the apartheid period. However, it does give a brief explanation of some apartheid energy policy reforms since they are likely to have an effect in the transition period. The apartheid era energy policy was developed by the minority government and mostly centred on energy supply security (Winkler, 2006; Van Horen & Simmonds, 1998). Indeed, the energy policy was mostly concerned with electricity consumption and aggregate growth rather than the effect of electricity prices on the various economic sectors of South Africa. The issues of electricity prices impacting on sectoral output were of little concern in the policy reform due to large and cheaper coal reservoirs which led to low electricity prices in the country.

The transition period saw the responsibility for policy-making on energy (electricity) across the various different departments. Energy reform policy became the responsibility of the Department of Minerals (DMR), the Department of energy (DoE) and NERSA (Winkler ,2007; Department of Mineral and Energy (DME), 2005). Winkler (2007) stated that from 1994, the energy policy focus shifted from supply to addressing demand and particularly broadened to include household access to electricity making energy and electricity more affordable for the poor. Indeed, there was more concern about the poor than the business sectors. Historically, the energy economy was largely dependent on abundant and cheap coal. In addition, the power industry was exempted from tax and dividend payment. This led to low electricity and declining prices which in turn led to an increase in investments and output growth. Contrariwise, Eskom Holdings Ltd (2017) propounds that the low and declining electricity prices made it difficult for the utility sector to sustainably amplify production and this eliminated the incentive for private sector investment. This was followed by an underinvestment in energy volume by both the public and private sectors that resulted in an energy supply crisis which in turn obstructed economic growth. The energy policies between 1994 and 2000 were more focused on the demand-side management. Indeed, such policy objectives aimed for a successful, efficient and competitive South African economy by providing low cost and high quality electricity inputs to economic sectors (Eberhard, 2001) – thus improving social equity by specifically addressing the energy requirements of the poor. In doing so, policies such as the Reconstruction and Development Plan (RDP) in combination of the free basic electricity (FBE) and the electricity subsidising policies resulted in 72% of households being electrified since the government wanted to achieve universal access to electricity by 2012 (Pegels ,2010). The FBE and the electricity price subsidy policy encouraged low electricity prices; however, they were not cost-reflective (without true economic costs of production). This resulted in the energy sector facing three major problems. Firstly, it faced undersupply resulting in a narrow reserve margin and power shortages. The second problem is that the energy sector needed the financial assistance of almost 300 billion rand for building new programs, since the electricity prices were not cost reflective. The energy sector has become the highest in emission intensity of the South African economy which results in global climate change and local pollution. Apart from that, the low electricity prices led to wasteful and inefficient use of electricity (Eskom Holdings Ltd., 2017). In doing so, the excess electricity capacity came to an end following electricity demand and supply imbalances which geared for new energy policy reforms.

According to Pegels (2010) and Winkler (2007), the fast growing output growth of about 5% under the Accelerated and Shared Growth Initiative for South Africa economic policy in the early 2000s led to rising electricity consumption . In fact, the future electricity prices were expected to rise since Eskom had been converted into a tax and dividend paying entity although it was fully owned by the state (Amusa *et al.*, 2013). Again, the electricity prices were still not cost reflective which encumbered refurbishment, maintenance and expansion of the power sector. Once more, the sector was in need of financial assistance to curb electricity supply and demand imbalances. In doing so, the DME and government introduced the national response to electricity and the electricity cost reflective pricing policies to tense power sectors' financial situation and encouraged electricity savings among households and business sectors. However, the programme has (still) been slow due public resistance (Eskom Holdings Ltd., 2017).

Baker (2016) added that the coal dependent and carbon dioxide intensity led the government and policymakers to opt for investment in renewable energy to reduce global climate change and local pollution. Sebitosi (2010) confirmed that the renewable energy policy took its mandate from the White Paper of 1998. The policy was mostly centred on the demand rather than the supply-side management. In doing so, it encouraged introduction of independent power producers (IPPs) so as to give end users the right to choose their suppliers. Moreover, the policy encourages renewable energy technologies with which the energy sources include solar, biomass and small scale hydroelectric energy. The policy is in line with climatic change policy which aims at reducing greenhouse carbon emissions and local pollution (Musango & Brent, 2011). The rationale behind the policy was to improve access to clean electricity in remote areas, reduce carbon emissions, enhance energy diversity and promote economic development, towards a sustainable path (Musango & Brent, 2011). However, the renewable resource is still low in progress since the IPPs are hesitant to enter the energy market because the energy prices are not cost reflective. Such challenges demotivate new investors in the market. Again, the programme made a slow progress due to lack of capital costs and personnel needed for testing installation of solar water heaters (Pegels, 2010).

One more energy policy mandated by the White Paper from early 2000 onwards, was the energy efficiency policy (Sebitosi, 2010). The energy efficient policy encompasses programmes such as the demand side management and energy proficiency to reduce energy consumption (Department of Energy South Africa, 2010). The energy efficiency policy targeted an energy efficiency of almost 15% by 2014/15 (Winkler, 2007). The standard offer model focuses much on key industry customers where the industries are being charged for consuming above the baseline. The Department of Minerals and Energy (DME) (2003) and Department of Minerals and Energy (DME) (1998) also suggest that the combination of the aforementioned policy measures will reduce energy system costs by R16 billion (2.2 billion dollars) and carbon dioxide by 770 million tonnes. Although the policy aims to save energy, it is does not consider how the prices affect output from those key industry (such as manufacturing, mining, construction, agriculture and trade and wholesale, and communication) customers.

The energy policy as per government perspective aims to improve access to affordable electricity, with the price target that ensures social equity and economic development. The NERSA negotiates with the government on lowering electricity prices. However, Eskom aims to minimise demand for electricity to avoid electricity wastage. More so, the power industry targets for a price that compensates production costs to avoid supply and demand imbalances. If the electricity pricing is one of the energy efficiency tools, then the NERSA, government and Eskom should be aware of how the electricity price affects output across economic sectors. In doing so, the use of the panel data analysis in this study can provide a better understanding of how electricity prices affect sectoral output. Given that, Eskom, the government and the electricity regulators will be able to identify an efficient price that induces both maintenance and expansion of the power industry as well as economic and sectoral output growth.

2.4 THE ENERGY – GROWTH POLICIES

From 1994 till the present, the South African government has been initiating a series of growth policies which include the Reconstruction and Development Programme (RDP) of 1994, the Growth Employment and Redistribution (GEAR) in 1996, the Accelerated and Share Growth Initiative of South Africa (ASGISA) of 2006 and the National Growth Path (NGP) of 2010.

The RDP growth policy was much concerned with the democratisation of the state and society to create a strong dynamic balanced economy. Concerning the energy sector, the policy considered involvement of various government bodies (such as DMR, DoE, National treasury, Environmental affairs and National Electricity Regulator (NER)) to participate in the energy policy reform process. More so, the RDP was successful in articulating the main aspiration of the movement for post-apartheid such as the FBE grant which was desirable for output growth and investments (Adelzadeh, 1996). However, lack of skilled workers led to the failure of the RDP to achieve is economic goals. The GEAR replaced the RDP in 1996 with the purpose of projecting employment and output growth and reducing deficit to below 3% of GDP and inflation below 6%. More so, the policy intended to achieve a competitive fast GDP growth of 4.2% by 2000.This meant that issues of fast output growth at sectoral output were of less concern. Faulkner and Loewald (2008) and Nattrass (1998) posited that the policy emphasises accelerated economic growth, reduction of unemployment, budget deficit, private and public wage increase, poverty and tightening the monetary policy with an inflation target of 3%-6%. Although the GEAR policy aimed for strong GDP growth, Weeks (1999) suggested that from 1996 the output growth performance fell far short of target and it declined continuously below 1% for each and every quarter from 1997 through 1998. Indeed the policy was unsuccessful to weaker currency and high interest rates.

The ASGISA policy aimed at reducing unemployment from 28% to 14% by 2014. The South African economy recorded the fastest growth rate of 5% and an increasing rate of investment to over 20% of GDP from 15% in 2005/6. The global financial crisis a led to a decline in economic growth. Moreover, the energy supply and demand imbalances, as well as load shedding and electricity price hikes among other factors were causes of output and investment decline in 2008/9 (Eskom, 2011). The new growth path (NGP) policy of 2010 targeted for macroeconomic stability as its aim is to create five million jobs by 2020 and reduce unemployment from 28% to 15%. The NGP policy follows the previous economic policies (RDP, GEAR and ASGISA) with its main focus on job creation and poverty alleviation as it encourages strong partnership between business sectors, government and other African countries. The policy has seen potential for job creation in various economic sectors such as construction, agriculture, mining, manufacturing, trade agro processing and other informal sectors of the economy. Indeed, Nattrass (2011) argued that the NGP policy suggests that the aforementioned economic sectors in combination with Eskom have the potential to unlock economic and employment opportunities.

According to Winkler (2006), electricity is regarded as an efficient high quality energy carrier and a critical input to key economic sectors and productive activities in South Africa. In other words, one cannot debate about economic development of a country without sectoral output performance. With the exception of the NGP, most policies were mainly focused on overall economic growth and employment instead of sectoral output. However, output performance as recommended in the NGP policy is determined by various factors, one of which is electricity that must be taken into consideration. Economic sectors such as mining, manufacturing, agriculture, construction, communication and transport, and trade are the major employers, food providers, exchange rate earners and export providers in the country. Their performance likely indicates the economic development of the country. Although the economic policies include the energy sector in their broad economic goals, issues of energy and electricity pricing were initially of less concern since the prices were low due to abundant and cheap coal which in turn led to inefficient use of energy and electricity. The load shedding and electricity price hikes that took place therefore affected output growth – the economists and analysts had wondered how it would be to be affected. Thus, the use of panel data regression will illustrate how the electricity price changes affect sectoral output movements in South Africa. Following the latter objectives of the abovementioned growth policies, the government, Eskom and electricity regulator should frame a better electricity pricing policy so as to get persistent, dependable and reasonable electricity for the betterment of the South African economy, particularly the economic sectoral output.

2.5 AN OUTLINE OF TRENDS IN ELECTRICITY PRICES, OUTPUT AND OTHER MACROECONOMIC VARIABLES: 1994-2015

The section is divided into three phases. The first subsection reviews a general outline of electricity prices and output for all economic sectors in South Africa from 1994 to 2015. This shows the direction of movement of the electricity price and overall output in all economic sectors in the country. The second phase shows trends in electricity prices and the sectoral output in South Africa from 1994 to 2015. Lastly, the section reviews a comparison of electricity prices and other economic variables (such as inflation, exchange rate and interest rate) of concern in this study.

2.5.1 Electricity prices and output for all industries in South Africa from 1994 to 2015

This section gives a general overview of overall electricity prices and sector output trends in South Africa from 1994 to 2015. Figure 2.5 points out that the overall output was increasing while electricity prices were low and declining from 1994 to 2007/2008. However, it became stagnant from 2008 to 2012 at an average of 5.6 million. Nonetheless, there was a sharp increase from 2012 upwards. Increasing output and investment was not only due to low electricity prices as stated in Inglesi-Lotz and Blignaut (2011). Indeed, the cumulative output was in line with the South African government policy (RDP) in the early transition period which decreased electricity prices. The main focus of the policy was on job creation, upgrading infrastructure to combine growth development with reconstruction and redistribution and reconciliation. However, the policy seems short sighted as the electricity prices were often lower than the cost of producing. The trends in Figure 2.5 show that output from 1994 to 2000 grew at an average of 3.2 million which is 2.7%. This follows Mahadea and Simson (2010) who suggested that the RDP was replaced by the GEAR strategy which focused much on transport and infrastructure investments. This implies that the economic growth responded positively to the stimulus from the public sector infrastructure.

Padayachee (2006) regarded the period between 1994 and 2004 as the development decade when the South African industry had to rapidly shift from an import substituting industrialisation growth path toward one engaging with competitiveness demands of the global economy. More so, South Africa recorded its fastest economic growth rate in 2004 to 2007/8 at an average of 5.7% under the ASGISA policy. The economic growth rate was thus accompanied by an increase of 1.8 million jobs from 2004 to 2010 in anticipation of the 2010 World Cup in South Africa (Mahadea & Simson, 2010; Department of Research and Information, 2013). However, from 2008, trends in electricity prices took a dramatic turn.

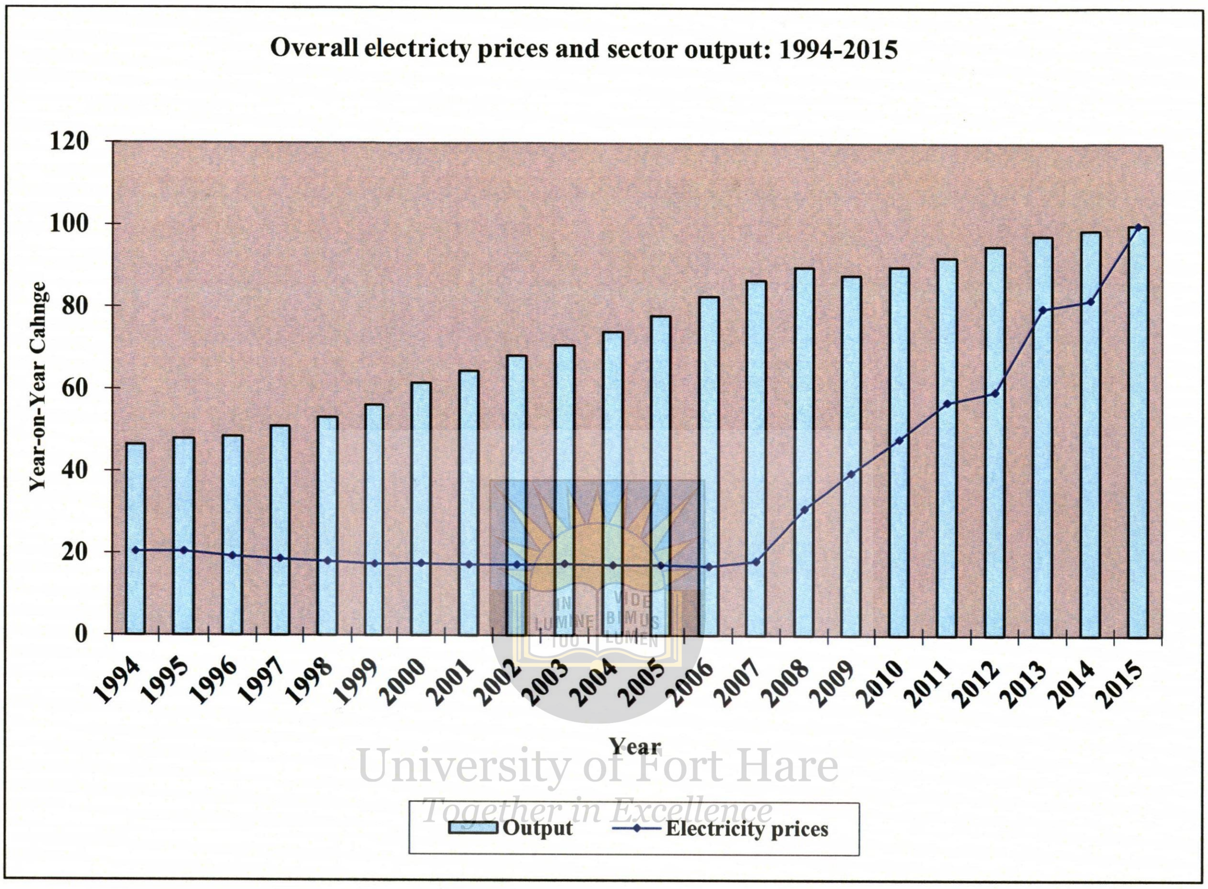

Figure 2.5 Overall electricity prices and sector output in South Africa from 1994-2015

*Sources: **Author's own sketch, Data from** Deparment of Energy (2016)and Quantec (2016)*

The trend in electricity prices outlines a rapid increase in the prices over the period 2007/8 to 2015. Although the trends seems to go in the same direction, Figure 2.5 promises a substantial fall in sector production as a result of the continuous electricity price hikes in the country. This is consistent with Inglesi-Lotz (2014) and Eskom (2011) who posited that there are high expectations of increasing electricity prices with severe constraints on the future economic production and sectoral output in particular.

Also as shown in Figure 2.5, the overall output was stagnant whilst electricity prices were increasing between 2008 and 2012/13. This implies that high electricity prices combined with electricity price shortages and outages comprised one of the significant binding constraints on the South African economy. Apart from that, the Organiasation for Economc Co-operation and

Development (OECD) (2011) suggested that the global economic crisis, mainly through the trade and financial crisis intensified with the collapse of Lehman Brothers, also contributed to a stagnant output trend. Again, the weak prices of export commodities and the stock market reduced output in the country. Additionally, a drop in export demand led to an output decline in sectors such as manufacturing and mining. An increase in overall output from 2012 upward may have been due to interest rate that was reduced by 500 basis points from 5.5% to 5% during recession (Department of Research and Information, 2013). Low interest rates reduce the cost of borrowing to investors, hence increasing productivity across economic sectors. The overall presentation of trends in Figure 2.5 make it hard to identify which economic sectors were affected by electricity prices.

Certainly, too much dependence on overall figures is likely to mislead the real conclusions and economic inference. This emphasises the significance of this study on the issue of output analysis at sectoral level movements in relation to electricity price changes in South Africa. Therefore, the use of panel data and disaggregated economic sectors in this study also helps the policymakers, the government, and the energy regulator to identify the real impact of electricity prices on the selected economic sectors (mining, finance, manufacturing, agriculture, construction communication, trade and wholesale). Figure 2.6 below provides an overview of electricity trends and sectoral output in South Africa from 1994 to 2015. This indicates movements of each sector output in relation to overall electricity prices in South Africa.

2.5.2 Trends in electricity prices and the sectoral output in South Africa from 1994 to 2015

According to Eather and Frawley (2015), the South African economy has declined due to higher borrowing and operating costs and lower commodity prices. Higher inflation rates and rand depreciation and a global financial crisis are some of the rampant factors which deteriorated the South African economy over the period of the study. This entails that the issues concerning electricity prices in relation to the economic output movements are of less concern. Given this, the current study has analysed the effect of electricity prices on sectoral output mainly to illustrate the reality of how the electricity prices correlate with sectoral output in the country. More so, the graph in Figure 2.6 illustrates a combination of trends on the selected economic sector outputs and the overall electricity prices (El pr). The sector outputs in Figure 2.6 are presented as min (mining), man (manufacturing), agri (agriculture), constr (construction), trad whol (wholesale and trade) and comms (communication).

The selected sectors in this study have diverse and substantive roles in the South African economy in terms of their contribution to GDP, exports, food provision, employment and exchange rate earnings (Deloitte, 2012). This also determines these sectors' behaviour towards electricity price changes. Sectors such as mining, manufacturing, wholesale and trade, construction and agriculture make higher contributions to GDP, employment and exports. The mining sector alone generates approximately 18% of the economic activity. Blignaut *et al.* (2015) reasoned that electricity price increases deteriorate consumption which is likely to cause economic sectors to close down other operations, leading to a decline in output growth. Some sectors of the South African economy are more labour intensive (with high employment to GDP ratios) than other sectors (Mkhize, 2016). Sectors such as construction, agriculture and trade make a much larger proportional contribution to employment than GDP. For instance, the agriculture and trade sector contributed 8.7% and 19.2% to employment respectively but only 2.3% and 15% to GDP in 2015 (Industrial Development Corporation (IDC), (2015).

According to Steyn (2003), electricity pricing structures in South Africa have been influenced by a complex mix of financial, economic, institutional and political factors. This research used these trends to analyse general factors that underpin the administration of electricity over the period of study in South Africa. Figure 2.6 shows the trends in electricity prices and sectoral output in South Africa over the period 1994 to 2015. Electricity prices, as illustrated in Figure 2.6, were consistently low over the period 1994 to 2007/8. This is consistent with Inglesi-Lotz and Blignaut (2011), who suggested that electricity prices in South Africa have been low and declining due to cheap and abundant coal. However, a sharp increase with some fluctuations are outlined from 2007/8 to 2015.

Figure 2.6 furthermore shows that electricity prices were low from 1994 up to 2005, with an average decrease of 0.238. This is consistent with the Department of Energy (2010) which stated that electricity prices decreased by 20% over the five year period from 1992 to 1996. During this period, Eskom announced its price compact with the persuasion that cheaply priced electricity was essential for rapid economic growth. Given that, the output within sectors was increasing rapidly. Inglesi-Lotz and Blignaut (2011) demonstrated that the under-pricing of electricity in

South Africa in the 1990s was mainly due to light financial requirements under full state ownership until 2001. Eberhard (2001) posited that the government financed the electricity subsidies and the power industry had been exempted from taxation and dividends payment. Again the low and declining electricity prices were politically oriented. This follows (Steyn, 2003) who suggested that some reduction in the electricity prices were influenced by political pressures such as the democratisation of the state resources. Thus, in the early 1990s, Eskom was under severe pressure and had little choice but to reduce prices as soon as the declining debt level would permit it. However, those low prices increased the inefficient use of electricity since the prices of electricity were lower than the cost of power production.

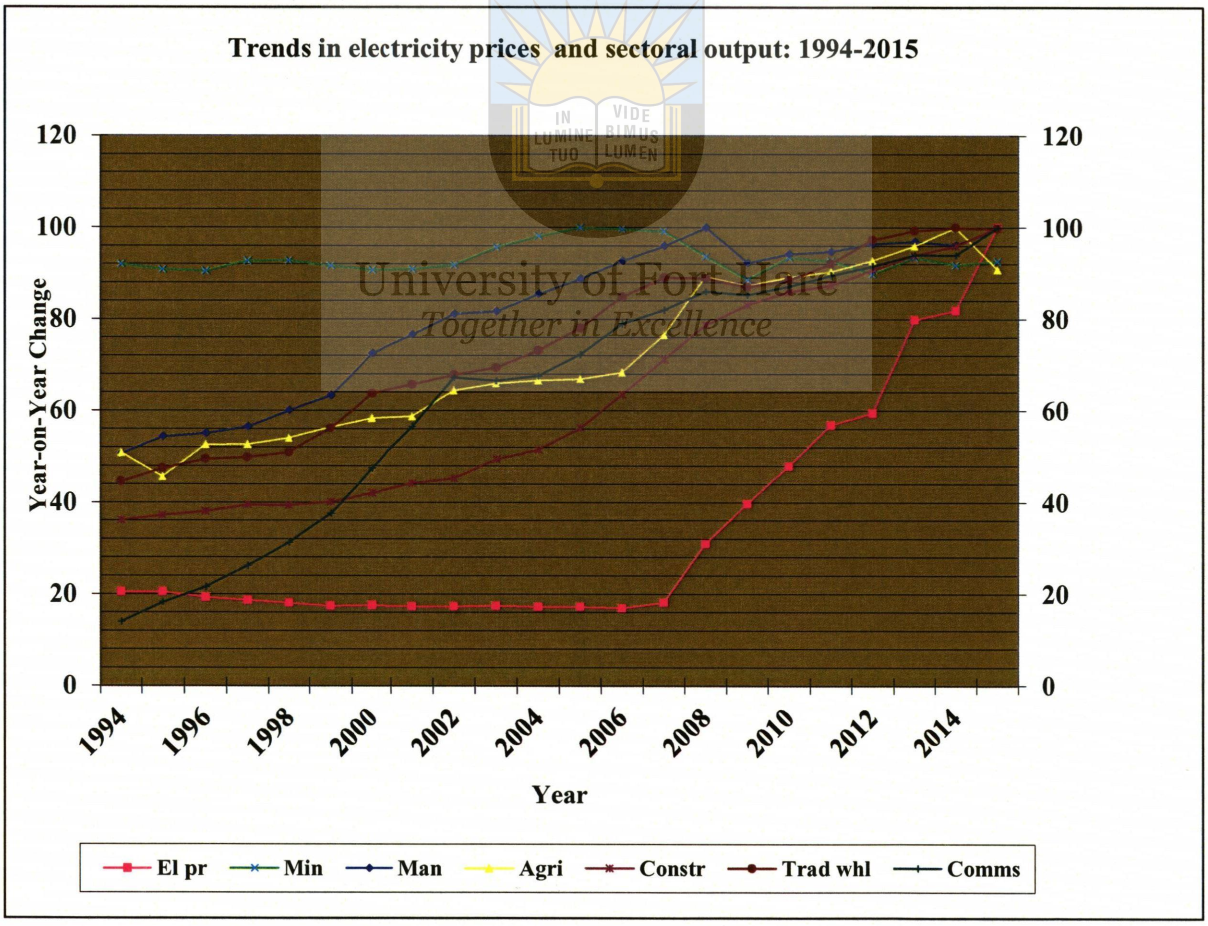

Figure 2.6 Electricity prices and sectoral output performance 1994-2015

Sources: Own compilation from data from Deparment of Energy (2016)and Quantec (2016)

Trends in electricity prices between 2001 and 2007 were mainly determined by the new regulatory framework based on the internationally accepted rate of return methodology. Although the new regulatory framework was introduced, the electricity prices increased in line with the inflation rate. Again, the South African government accompanied by the NERSA advocated the FBE grant policy which aimed to provide electricity to all, irrespective of income levels. This follows Thopil and Pouris (2013) who stated that the government and the power industry had agreed on a 15% decrease in the electricity prices mainly to provide electricity to the mass. This in turn geared a dropdown in electricity prices. As a result, the economy experienced an increase in sectoral output from 20001/2 to 2006 as shown in Figure 2.6. For instance, the mining sector showed an increasing trend in its output over the period 2003-2006. The sector contributes to 1.3 million jobs and is an exchange rate earner of which 50% are merchandise exports (Antin, 2013). This accords with Steyn (2003) who pointed out that the low prices were a source of competitive strength for the economy. Therefore, if lower prices are a source of economic strength, electricity prices are likely to be a substantive constraint to the South African economy and the sectoral output in particular.

Deloitte (2012) posited that these low prices shrank the future generation capacity of the power industry. This implies that the low electricity prices could not compensate generation, transmission and distribution costs. Such predicaments and reluctance by the power regulators caused electricity shortages which then pushed the power industry to introduce load shedding and increase the electricity prices in 2008 so as to compensate production cost as well as power industry expansion. Again, Eskom received the permission for its overdue capacity expansion programme (Eskom Holdings Ltd., 2017). These developments initiated electricity price increases between 2007/8 and 2013 (as shown in Figure 2.6). The real electricity price increase was accepted by NERSA to ease capital raising (Sebitosi, 2010). The electricity price increase of 10% was initially granted for the first MYPD period. However, this increase was unsatisfactory to uphold expansion of projects such as the Medupi power plant. Therefore, in 2007, the electricity regulator approved a revised increase of 14.2% for 2008 (Deloitte, 2012). This caused a decline in demand for electricity as the economy entered a recession. The electricity price continued to increase by 13.3% which then added up to a total of 27.5% in 2008/2009. Electricity prices persisted to increase to 24.8%, 25.8% and 25.9% for 2010, 2011 to 2013. The NERSA pricing resolutions gave rise to a 78% increase in real electricity prices.

The output trend in manufacturing, agriculture, communication trade and mining as shown in Figure 2.6 is slanted downwards. This suggests that the increasing electricity prices and a decrease in electricity consumption after a world financial crisis resulted in a slowing economic growth (Department of Energy, 2012 & Department of Energy, 2011). Therefore, many economic sectors now face challenges such as maintaining and increasing their output. Indeed, the Department of Energy (2013) indorses that the electricity price increases have been blanketed across all economic sectors. This correlation implies that electricity prices have a negative effect on the sectoral output in South Africa.

Figure 2.6 also shows that electricity prices continued to grow from the middle of 2013 till 2015. The real electricity price increases and output decline over the period were associated with various factors. These include public resistance, load shedding (which was reintroduced), and regulatory uncertainties. Although the public challenged the power regulator' decisions (Eskom Holdings Ltd., 2017), the electricity prices still followed a steep annual increase as noted in Figure 2.6. This follows Koen (2012) who advocated that the main idea for cost reflective prices was to ensure a sustainable power industry with health pricing signals which improve energy and economic efficiency. Further electricity price increases of 24.8%, 25.8% and 25.9% were recorded in 2010/11, for 2011/12 and 2012/13 respectively. In response, the output was decreasing. The electricity price for 2014/15 was also expected to be a little higher than the previous rates. However, the NERSA decided to prohibit over R100 billion worth of income over the MYPD3 period (Eskom Holdings Ltd., 2017; Kenny, 2015). It appears that the electricity regulator's decision was predisposed by concern about the adverse economic impact that tariff increases would have on the economy which in turn was centred on concerns raised by stakeholders. The regulator announced that it had approved a 12.7% tariff increase in 2015/16 instead of the 8% approved under MYPD3. Bearing all these facts in mind, this study aimed to examine how these perpetuating electricity prices affect the sectoral output in South Africa. The study focused on how these electricity prices affect each and every sector's (communication, finance, mining, agriculture, wholesale and retail, trade and catering and manufacturing) output. The impact of electricity prices on sectoral output is presented in Chapter Five of this study.

2.5.3 Comparison of electricity prices and other economic indicators from 1994 to 2015

The trends below give an overview of electricity prices compared to other economic indicators such as interest rate, exchange rate, inflation and oil prices in South Africa.

According to Vlahini (2010), an increase in energy prices in the near term leads to an increase in the domestic price levels and decreases output due to higher costs. Therefore, the aggregate demand decreases and the economic sectors may cancel or change their investment plans since electricity prices can lead to higher interest rates. More so, higher energy or electricity prices imply higher input prices and cost which then reduces profitability in different economic sectors in the country. Again, if the electricity price rises above inflation, then the economy and economic sectors may incur production costs which will hinder production. This is in keeping with Eskom (2011) who suggested that the ever increasing costs of Eskom's electricity prices have had severe inflationary consequences in South Africa. More so, it will have a negative effect on every investor and all sectoral business activities. Figure 2.7 shows the trends on overall electricity prices and other economic indicators in the model (such as inflation (Inf) interest rate (Ir) and Exchange rate (Ei)) in South Africa from 1994 to 2015.

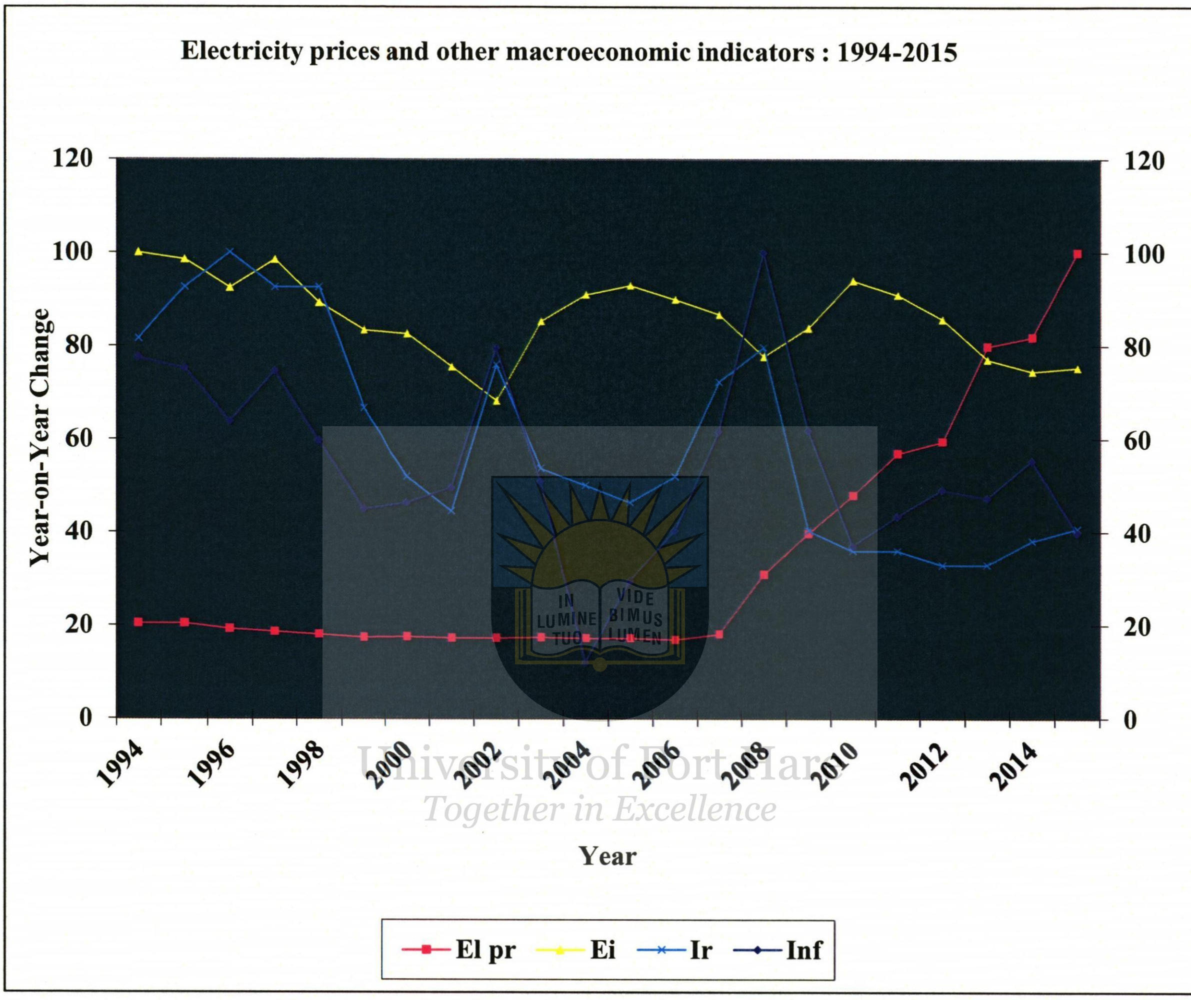

Figure 2.7 Electricity prices and other economic indicators

Sources: *Own compilation from data from the Department of Energy (2016) and SARB (2015)*

The trends indicate that electricity prices were low and declining between 1994 and 2006/7. This is consistent with Inglesi-Lotz and Blignaut (2011) who suggested that from 1994 to 2007, the prices were low and kept declining and thus their effect on the economy gradually decreased. More so, inflation fell sharply from 2002 up to the last quarter of 2004, then grew rapidly from 2005 to 2008.

Furthermore, Figure 2.7 shows that electricity prices and inflation rates move in tandem. High rates of inflation was regularly recorded during the high electricity price regime. This follows high records of high electricity prices in 1994 to 1998 when inflation was above the South African target band. Again, in 2000, 2007 and 2008, the inflation rate was above the 6% target

(9.2%, 7.1% and 11.5%) whilst electricity increased at a rate of 13.1%, 13.7% and 23.31% respectively.

Figure 2.7 also displays that the electricity prices were steadily low in the 1990s up until they rose in 2008. Contrariwise, from 2008 till 2015, electricity prices grew rapidly above the inflation rate. The Department of Energy (2012) reported that since electricity prices increased in 2008, they have always been over the inflation rate. This implies that the input costs may have risen which gave rise to cost push inflation. Prices of electricity adjustments have deviated far above the consumer price index (inflation rate) since 2008. In doing so, this econometrical reaction shows that the increase in electricity prices greatly affects its consumption. Therefore, it is vital to examine the impact it has on sectoral output. Sectoral output and electricity prices also affect electricity consumption. This may ultimately affect the economic sectors' (mining, manufacturing, agriculture, construction, banking and trade) output since their costs of production will be high.

More so, the trends on Figure 2.7 demonstrate a fluctuating exchange rate drift from 1994-2015. It is clear from the figure that the exchange rate is volatile, particularly from 2004 when this caused price pressures such as the electricity prices. Figure 2.7 further shows a fluctuating trend in interest rates from 1994 to 2009. This may have been due to monetary policy control of money supply in the county. The interest rate continued to drop from 2009 to 2015 as the electricity prices levels rose. Even though electricity prices were below the exchange rate at some point, the prices increased sharply from 2008 to 2015. Moreover, all indicators in Figure 2.7, with the exception of electricity prices, illustrate a declining and fluctuating trend from 2007/8 to 2015 while electricity prices followed a sharp increase trend in that period.

2.6 CHAPTER SUMMARY

The chapter presented an overview of trends in electricity prices and economic sector output and other macroeconomic variables (such as inflation, interest rate and exchange rate) in South Africa from 1994 to 2015. Coupled with that, energy and growth policies were discussed over the same period. The first section of the chapter provided an overview of the South African electricity sector. Issues concerning generation, transmission, distribution and usage of electricity were all discussed in the first section. Furthermore, the chapter discussed energy and growth policies between 1994 and 2015. It seems that the transition period policies discussed above are more concerned with the demand than the supply side management. In other words the policies encourage FBE grants for all. However, the energy policy should consider issues of electricity prices since they are likely to affect both the power industry supply and the economic sector output in the long run. Electricity prices affect both supply and demand of electricity which in turn will affect consumption by end users, particularly the economic sectors in the long run. The last section of the chapter provided trends on electricity prices and overall output for all economic sectors, sectoral output and other macroeconomic variables. The above exposition demonstrates that both the government's and Eskom's prospective aim is to meet a common objective. Eskom, the energy regulator, government and the electricity end users aim to achieve a balance between economic growth and environmental goals. Eskom aims to ensure that the electrification targets are met, whilst the government aims for an affordable electricity price to improve economic growth. Taking this into consideration, the study used the panel data analysis to give a clear picture on how these prices affect the sectoral output. This intends to assist both the electricity sector, the electricity end users, the regulatory institutions and the government to facilitate favourable policies to enhance sector output growth in the country. Given this, it is vital to look at the theoretical and empirical explanation of the sectoral output responsiveness with regards to electricity price changes in developed and developing economies, and South Africa in particular.

CHAPTER THREE
LITERATURE REVIEW

3.1 INTRODUCTION

The researcher reviewed the critical synthesis of previous works, comparing different authors' views of electricity prices bearing on sectoral production – these are discussed in this chapter. The review of this literature assisted the researcher to identify potential variables and the existing gap in the literature. The chapter also covers the evaluation of different studies on the impact of electricity prices on real sectoral output. Furthermore, the researcher will discuss various studies she reviewed that were conducted to analyse the effect of electricity prices on sectoral output in various regions of the world and South Africa. Diverse studies have arrived at different results using the same choice of study. The chapter consists of three sections: the theoretical and empirical literature as well as the assessment of literature. The first section focuses on the theoretical literature and the mainstream production and the energy-growth models. The second section then provides empirical literature from developed countries and developing countries, including South Africa. The empirical literature section assesses literature in terms of methodologies, periods and data analysis. The last part of the chapter provides an assessment of the literature review, both theoretical and empirical, in developed and developing countries, including South Africa.

3.2 THEORETICAL LITERATURE

The research encompassed the mainstream production (Kummel, 1982), energy growth and the production and technical change theories. The production theory provided the researcher with the basic inputs of production for an economy or sector output. However, the mainstream theory does not consider energy and electricity in particular as a separate and substantive input. Nonetheless, Kummel (1982) suggested that energy or electricity is an input factor of production that can be treated independently and separately. The substitution and technical change theory (Rosenberg 1983; Schurr & Netschert, 1960) contends that a sector's production is expressed as a function of the input (capital, labour, electricity, non-electrical energy, material and time) prices. Therefore, output for a sector can be input–saving or using.

3.2.1 The mainstream production theory

The neo-classical growth model is a useful tool for gaining insight into key factors that determine the ability of an economy to sustain itself in the long run. Economic sectors differ with respect to their capital intensity, stages of development and energy use. However, in this scenario, various economists and energy-growth analysts such as Sorrell (2008) criticised the typical production theory in that it leaves the issue of electricity as a vital input of production unexplained.

The mainstream theory of production pays no attention to energy (electricity) as an important input of production. The theory is concerned with the fact that output is produced by inputs of labour and capital only (Lindenberger & Kummel, 2002). Therefore, growth will be a result of increased labour or capital or their quality (Vlahinic-Didarevic & Zikovic, 2010). Energy inputs are regarded as intermediate inputs (partly finished goods used as inputs in the production of other products) in the mainstream production theory. The typical theory has accepted the concept of primary intermediate factors of production, where primary factors include land, labour and capital while the intermediate factors include fuel, materials and electricity or energy. Therefore, this approach has led the typical theories to focus on primary factors while the intermediate factor inputs have a weak and indirect role. However, energy or electricity has a vital contribution to the production of wealth or output (Sorrell, 2008; Tryon, 1927).

The neo-classical theory posits that the factor productivities had to equal factor prices. Therefore, the weights with which the production factors contribute to generation of output (the elasticities of production) should be equal to the factor cost shares. Stresing *et al.* (2008) reckoned that energy has high productive powers as revealed by its high elasticity of production. Energy elasticity in other sectors of the economy (such as manufacturing, communication and trade) is half the size of capital and labour together. Labour elasticity production is far below its cost share. However, the capital elasticities of production and cost shares seem to be in equilibrium as presumed by the mainstream production theory.

The output elasticities provide the economic weights of production factors. Therefore, for labour, the productive powers are small but for energy they are larger than the cost shares (Stresing *et al.,* 2008). In contrast, the neo classical theories suggest that the output elasticities are assumed to equal their cost shares. Thus, the economic sectors can maximise profit without any constraints on factor combination, unlike the energy-dependent production where there are constraints on factor combination. Energy and electricity have been dealt with in economic literature. The first oil crisis in 1973 to 1974 also gave more attention to many economists and analysts who started to formulate energy-dependent production functions that include energy and materials besides conventional labour and capital inputs (Brendt & Wood, 1979).

3.2.2 Critics of the mainstream theory

The ecological economic theory shows that when energy is limited, it executes resilient constraints on economic growth. However, when it is abundant, its effect on output growth is much reduced. According to van Zon and Yetkiner (2003), most researchers address the problem of endogenising growth by involving growth performance to turnover incentives, but they have continued to ignore the fact that equally endogenous energy savings and technical changes will be necessary to make this growth path sustainable in practice.

The oil crisis in the 1970s which slowed down production was an exception. The crisis led many economists to realise that energy is an indispensable factor of production, since its scarcity shakes the sector production (Chontanawat *et al.*, 2006) . Economists and analysts began to wonder how the energy inputs affect growth, since the role of energy in growth cannot be achieved without comprehending its role and impact in sector production. Much research has been devoted to energy consumption, price and demand with economic growth. This led to including intermediate inputs of production such as material and energy in the production function (Baptist & Hepburn, 2012). In doing so, numerous studies estimated the capital, labour, energy and material production functions where energy was then added as an inside variable of production function. Moreover, the fact that energy must be integrated into machines, workers and materials in order to be made useful, provides a biophysical justification for treating capital and labour as factors of production. However, capital and labour can be measured whilst energy cannot, unless there is use of input costs in different sectors of the economy.

3.2.3 The Kummel Capital-Labor-Energy and Creativity (KLEC) model

Kummel (1982) posited that labour manipulates capital and energy (electricity) activates capital. The creativity factor is specific human contribution through ideas, inventions and decision making (Kummel, 2007). Therefore, capital, labour and energy are considered as independent variables in the sense that within technological limits firms can diverge them independently per their decisions on the capital stock, quality, quantity and degree of utilisation as well as variations of labour and energy (Kummel, Henn & Lindenberger, 2002; Kummel, 1982).

The Kummel model of economic growth includes not only capital and labour for industrial or sectoral production but also includes energy (such as oil, fuel coal and electricity) and creativity as factors of production (Zyga, 2014). In doing so, energy is considered as a third significant factor of production in any sector or economic production. The Kummel theory is in consensus with the Unified energy-growth theory (Stern & Cleveland, 2004) which regards energy as a significant factor of production. Lindenberger and Kummel (2002) and Kummel (1982) suggested that the neo-classical growth model helps economists to understand economic output growth. However, the typical theory leaves so much unexplained which is a little unsettling. Solow (1956), as the founder of the growth theory, recommended that the production or growth model is a theory that leaves other factors (such as electricity, nonelectric factors and creativity) of economic growth unexplained (Lindenberger & Kummel, 2002). As a result, this helps economists, analysts and researchers to discover some important factors that have been left out to define economic growth or production theory. The KLEC theory argues that the missing component in the economic output process is the energy factor. In this study, the form of energy employed was electricity. The model advocates that energy should be considered as the third factor of production on par with the traditional factors of labour and capital for sector production. The proposal of the new production theory has been different to the mainstream growth model where factors of production have diverse economic weights representing their productive power within sector production. In this manner, the mainstream model recommends that the output elasticities for the factors of production should be equal to each factor's cost share. Thus, labour costs' share is 70%, capital is 25% and energy is 5% (Stresing *et al.,* 2008). Again, the typical production theory shows that energy has a smaller cost share than other factors, which may imply a small productive power. Contrariwise, economic researchers, such as Kummel (1982), in their analysis found that unlike the Solow (1956) model, the economic weights of labour and energy are not equal to their cost of share. Thus, the economic weight of energy is much larger than its cost of share while it is smaller for labour. This implies that energy has much greater and higher productive power than that of labour since labour energy is cheaper than labour.

More analysis of energy as the third factor of production has been done in developed countries than in developing countries (Thompson, 2006). The neo-classical economists posited that economies should operate in an equilibrium where profit or output has a maximum (Snowdon & Vane, 2005). Therefore, maximisation occurs with no restraints on the combination of factors of production. The Kummel theory of energy and growth also apply the issue of maximisation of output, but also take into account technological constraints on production factors' combination. The price of electricity is also a production factor constraint. Thus in reality, a production system cannot operate at more than full capacity and its degree of automation at a given time is limited by the quantities of energy conversion devices and information processors that the system can accommodate at that time.

Lindenberger and Kummel (2002) suggested that the KLEC theory avoids the neoclassical equilibrium assumption of the equality of elasticity of production and cost share. Nevertheless, the energy-dependent model suggests that every purposeful activity in any economic sector requires work performance and information processing. Capital, labour and energy are thus independent variables for production output. This means that within technological limits, sectors can vary independently based on their decisions on the capital stocks' quality and quantity. For instance, capital could be totally unproductive without a flow of energy to drive the machines and heat or cooling and office buildings which protect the machines and people (labour) who handle them.

3.2.4 Substitution and technical change econometric model of productivity growth

The substitution and technical change theory is based on the view that modernism increases the share of an input in the amount of output for a given set of input prices including the prices of electricity (Rosenberg, 1983; Schurr, 1960). This theory incorporates substitution among productive inputs in response to changes in relative prices. Consequently, the economic sector output/productivity becomes the function of relative prices. The concept is based on sectoral output price and output function as it summarises the possibilities for substitution among inputs and patterns of technical change.

The notion explains bias of productivity as the result of technological changes on each input value. Thus, the bias gives the change of the share of input (electricity, labour, capital, material and technology) in the value of output in response to changes in the level of technology.

Correspondingly, the theory considers technical change as the parameter on examining the role of an input in productive growth which indicates the specific role of an input and how it influences output. Hence, the technical change can be input-using (positive bias), that is when the share of the input in the value of output increases with technical change while the rate of technical change increases with a decrease in the price of that input. In contrast, technical change increases with an increase in the price of the input. Hence an increase in the price of an input, increases the rate of productivity/output growth associated with negative bias. In this regard, Rosenberg (1983) and Schurr and Netschert (1960) explained the substitution and technical change econometric model of productivity growth in both the output price and output/productivity functions respectively.

The theory regards the output price/output of a sector as function of its input prices (such as capital, labour, electricity, and non-electrical energy, material) and time which represents the level of technology in a sector. If the econometric model is used to observe the role of an input in productivity growth, then the key parameter is the bias of the productivity growth for that input. This implies that, in any econometric model, the relationship determining the value shares of the various inputs and the rate of productivity growth involves unknown parameters. Again, unknown parameters are a bias of productivity growth that indicates the effect of change in the level of technology on each input value share. For instance, the bias of the output/productivity growth for electricity input, gives the change in the share of electricity in the value of output in response to changes in the level of technology represented by time. Then that productivity growth is electricity-using if the bias of productivity growth for electricity is positive. This implies that the share of electricity input in the value of output increases with technical change while the rate of technical change increases with a decrease in the price of electricity. Contrariwise, the theory suggests that productivity growth is electricity-saving if the bias of productivity growth for capital input is negative. The model confirms that electricity prices can explain the changes in the movements of economic and sectoral output in particular.

3.3 EMPIRICAL LITERATURE

This section covers the evaluation of different studies concerning the impact of electricity prices on real output. Studies for developed countries and developing countries, including South Africa, were assessed for this section in terms of methodologies, periods and data analysis. This was done to possibly assist the researcher to identify appropriate variables to adopt for the study. The oil crisis in the 1970s and 1980s led the energy resources and their prices to gain much more research attention. Starting with the seminal work of Kraft and Kraft (1978), most works utilised causality tests to investigate the relationship between energy and economic growth in developed and developing countries, in South Africa in particular. Again, short-run increases in energy lead to an increase in domestic price levels and a decrease in output due to higher cost of production in different economic sectors. This implies that electricity prices have a significant relationship with sector production.

3.3.1 Empirical literature in developed countries

The literature on energy/electricity and output relationship has focused more on the direction of causality between electricity consumption than electricity prices on aggregate GDP. In other words, income is considered as a prevailing macroeconomic driver of electricity demand. Significantly, electricity utilisation is normally more reactive to variations in GDP than it is to fluctuations in electricity tariffs. More works have focused mainly on the association between electricity consumption on aggregate output than electricity prices.

Following the oil price shocks in the 1970s, most authors have applied causality tests to examine the link between energy consumption and output growth. The works on the relationship were mainly focused on the existence and direction of causality between the two variables in either bivariate or multivariate models (Ghali & El-Sakka, 2004). For instance, earlier studies such as Kraft and Kraft (1978) found evidence that electricity consumption is driven by the national income changes in the United States of America (USA) over the period 1947 to 1974. Additionally, numerous studies also support that output growth increases electricity consumption. These include studies in Canada, Norway and Ecuador (Fei, Rasiah & JiaShen, 2014), Greece (Polemis & Dagoumas, 2013), Japan, USA, the United Kingdom (UK) (Bildirici, Barkitas & Kayikci, 2012) and Italy (Soytas & Sari, 2003). The abovementioned studies utilised the autoregressive distributed lag (ARDL), vector error correction model (VECM), Granger causality and cointegration regression methods. Although the studies were conducted in different countries, the periods of the studies were almost the same ranging from 1970 to 2011.

Using the ARDL model, Bildirici *et al.* (2012) found that electricity consumption increases GDP whilst the same estimation technique in Fei *et al.* (2014) supports the evidence that electricity consumption in Canada is driven by output growth. However, the aforesaid studies found similar results – that GDP in South Africa prompts electricity consumption. The different results in Fei *et al.* (2014) are due to different type of electricity (fossil fuel powered electricity) used in the study. More so, other studies (Soytas & Sari, 2003) utilised low quality energy sources such as coal. Ciarreta and Zarraga (2010) added that some earlier studies (Soytas & Sari, 2003) suffer unreliable econometric inferences due to small sample sizes.

In energy and output growth literature, there are cases where electricity/energy price, electricity consumption and GDP are jointly determined and affected simultaneously. These include studies in Canada (Ghali & El-Sakka, 2004) and the USA (Stern, 2000; Stern, 1993). A study by Ghali and El-Sakka (2004) employed the vector error correction (VECM) and Johansen cointegration technique from 1961 to 1997 and found that the variables were cointegrated. Also, Stern (2000) and Stern (1993) used the vector autoregressive (VAR), Granger causality, single static and dynamic cointegration analysis over the period 1947 to 1990 and 1948 to 1994 respectively. The aforementioned studies avoided the bivariate analysis since they failed to detect the causality link because of the substitution effect that may have occurred between electricity consumption and other inputs. The studies also include labour and capital since large parts of growth effects of energy are due to substitution of higher quality of energy (electricity) to low quality sources such as coal (Jorgenson, 1984). In doing so, the studies by (Ghali & El-Sakka, 2004; and Stern, 2000, 1993) found that energy/electricity and growth cause each other in both directions. However, this analysis put more emphasis on aggregated variables such as economic growth and energy use. Therefore, there is still no clear picture on how the energy input affects output growth at sectoral levels. Even though the studies use the multivariate models, the use of time series, classical Granger causality, cointegration and the VECM methods indicates that the models also suffer heterogeneity bias in variables. However, the current study utilised the panel data analysis which caters for individual heterogeneity within variables, sector-specific variable electricity, sectoral output and other variables.

Electricity is regarded as a limiting factor of economic growth in developed countries. Such evidence is provided from different estimation techniques (VECM and ARDL) (Bildirici *et al.,* 2012) and the dynamic panel data Granger causality (Ciarreta & Zarraga, 2010) and the period of studies. The studies include USA and Canada (Bildirici *et al.,* 2012), 12 European countries

(Ciarreta & Zarraga, 2010), and the G7 countries (France, German and Japan) (Soytas and Sari, 2003). The study by Ciarreta and Zarraga (2010) proved to be a bit different from other studies since they employed trivariate and panel data general methods of moments system analysis. The study also included electricity prices as one of the variables to avoid the problem of omitted variable bias. Even though Ciarreta and Zarraga (2010) employed the panel data analysis, the technique was mainly utilised for regional analysis, thus sectoral analysis was still not emphasised.

Although Ciarreta and Zarraga (2010) used the panel data from 1970 to 2007, Bildirici *et al.* (2012) also employed the time series from 1970 to 2010 and the ARDL for the multi-country analysis. These studies are in consensus that electricity consumption and prices are limiting factors of output growth in different developed and industrialised economies (such as Canada, USA and other European states). Apart from that, the works of Bildirici *et al.* (2012) and Ciarreta and Zarraga (2010) indicate that the electricity prices have a weaker impact on electricity consumption in the aforementioned economies. Even if the studies employ multivariate models and dynamic panel data analysis, they are still consistent with overall GDP, energy consumption and prices. Once more, the studies are devoted more to the causality links and significance and not on the impact. Again, there is no clear explanation of output response to energy/electricity prices and consumption at sectoral level.

In some other cases, measurement of energy prices is presented by consumer price index and world crude oil. This follows Tang, Shahbaz and Arouri (2013) and Tang and Tan (2012), who used time series, multivariate approach, cointegration and Ganger causality methods in examining energy and output nexus in Portugal. Both studies considered the issue of the multivariate approach. Thus foreign direct investment, trade openness and output consumption energy prices were included in the models. Conversely, their energy price proxies were different. The energy prices in Tang and Tan (2012) were measured by consumer price index whilst Tang *et al.* (2013) used the world crude oil prices. However, both studies are in consensus that Portugal is an energy-dependent country for all its economic production and growth development. Indeed, they recommended that policy plans to reduce electricity/energy consumption should be implemented with caution. The abovementioned works show that the issue of electricity prices and growth analysis is still a trivial issue. Instead, they are much concerned with other forms of energy.

Other studies have examined the relationship between energy and output growth at sectoral levels. These are the European union (Capros, Paroussos, Charalampids, Fragkiadakis, Karkatsouils and Tsani, 2016), Germany, Italy, Spain, UK and France (Timilsina, Mevel and Shhrestha, 2011), France, German, UK and Italy (Jiménez-Rodríguez, 2008) and USA (Jorgenson, 1984). However, they still utilised the time series analysis. Other studies (Jimenez-Rodriguez, 2008) employed oil price instead of other forms such as electricity as the proxy for energy prices. More so, the manufacturing and agriculture sectors were considered the most. Jorgensen (1984) applied the econometric model of production and technical change theory in examining the role of electrification on output productivity in the USA. The study examined the output as a function of the prices of all the productive inputs (capital, labour, electricity, non-electrical energy and materials) per each sector. The time series from 1958 to 1979 suggests that productivity growth in the USA is electricity-using. The use of electricity prices as a separate productive input and variable of output /productivity growth in Jorgenson (1984)'s study indicates that electricity prices and output are related. This is consistent with Templet (2001) who suggested that energy (electricity) is essential for technological, social and economic processes where it supplements capital and labour and in the production process. Thus, a dearth of energy adversely affects economic growth and technological progress.

In addition to that, Jiménez-Rodríguez (2008) used VAR methodology to investigate the output response of the manufacturing industries to energy price shocks in France, German, Italy, Spain, UK and the US from 1975-1998. The study found that the energy price shocks in those countries affect the transport and production costs, thereby adversely affecting output in the manufacturing sector. Although the study considered sectoral (food and beverages, tobacco, paper, metal and non-metal products, machinery and equipment) analysis, it suffered data unavailability. For instance, the sample data used in the study runs from 1975 to 1998 for all countries but for France and Spain the data starts in 1980. Again, the use of time series data suffers heterogeneity bias. The study only considered oil prices and the form of energy, leaving other forms such as coal, gas and electricity unexplained. Consistently, other multi-country studies such as those by Timilsina, Mevel and Shhrestha (2011) employed different econometric methods such as computable generalised equilibrium (CGE) to analyse impact of energy prices on the agriculture sector for 25 developing and developed economies. The findings of the study suggest that the aggregate output drops due to oil price increases and reduces global food supply. Although the study suggests that energy is an important source of economic growth, it does not explain sectoral output responsiveness to energy consumption or prices, for instance which sectors are most affected or in need of energy to operate. These studies were mainly concerned with time series and overall analysis which are likely to suffer heterogeneity biases.

3.3.2 Empirical literature in developing countries

The investigation of the relationship between energy/electricity and output in developing economies is mainly focused on electricity consumption and overall GDP. Again, the contrasting and conflicting empirical findings on nexus lie in the variety of methodologies and testing procedures used in the analysis.

Although with different results, several works have some similarities at some point. Various writings on electricity/energy and output growth have a common interpretation concerning the direction of causality between electricity consumption, price and GDP. Studies in Bangladesh (Masuduzzaman, 2013), Botswana (Adebola, 2011), Kenya (Odhiambo, 2010), Tanzania (Odhiambo, 2009b), China (Yuan, Zhao, Yu and Hu, 2007) and Turkey (Soytas & Sari, 2003) utilised the VAR Granger causality tests. Their findings suggest that the output in those countries are energy driven from 1981-2011, 1980-2008, 1972-2006, 1978-2004 and 1950-1992 respectively. In doing so, the said literature indicated that energy or electricity in those countries is a limiting factor of production. Therefore, shocks in the electricity supply will adversely affect output growth. However, more is said about the demand for electricity than the electricity price. These studies, with the exception of (Odhiambo, 2010), were mainly concerned with the causality between the variables and not on the impact of electricity supply shocks (such as electricity price hikes) impact on output. Apart from that, there are studies that are in consensus that economic growth is not entirely dependent on electricity consumption or affected by electricity prices. These include Malaysia from 1970 to 2009 (Tang & Tan, 2013), Pakistan between 1960 and 2008 (Jamil & Ahmad, 2010), Congo from 1972 to 2006 (Odhiambo, 2010), Philippines and Malaysia from 1971 to 2006 (Chen, Kuo and Chen, 2007) and India between 1950-1956 (Ghosh, 2002). This shows that electricity prices are ineffective in these economies.

Therefore, the conservation policies in these economies can be implemented without disturbing economic growth in the countries.

Literature on electricity prices, consumption and GDP in developing countries is at odds although they utilised similar approaches. The VECM Granger causality test in Altinay and Karagol (2005) found a weaker evidence of electricity prices and consumption from 1950 to 2000 in Turkey. Consequently, the study indicated that supply of electricity is vital in Turkey since the Granger causality runs from electricity consumption to output growth. The electricity-growth literature is much concerned with aggregated economic indicators such as consumption and price levels. Again, very little attention was focused on sectoral output analysis. Likewise, Chen *et al.* (2007) applied the same method on the time series data from 1971 to 2012 in the case of Hong Kong and Korea. The results of the study, however, indicate that that the prices of electricity in Hong Kong and Korea are very low. Therefore, an increase in output in those countries causes an increase in electricity consumption.

Conflicts of results also occurred between different studies of the same country. Thus, Jamil and Ahmad (2010) employed a multivariate equation to examine the relationship between electricity consumption, price and output growth using VECM from 1960 to 2008 in Pakistan. The findings of the study indicate that economic output growth in Pakistan increases electricity consumption and prices. However, Javid, Javid and Awan (2012) used a similar method on the time series data from 1971 to 2008. The findings of the study indicate that Pakistan's economic growth is electricity-dependent. Indeed, the disparate results between these studies may have been caused by different variables set up. Thus, the use of bivariate equations in the latter study created the danger of omitted variables. More so, Jamil and Ahmad (2010) considered the issue of sectoral output (such as residential, commercial, manufacturing and agriculture) analysis unlike the overall GDP in Javid *et al.* (2012). This study provides a clue on the relationship between electricity prices and sectoral output and hence it assisted the researcher to identify appropriate variables for the model of this study

Other studies used different methods but yielded similar results. For instance, Masuduzzaman (2013) Adebola (2011),Yuan *et al.* (2007) and Altinay and Karagol (2005) employed Johansen cointegration, ARDL and error correction model Granger causality test in investigating the electricity use and economic growth relationship. The findings from these studies were that electricity consumption and price shocks have an adverse effect on output growth. The panel data regression in East Asia (Furuoka, 2015) and the ARDL in Congo (Odhiambo, 2010) provided similar evidence, namely that the electricity conservation policy in those countries can be instigated without distressing output growth. This follows the empirical upshots which maintain that output is the main driver of electricity consumption. Once more, Javid, Muhammad and Awan (2012) employed the VAR method in examining the relationship between electricity consumption and economic growth in Pakistan from 1971 to 2008. In conjunction with that, Naseem and Khan (2015) investigated the impact of the energy crisis on economic growth in Pakistan over the period 1971-2011, using the correlation analysis. Although Javid *et al.* (2012) and Naseem and Khan (2015) used different methodologies and time periods for the same country, they are in consensus that energy and electricity in particular are vital for economic growth in Pakistan. The aforementioned works of Naseen and Khan (2015), Tang and Tan (2013) and Javid *et al.* (2012) were more concerned with electricity consumption than electricity prices and economic growth at aggregated levels.

Literature on panel data and sectoral output analysis with regards to electricity prices is scarce as much of the work is devoted more to GDP and overall energy consumption and prices. The VECM Granger causality shows that growth in manufacturing, agriculture, residential and commercial output tended to increase electricity consumption between 1960 to 2008 (Jamil & Ahmad, 2010). Mehmood Mirza, Bergland and Afzal (2014) utilised the time series from 1971 to 2009 and the VAR Granger causality and Johansen cointegration to investigate the electricity conservation policies and sectoral output in Pakistan. However, an increase in electricity prices in Pakistan (Mehmood *et al.,* 2014) from 1971 to 2009 tended to decrease electricity consumption. The VAR Granger causality and Johansen cointegration tests results found that price hikes decrease output in the industrial sectors and service output in the long run. Therefore, the use of time series which suffers heterogeneity bias, different methodologies and study time periods resulted in incongruent inferences. Nevertheless, the studies are in consensus that policies that induce improvements in energy efficiency will have a positive impact on sectoral output. The works show that electricity demand in Pakistan is highly responsive to electricity prices.

Kwon, Cho, Roberts, Kim, Park and Edward Yu (2016a) investigated the impact of electricity prices policy on manufacturing output and electricity demand in South Korea. The study was conducted over 16 regions including seven metropolitan cities from 2004 to 2012. Kwon, Cho, Roberts, Kim,Park and Edward Yu (2016b) used the monthly data from January 2004 to December 2012 in the same regions. The same panel data methodology was employed to examine the short and long run effects of electricity prices on electricity intensity on the manufacturing sector. Although the two studies used different panel data series (annual and monthly), they still yielded the same results that an increase in electricity prices reduces electricity demand which adversely affects the manufacturing output. However, Kwon, *et al.* (2016b) suggested that electricity prices are likely to be effective as a long-term tool to improve electricity efficiency in the manufacturing sector. The studies were mainly concerned with the aggregated manufacturing sector. This did not account for firms facing different adjustment cost having different optimal equipment substitution speeds.

The literature on energy/consumption, price and economic growth is mainly focused on testing the direction of causality and an overall analysis between the aforesaid variables. The use of panel data analysis in these works aimed to examine country level analysis. The studies include Rezitis and Ahammad (2015), Furuoka (2015), Odhiambo (2010), Chen *et al.* (2007), Wolde-Rufael (2006), and Asafu-Adjaye (2000). Among these countries, some employed panel data and others employed single regression tests such as ADRL (Odhiambo, 2010). However Chen *et al.* (2007) considered sectoral analysis and found that expansion in output growth increases electricity consumption in the construction, manufacturing and transport sector in the ten Asian countries. Odhiambo (2010) and Wolde-Rufael (2006) provided conflicting results for Congo from 1971 to 2001. For instance, the cointegration ARDL model (Odhiambo, 2010) shows that an increase in output growth leads to continuous increase in electricity prices and consumption. However, the Pesraran cointegration and the new version Granger causality from 1971 to 2001 (Wolde-Rufael, 2006) suggests that GDP is energy-dependent. This implies that the magnitude of electricity prices and consumption is likely to be determined by prices, level and characteristics of economic activities in those economies (Khanna & Rao, 2009). Electricity prices are scarcely discussed in this literature since numerous researchers believe that the cost share of electricity is very small. While the study confirms that economic output can cause high electricity consumption, issues of causality at sectoral analysis are not clearly explained in these countries. Indeed, overall GDP does not define individual output responsiveness to electricity consumption.

Although the issue of electricity prices is of less concern in the energy and output growth literature, other studies also provide evidence that electricity price changes have a significant impact on output. The studies include Ghana (Enu, 2014), China (He, Zhang and Hao, 2015), Nigeria (Osigwe & Arawomo, 2015) Korea (Lim & Yoo, 2013) and Jordan (Bashier, 2016). The said works utilised different methods and time periods. For instance, Enu (2014) used the ordinary least of squares (OLS) estimation technique to analyse the impact of electricity consumption on real output in Ghana, using time series data. He, Zhang and Hao (2015) analysed the electricity price policies on economic growth in China from 2000 to 2010. Both studies found that the prices of electricity have a strong significant bearing on both consumption and the economic growth. However, the impact of electricity prices on growth at sectoral level was not clearly explained.

Furthermore, Osigwe and Arawomo (2015) included electricity prices in the investigation of electricity consumption, prices and economic growth from 1970 to 2012. The Granger causality and error correction term system recommends that electricity prices affect consumption. Electricity is vital input, therefore changes in its prices are expected to cause a chain reaction in cost and hence prices in all industries. Despite the different methodologies (VECM granger causality and ARDL) from 1976 to 2013, Jordan (Bashier, 2016) also revealed that low electricity prices increase consumption which boosts GDP in Jordan. Also, Lim and Yoo (2013) investigated the impact of electricity price changes on industrial output and general price level in Korea using the input-output model for 168 sectors. The study found that the wood, paper products and water supply sector are sectors facing the highest effects from the increase in electricity prices. Transportation, finance, insurance and administration, defence and the agriculture sectors face the least effect from the electricity prices. This also indicates that electricity prices are negatively related to electricity consumption and output growth.

3.3.3 Empirical literature in South Africa

Most studies (Amusa *et al.,* 2013; Bildirici *et al.,* 2012; Odhiambo 2010; Odhiambo, 2009 Ziramba, 2008; Wolde-Rufael, 2006) done in and for South Africa were more concerned with electricity consumption than prices and GDP analysis. The time period for most of the studies was when electricity prices were very low in the country. This made it more challenging for the said studies to detect the real effect of electricity prices on either electricity demand or output. Although some studies (Inglesi-Lotz & Blignaut, 2011; Blignaut *et al*., 2015) used panel data regression, they were more concerned with electricity consumption than electricity prices.

There are multi-country studies that considered South Africa. For instance, Wolde-Rufael (2006) found no causality relationship between electricity consumption and output growth from 1971 to 2001. This was due to cheap and abundant supply of coal in South Africa (Kenny, 2015). The use of the bivariate framework is likely to have suffered omitted variable bias. However, the ARDL with additional variables in Odhiambo (2010) yielded a different inference that the South African economy is energy dependent. Also, the use of other forms of energy such as oil in Timilsina *et al.* (2011) suggested that energy prices in South Africa cause output decline. Apart from that, the ARDL from 1970 to 2010 (Bildirici *et al.,* 2012) and the VECM Granger causality tests from 1974-2011 (Fei *et al.,* 2014) provided similar evidence that a permanent increase in output in the country tends to increase electricity consumption. The issue of electricity in these cases is of less concern and difficult to detect since the studies employed a longer time period (1970-2007) for low electricity prices and a shorter time period (2008-2011) for high electricity prices.

Altman, Davis, Mather, Flemming and Harris (2008) used economic modelling, financial modelling, substantial interaction with stakeholders, and experts in a range of sectors to examine the impact of electricity prices on the South African economy. The study posited that raising prices will reduce demand without requiring choice about the allocation of the cuts. Altman, Davies, Mather, Fleming and Harris (2009) added that the impact of electricity prices was already affecting food security in South Africa. However, income was the main determinant of electricity demand between 1960 and 2007. Altman *et al.* (2008) stated that demand and consumption of electricity can be affected by price and hence consumption is affected by the cost to the user's ability to respond to price increases in South Africa. In addition to that, Altiman, Mather, Fleming and Harris (2010) posited that electricity prices in South Africa were very low compared to world standards. Therefore, the low electricity prices in South Africa show a weak/-negative effect on economic growth. Lower past electricity prices were due to abundant coal reserves maximising economies of scale through technology use, exclusion of externality costs, and exemption of Eskom from taxation and payments of dividends. This shows that the aforementioned studies were more concerned with electricity availability and not the prices.

Inglesi-Lotz and Pouris (2010) examined the impact of electricity prices on electricity demand using the projected data from 2007 to 2030, the cointegration and Engel Grange test. The study determined that electricity prices have a high impact on electricity use. Likewise, Boonzaaier *et al.* (2012) found that erosion in operating profits will likely have an impact on investment decision. Boonzaaier *et al.* (2012) used financial information from 21 large firms in various sectors, to investigate the impact of rising electricity tariffs at firm and sectoral level in South Africa. The study indicated that if the electricity prices go up, the firms may choose to cut costs, implement energy efficiency measures, close parts of the operations, move plants to other countries as well as invest in other sectors and invest in own generation capacity. When electricity prices rises, some sectors choose to generate their own power, but others will simply look to reduce consumption and output and invest less in energy intensive sectors. Although the two studies use different methodologies, they are in consensus that electricity prices have a great impact on both electricity demand and output.

Inglesi-Lotz and Blignaut (2011) reconsidered electricity consumption with regards to electricity price fluctuations and economic output from 1993-2006. The panel data framework shows that output in South Africa is energy driven except for the industrial sector which is a more sensitive sector in response to electricity price fluctuations. Blignaut, Inglesi-Lotz and Weideman (2015) utilised the same methodology to examine how sectors behave in response to electricity consumption. The study also added electricity tariffs in the regression model. However, the time interval was much shorter (2002-2011) (Inglesi-Lotz & Blignaut, 2011). More so, Blignaut *et al.* (2015) included the period after sharp rises in electricity prices which was for just four years. The panel data analysis revealed that the effect of electricity prices was insignificant for the majority of sectors. However, the study found that from 2008 some sectors like the manufacturing and trade sectors showed a sensitivity to price changes. The study posited that with high electricity prices for small and medium enterprises, it becomes unbearable and causes them to close down, thus putting severe constraints on the economic production. Much of the electricity price data recorded the period of low electricity prices to be a short period of four years. The studies made an important contribution in the sense that they identified a reaction of electricity consumption with regards to changes in electricity prices. However, the issue of the output sector reaction with regards to electricity prices is still in suspension. The period of study was characterised by low and declining electricity prices in the country. Hence it becomes difficult to identify the electricity price effect on sectoral output. The mining sector was found to have reacted negatively to price changes even during low electricity price periods. More so, Inglesi-Lotz Blignaut (2011) and Blignaut *et al.* (2015) also suggested that sectors such as mining show an insignificant response to electricity prices since they are engaged in generating their own electricity or creating smaller power units.

Eskom (2011) examined the impact of electricity price hikes on the South African economy. The time series macro-economic approach and the computable general equilibrium (CGE) methods suggests that electricity price hikes in South Africa have a negative impact on both the sectoral output and the macro economy. The study also found that rising electricity prices in the long run will cause a negative impact on the entire macroeconomic system. The outcomes depict that electricity prices have a significant negative long run impact on the entire macroeconomic system. Kholer (2013) investigated differential electricity pricing and energy efficiency in South Africa from 1989 to 2010. Although Kohler (2013) employed a different technique (Engel Granger cointegration and ARDL), his results also indicate that electricity price hikes reduce economic output.

Deloitte (2012) examined the electricity price impact on various sectors of the South African economy using a CGE and dynamic time series macro-econometric framework – the findings confirm that only the mining and manufacturing sectors are likely to suffer a decline in output and employment as electricity prices rise. Eather and Frawley (2015) added that limited electricity availability is expected to adversely affect the manufacturing and other economic sector performances in future. Both historical and electricity price changes were analysed and the findings are that the manufacturing sectors are likely to suffer the largest decline in output and employment as electricity prices rise. Nonetheless, the results only display the impact on a few sectors of the economy. Deloitte (2012) proposed that literature on the electricity and output relationship focuses only on the short run impact of rising prices on employment and output. However, they fail to note that in the absence of cost reflective prices, a costly mismatch between supply and demand is likely to continue. Therefore, panel data techniques allow control of unobserved variables which in this case will cater for those unobserved variables.

Furthermore, works of Deloitte (2012) suggest that power outages have a greater cost to the economy than rising electricity prices. However, there is no econometric outline to prove this power outage effect on the economy.

Amusa, Amusa and Mabugu (2013) employed a bound testing approach to cointegration to investigate aggregate demand for electricity in South Africa. The study found that income was the main driver of electricity demand while electricity prices had an insignificant effect on electricity consumption from 1960-2007. Inglesi-Lotz (2014) used a different methodology (Kalman Filter) in investigating the sensitivity of the South African industrial sectors to electricity price fluctuations. The findings of the study indicate from 1970-2007 electricity price sensitivity experienced an inelastic demand. Thus, electricity prices have no effect on electricity consumption. Ziramba (2008) also investigated the electricity prices, consumption and income nexus for the residential sector. However, the ARDL and OLS results indicate that electricity prices had no effect on income whist electricity use rose with income from 1985 to 2005. Likewise, the study indicated that electricity prices had no impact on output or electricity demand since their time periods were associated with low and declining prices in South Africa. The above studies have employed electricity prices in their analysis. They also employed different methodologies. However, the similar study period range resulted in similar findings, namely that electricity prices and output have a weaker connection.

Furthermore, Montmasson-Clair and Ryan (2014) investigated the impact of electricity prices on the mining sector's output in South Africa from 1972 to 2018. The study explained that there are different types of mining in South Africa, such as the surface and deep shaft mining. The surface mining which depends more on diesel has been less affected than the deep shaft mining which relies more on electricity. The mining sector has thus not been affected much by electricity price changes since they adopted traditional solutions such as load shifting and diesel backup generators. More so, the mining sectors embarked on new innovations around the implementation of new energy efficient technologies and the use of cogenerations and renewable energy. This implies that the electricity prices have a diverse impact on the mining output since the mining sectors vary in terms of energy use and business operations.

Past electricity prices in South Africa became a great challenge for researchers on how to predict the future effect of electricity prices on both aggregate and disaggregate output. This implies that numerous studies on this matter have proven income as a key driver of electricity consumption considering a neutral hypothesis between electricity price and economic growth. The low and declining electricity prices in South Africa over the periods of study made it difficult for numerous researchers to identify the impact of electricity prices in the country. However, the current study has included a period when electricity prices were declining and increasing (1994-2015). Also, the use of panel data instead of time series and cross sectional data allowed output analysis at sectoral levels.

3.4 ASSESSMENT OF LITERATURE

This chapter has presented the theoretical literature that shows the relationship between output, energy and electricity in particular. From the reviewed theories, the mainstream theory gives the leads on specification of a production function. However, it does not include electricity as independent and separate factor of production. In contrast, the Kummel (1982), Rosenberg (1983) and Schurr and Netschert (1960) theories suggest that energy is a substantive factor of production and that output is determined by prices of inputs (such as labour, material, electricity and nonelectrical) of production.

The issue of the electricity and output growth relationship has been debatable in both developed and developing countries, particularly in South Africa. The findings on the relationship between energy and output growth are disparate and contrasting among countries and studies of the same countries. Those differences may have been caused by different institutional and structural characteristics, exposure in energy sources, supply crisis, prices, climatic conditions and behavioural patterns. Although with conflicting results, most of these studies have several similarities. A noticeable similarity in the abovementioned energy and growth literature is the utilisation of causality tests to investigate the relationships.

Empirical studies have regarded electricity as an additional factor of production and others do not recognise it as an important factor. The studies the researcher reviewed focused much on the relationship between electricity consumption and GDP. The electricity price variable has been regarded as an additional variable to avoid an omitted variable trap. Therefore, the effect of electricity prices have become relatively less substantial in the causal chain. Furthermore, the empirical literature indicates that the Engel Granger causality and cointegration has been the most common used technique in the energy (electricity) growth literature. The studies mainly focused on testing the direction of causality between electricity consumption or prices and output instead of the impact. Studies that used the multivariate system on the relationship between electricity and output also considered capital formation and employment. Much less attention has been devoted to panel data analysis than time series and cross sectional. Works from the developed and developing regions, including South Africa, demonstrated mixed hypotheses. Much focus was on the impact of electricity on overall economic growth rather than the impact on economic output at sectoral level.

There is a lack of studies that have looked at electricity prices and the sectoral output relationship in South Africa. Among those that attempted to do so, Inglesi-Lotz and Blignaut (2011) and Blignaut *et al.* (2015) are the notable exception that used panel data analysis to examine sectoral electricity demand in response to electricity price. However, their studies were conducted when electricity prices were very low and declining, such that the impact of the prices on either output or consumption could not be identified. Although the studies utilised panel data analysis and examined how each sector consumption responds to electricity prices, the issue of sectoral output responsiveness to electricity prices change was not discussed much. Also, most of the previous studies considered the effects of electricity consumption and prices on overall output. Moreover, studies that used output as their outcome variable used their predictors as electricity consumption and overall electricity demand. Therefore, studies that focused on electricity prices and sectoral output using panel data in South Africa are exceptional. Most of the panel data analysis widely covered industrialised countries such as UK, USA, Japan and China. Although panel data was employed in studies in developed countries, most of the studies utilised the data for country-level analysis instead of sectoral level. However, the same cannot be said in developing regions and South Africa in particular. Previous studies used time series as well as surveys and rarely used panel data.

One other concern with the results for individual countries is that they are often impaired by a short data span that lowers the power of unit root and cointegration tests. Yet another issue is unavailability of data (Jiménez-Rodríguez, 2008) for energy prices, hence other studies proxied the variable with consumer price index and oil prices (Wolde-Rufael, 2006). Most studies concentrated on electricity consumption to price elasticity as well as the impact of electricity prices and demand of electricity on aggregate output and not on the sectorial level. In addition, most studies focused on impact of load shedding. Different methods of analysing the impact of electricity supply, demand, consumption and use resulted in different results. More specifically, the literature in developed and developing countries, including South Africa, employed the time period between 1970 and 2010 when electricity prices were very low. Therefore, detecting the impact of the electricity price on output was regarded as trivial. However, the present study used more recent panel data (1994-2015) to examine output response to electricity prices at sectoral level.

3.5 CHAPTER SUMMARY

This chapter assessed the theoretical literature that shows the relationship between output energy and electricity in particular. The mainstream theory gives leads on the output function although it pays less attention to energy or electricity as a factor of production. The Kummel model shows that electricity, among others (capital, labour and material), is a substantive factor of production that can be treated as an independent and separate input. The Rosenberg (1983) Schurr and Netschert (1960) theory reckons that output or output prices can be affected by prices of production inputs of which electricity is one of the factors. Apart from that, the chapter discussed empirical literature from different economies which include developed and developing countries, including South Africa in particular. Much of the empirical studies consider economic growth as the main driver of electricity consumption. Electricity prices show an insignificant impact on economic growth in developing countries compared to developed countries. Numerous studies were more devoted to analysis of economic output, energy prices and consumption at overall levels than the sectoral level. Furthermore, empirical studies were more concerned with time series and cross-sectional analysis than panel data which controls heterogeneity bias. To sum up, the chapter provided an evaluation of works which have underlined the contribution of the present study. The following chapter presents the research methodology and empirical estimation techniques utilised in this study.

CHAPTER FOUR
RESEARCH METHODOLOGY

4.1 INTRODUCTION

The review of literature on energy (electricity)-output and an overview of energy growth theories shed some light on the connection between sectoral output and its potential determinants. This chapter provides the research methodology used in this study to address the objectives of the study stated in the first chapter. The chapter is fragmented into three major sections. The first section is the model specification which includes the definition of variables and their expected priories with data source. The second section presents the estimation techniques which cover stationarity tests, panel data estimation analysis, diagnostic tests and the justification for using robust standard error estimators. The last section is the chapter summary.

4.2 MODEL SPECIFICATION AND DEFINITION OF VARIABLES

To investigate the impact of electricity prices on sectoral output in South Africa, the study adopted the model proposed in Ghali and El-Sakka (2004) and the model used in Ciarreta and Zarraga (2010). The Ghali and El-Sakka (2004) model emphasises that energy is a substantial input of production whereas the Ciarreta and Zarraga (2010) model reviews the relationship between electricity prices and consumption and GDP using panel data. The two models are presented in equations 4.1 and 4.2 respectively. Ghali and El-Sakka (2004) employed the conventional neo-classical one sector aggregate production framework where labour, capital and energy are treated as separate inputs. In addition, the study used multivariate cointegration analysis to investigate the relationship between energy use and output growth in Canada. This model regards energy and output in overall terms.

Ciarreta and Zarraga (2010) used the panel data analysis to study the long run and causal association between electricity consumption, price and real output for 12 European countries using annual data from 1970 to 2007. Although the study used panel data analysis at country level, the output variable was still analysed in aggregate terms. However, this study modified the energy production function where the output was disaggregated into sectoral output and the form of energy used was electricity. The conventional neo-classical production model is presented in an equation where the aggregate output is a unique function of capital, labour and electricity which is expressed in equation 4.1 as:

$$Y_t = f(K_t, L_t, A_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4.1)$$

Where Y_t the aggregate is output, K_t denotes the capital stock, L_t is the level of employment and A_t is the total energy consumption in aggregate levels

This model confirms the energy-growth production function where all three inputs (labour, capital and energy) are treated distinctively. The ideal avoids mainstream replicas such as the Solow model of production which does not include energy as an effective factor of production (Sterm, 2004). Also, the energy-production function considers energy or electricity and capital as possible complements rather than substitutes. The Ciarreta and Zarraga (2010) model is consistent with Rosenberg (1983) and Schurr and Netschert (1960) who suggested that output price or output of a sector is determined by the price inputs (such as labour, capital and electricity) used for production. Additionally, the Ciarreta and Zarraga (2010) model is presented in equation 4.2 as:

$$GDP_{it} = \alpha_i + \delta_{it} + \beta_{1i}EC_{it} + \beta_{2i}EP_{it} + \varepsilon_{it} \ldots.i = 1 \ldots\ldots.N, t = 1 \ldots\ldots..T \ldots\ldots\ldots\ldots.(4.2)$$

Where α_i is the country specific intercept, with δ_{it} being the deterministic trend specific to individual countries in the panel. β_{1i} and β_{2i} are slope coefficients which can vary from one individual to the other allowing cointergration vectors to be heterogeneous across countries. Furthermore, GDP_{it} , EC_{it} and EP_{it} denote real gross domestic product at country level, electricity consumption and electricity prices respectively. The subscript it is the cross-country units (12 countries) and time period of 37 years respectively.

The above models were then modified, where the sectoral or individual output *i* with eight panel dimensions, at time *t* with 22 time measurements comprise the function of electricity prices, sector specific variables (unit labour cost (Ulc), remuneration (Rem), sector imports (Ipt), intermediate input prices (Iip)), macroeconomic control variables (such as inflation, exchange rate and interest rate), dummy variable and the error term. The panel data model of the study is presented as:

$$SY_{it} = \beta_0 + \beta_1 EP_t + \beta_2 SR_{it} + \beta_3 ME_t + \varepsilon_{it}, i = 1, \ldots..N, t = 1 \ldots..T \ldots\ldots\ldots\ldots\ldots.\ldots\ldots(4.3)$$

Where:

SY_{it} = Real output in sector *i*=8 at time *t*=22years thus T >N

ε_{it} is the error term which consists of an idiosyncratic component and an unobserved heterogeneity component. The disturbance term varies for each individual at each point time.

EP$_t$ = The electricity price and is the main independent variable in this study.

SR$_{it}$ = Sectoral specific variables at time t in sector i (unit labour cost, remuneration, labour productivity, among others). These are observable characteristics that affect sectoral output. The fixed or random effect specific to individual (group) or time period that is not included in the regression can be called an unobserved component latent variable or unobserved heterogeneity.

ME$_t$ = Macroeconomic control variables (inflation, expenditure on health, interest rate, exchange rate). Macroeconomic variables such as interest rates, inflation and exchange rate have a t subscript, since they do not vary across sectors.

The independent variables can be observed with the sample whereas the goal is to estimate the coefficients. The t is the subscript that denotes the time period that is 22 years. The i is the i^{th} cross-sectional unit which signifies eight numerous economic sectors denoted by subscript i which includes agriculture, manufacturing, trade, mining, transport and communication, general government and finance. β_0 is the constant and $\varepsilon_t$is the disturbance or stochastic error term which signifies all those variables that affect sectoral output but are not taken into account explicitly. β_1, β_2, β_3 and β_4 are coefficients of the predictor variables to be estimated which can be the same in each time period

4.2.1 Definition of variables and the expected a priori of each

SY is the sectoral output which is the dependent variable; it is the quantity of goods or services produced in each sector selected in this study in a given period of time. It is a measure of productivity which attempts to account for all direct inputs to production such as capital, labour, energy, and material purchased and services purchased (Snowdon &Vane, 2005). The study expected to determine a significant relationship between the dependent variable and its predictors. The study also broadly expected a negative and significant relationship between the dependent variable (sectoral output) and the main regressor (electricity prices).

Electricity price (LEP) is the main predictor of the study. It is defined as the combination of charges (covering different aspects) of supply of electricity to a customer. In South Africa, the electricity prices are determined by the National Electricity Regulator South Africa (NERSA)

(Amara, 2013). Numerous studies on energy and output have considered electricity consumption as the proxy for electricity. However, this study employed electricity prices as the proxy and the main explanatory variable for the research. The study expected to find a negative relationship between electricity prices and sectoral output. Large sectoral output was expected when the prices are low whilst high prices decline the sectoral output.

LSR represents the sector specific variables. These are variables that affect sectors accordingly. The variables include sectoral imports, remuneration, intermediate input prices, unit labour cost, remuneration, real gross fixed capital and labour productivity. These variables are expected to have a diverse significant impact on sectoral output. For instance, changes in sectoral imports are expected to have a negative impact on sectoral output.

Unit labour costs (ULC) measure the average cost of labour per unit of output and are calculated as the ratio of total labour costs to real output. ULC presents the cost of labour required to produce one unit of output. Labour costs show how much output a sector receives relative to wage or labour cost per unit of output. Venter and Botes (2016) suggested that the ULC is an index of the total salaries and wages paid out by a sector or an industry. The economic theory suggests that if the labour costs of a sector or an economy increase, it shows that productivity is decreasing (Snowdon & Vane, 2005). Given that, this research expected to find a negative relationship between the unit labour costs and the real sectoral output.

Remuneration is the total amount paid to employees in money or in kind and includes salaries, wages, bonus and employers' contribution to pension and provident funds (Ramzan, Zubair, Ali & Arslan, 2014). Remuneration consists of payments and benefits given to stimulate better performance in return. Better performance could be in monetary as well as non-monetary terms. Again it could be based on group performance as it helps to keep labour turnover within stable limits. However, it can be costly to those economic sectors, hence boosting productivity and performance within a sector. Therefore, this study expected a positive connection between the variables.

Sector imports are usually considered to be a drag on the economy (Quantec, 2014). Thus, imports represent an outflow of the funds from the country and the economic sectors through payment made by the local sectors to exporters. However, high importation of goods and services may decrease output growth for sectors. Low rate of import penetration could imply that there are import limitations. This may reflect superior productivity or lower prices of domestically produced products.

Intermediate input price is the weighted average of the prices that the sector has to pay for its raw materials. Lee (2002) suggested that intermediate prices can pass through increasing production costs to final consumer prices. Therefore, if the consumer prices go up, consumption for a certain product will decrease. Consequently, the output will fall as aggregate demand goes down. Given this, this study expected the real sector output to go down as intermediate input prices increase.

Real gross fixed capital stock (*Rs)* is the total value of the fixed capital goods in the economic sector or an economy at the end of the year shown for each and every sector. It also includes spending on land improvements such as fences, drains, transport equipment, buildings, plant machinery and equipment purchasing, construction of roads and private dwellings. Saleh (1997) opined that gross fixed capital formation covers human as well as material capital, which includes investment in skills, education, etc. Thus, if a sector cannot replace capital goods then production declines. Generally, the higher the capital formation, the faster a sector can grow its real output. By so doing, this study expected a positive connection between sectoral output and Rs.

Labor productivity measures the real value added to labour input measured as the number of workers. According to the Bureau of Labor Statistics (2016), labour productivity describes the relationship between real output and the labour hours involved in its production – the amount of goods and services produced by one hour of labour. It thus relates output to the number of employees in a particular industry. Thus, if productivity goes down the output follows the trend.

LME refers to the macroeconomic variables such as inflation, interest rates and exchange rate. Inflation rate is the percentage rate change in price. In addition to that, unanticipated currency fluctuations appear more significant with varying effects on sectoral output (Mishkin, 2004). Macroeconomic variables are the economic indicators which have an influence of the economy as a whole. However, their effect may vary across different sector outputs.

Expenditure in health includes the activities performed by the government through the application of medical knowledge and technology to promote, restore or maintain health in the country. In this case, the government spends money on health goods and services (Paruk, Blackburn, Friedman and Mayosi, 2014). Therefore, healthy employees boost production and hence high output growth, while unhealthy labour decreases output growth. The study expected to find a positive relationship between expenditure on health and sectoral output.

Inflation is the constant prompt increase in prices as measured by an expansive index (such as consumer prices index) and fall in the purchasing value of money. López-Villavicencio and Mignon (2011) argued that the relationship between inflation and output is positive for low levels of inflation but negative or non-significant for high levels. Inflation in this study is the independent macroeconomic variable. High prices for commodities and other goods and services affect the entire economy in different ways. Inflation may mean an increase in price levels or money supply. In a world where price levels rise, individuals and economic sectors spend more money because they know it will depreciate in future, and this causes an output increase in the near term (Faria & Caneiro, 2001). Therefore, expansion of money supply in an economy causes inflation which may have been caused by low interest rates or quantitative easing. If an economy has contingents on exports, then its output may increase during periods of high inflation. However, economic theory suggests that rising prices impact the cost of investment and borrowing and reduce the rate of savings. Inflation also lowers the value of money. This causes inefficiencies in the economic sectors which may slow business processes. By doing so, one can assume that inflation negatively affects economic sectors. Indeed, the researcher expected to find a negative relationship between inflation and sectoral output in South Africa.

Exchange rate measures the value of one currency for the purpose of conversion to another. Generally, unanticipated currency fluctuations appear more significant with varying effects on output. Depreciation of domestic currency is the primary reason why the export business has remained competitive in international markets. Thus, the exchange rate plays a substantive role for firms which export goods and import raw materials. A devaluation of currency will make exports cheaper and exporting firms will benefit as foreign buyers demand more exports. However, rand depreciation gives rise to higher costs of importing raw materials. Therefore, exports will be more expensive and reduce the competitiveness of exporting firms, thereby reducing sectoral output (Vieira *et al.*, 2012). This will lead to lower demand for the domestic goods by foreigners. The research expected to find a negative relationship between exchange rates and sectoral output.

Low *interest rates* increase investments such that a high level of investment requires higher savings which can be induced by higher income or output levels (Snowdon & Vane, 2005). However, high interest rates lead to a decrease in investment spending and a decrease in demand for goods. Rising costs of borrowing reduces investments and production in various economic sectors. Thus, if interest rates rise, the output levels for various firms goes down. A negative relationship was thus expected between these variables in this study.

4.2.2 Data sources

The study utilised the annual data from the electronic databases of the South African Reserve Bank (SARB), Statistics South Africa and Quantec easy data over the period 1994-2015. The period covers the transition period after apartheid when new policies were implemented. The electricity regulator changed from NER to NERSA. The period of the study includes the low electricity and increasing electricity price era in South Africa.

4.3 RESEARCH ESTIMATION TECHNIQUES

There were issues to consider in developing the methodology of this study. Firstly, most studies as confirmed with the empirical literature in the previous chapter were more devoted to time series and aggregated analysis. The time series suffers heterogeneity biases as well aggregate variables such as GDP, energy consumption or prices which also suffer aggregation biases. This study employed the panel data technique which consists of three basic methods (pooled, fixed and random effect) to examine the impact of electricity prices on sectoral output in South Africa from 1994 to 2015. More so, the study employed panel data econometric techniques which allow control of individual heterogeneity and unobserved variables unlike the time series and cross-sectional data. Likewise, panel data allowed the researcher to have choice of techniques depending on the type of data gathered. Thus if the explanatory variable is uncorrelated with the error term, the random would be appropriate, whilst the fixed is appropriate if the predictors are correlated with the idiosyncratic error terms. Out of the three basic methods, only one model should be appropriate. The appropriate model was detected with the Pagan/Lagrange Multiplier (BP/LM) and the Hausman test. According to Reed and Ye (2011) and Hoechle (2010), the panel data technique allows the use of robust standard error estimators if the basic model suffers violation of the linear panel regression assumptions. The use of the diagnostic check in the study assisted the researcher in identifying the appropriate robust standard error estimators to use if serial and cross-sectional, heteroscedasticity happens to exist in the model of the study. The study employed eight economic sectors (agriculture, communication and transport, construction, finance, general government services, manufacturing, mining and trade). The research also assumed the sample to be characterised by heterogeneity in their behaviour towards electricity usage in production processes. More so, the main objective of the study as stated in the first chapter was to examine how the electricity prices affect output of the selected sectors in the study. Therefore, the study implemented the seemingly unrelated regression (SUR) model to capture the impact of electricity prices on each of the sector outputs separately. In addition to that, the researcher carried out the panel unit root test so that the data should be integrated of the same order. Correspondingly, the estimation techniques in this research were practically implemented on the Stata package so as to attain the research objective stated in the first chapter of the study.

4.3.1 Stationarity Test

The assumption of the classical model necessitates both the predictor and the outcome variables to be stationary and the errors should have a zero mean and finite variance (Gujarati, 2004). Non-stationary variables result in spurious regression (Brooks, 2008). Therefore, the study performed the stationarity tests for each variable to avoid high R^2 and low Durbin Watson statistic.

4.3.1.1 Panel data unit root techniques

Panel unit root tests are similar; however, their strength differs depending on the data series (Nell & Zimmermann, 2011). The stationary panel data equation is the first order autoregressive component. Thus, the unit root test for panel data series equation can be given as follows

$$\boldsymbol{Y_{it} = \rho_i Y_{it-1} + X_{it}\beta_i + \varepsilon_{it}\ where\ i = 1, 2..N; t = 1, 2 \ldots T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.4)$$

Where:

i is the index panel and t is the index time, $X_{it}\beta_i = 1$ is the exogenous variable in the model including any fixed effects or individual trends, ρ_i are autoregressive coefficients, ε_{it} is white noise which is assumed to be mutually independent. Further, $N\ and\ T$ are panel and time dimensions respectively.

Thus if the $\rho_i < 1$ then the dependent variable is said to be weakly (trend) stationary. However, if the autoregressive coefficient is equal to one, then Y_{it} is non-stationary. Therefore, to perform both the individual and common unit root test, two assumptions were considered. The first assumption entailed that the persistent parameters were common across cross sections so that $\rho_i = \rho$ for all (i) sector output in this study. The second assumption was that the autoregressive coefficient are allowed to vary freely (Breitung & Pesaran, 2005).

This study used the panel unit root data system, thus considering the asymptotic behaviour of time series dimension T and the cross-sectional (N) dimension. The way in which N and T converge to infinity is critical if one does not determine the asymptotic behaviour of estimators and tests used for non-stationary panels (Nell & Zimmermann, 2011). The panel unit root tests are divided into two systems which include the individual and the common unit root processes. The common panel unit root tests include the Levin, Lin and Chu (LLC) (2002) Breitung and Hadri tests. Conversely, the individual unit root test includes the Im, Pesaran and Shin (IPS) (2003), Augmented Dickey-Fuller (ADF) and the PP tests.

The aforementioned unit root tests have their own asymptotic properties which warrant caution when comparing results. The LLC is a common unit root test which is powerful if the time dimension T is large (Breitung & Pesaran, 2005). The IPS test is not as restrictive as the LLC test since it allows for heterogeneous coefficient. The Monte Carlo simulations suggest that the small sample performance of the IPS test is better than the LLC test. The individual unit root test differs from the LLC since it relaxes the restrictive assumption that the autoregressive coefficients must be the same for all series under the alternative hypothesis (Im *et al.*, 2003).

Stationarity tests in panel data are also determined by whether the panels are balanced or unbalanced. For instance, the Fisher tests can still perform well even if the data is unbalanced. StataCorp (2013) posited that the size of the researcher's sample determines the appropriate test in a given situation. Thus, the panel that assumes that N is fixed or that it tends to infinity at a slower rate than T is likely to perform better than the ones that are designed for cases where N is large. For instance, the LLC test assumes that N/T=0, so N should be small relative to T. However, the Harris-Tsavalis test undertakes that the time dimension is fixed whereas cross-sectional units go to infinity. Therefore, when choosing a panel unit root test, the researcher should consider the relative sizes of N and T and the comparative speeds at which they tend to go to infinity or whether either N or T is fixed. The Hadri test, unlike other tests, assumes stationarity in panels when the probability value is greater than 5% where the researcher cannot reject the null hypothesis. Some tests are not robust when T or N is small. Since there are a variety of panel data unit root test techniques with strengths and weakness, the researcher took the decision on the basis of the majority of methods. To overcome this constraint, Nell and Zimmermann (2011) suggested that it is advisable to examine the outcome of both the common and individual unit root test such as LLC and IPS.

This research employed the LLC, ImP and Breitung test to test for unit root in panels. These three panel unit root tests assume that N goes to infinity at a slower rate than the time dimension. More so, each panel data series for this research had a similar number of observations covering the same life span. In other words, the panel data used for this study was balanced and thus LLC, ImP and Breitung were likely to perform better than the Hadri and Fisher tests where N increases faster than the T dimension.

4.3.2 Panel data estimation analysis

The data for this research comprised a combination of 22 time dimensions (from 1994 to 2015) and eight cross-sectional economic sector outputs. According to Gujarati and Poter (2009), if the data set has multiple entities where each of them has repeated measurements at different time periods, it then becomes panel. Panel data have individual (group) or time effects which are then examined by fixed or random effect models (Pfister, 2010).

According to Hatz II (2011), a balanced panel exists if the panel data contains no missing values, and individuals are observed an equal number of times. Conversely, if the length of the time series or periods varies across individuals, then the data set becomes unbalanced (Söderbom, 2011). This study employed the balanced panel since the time periods for data are the same for all N individuals. Unlike the time series which uses a single subscript, the panel data has doubled subscripts (it)on its variables, where i is the cross-sectional dimension whilst the t signifies the time measurements. The panel data regression analysis is presented in the following equation (4.6) as:

$$\boldsymbol{Y_{it} = \beta_1 X_{it} + (\alpha_i + \varepsilon_{it}) \ldots\ldots\ldots i = 1 \ldots\ldots N \ldots\ldots\ldots t = 1 \ldots\ldots T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.6)}$$

The above equation assumes that all variables in the equation are not observed. Variable X_{it} is the 1*K vector of regressor (which can be the same but does not have to change over time) and β_1 is K*1 vector of parameters.

The equation 4.6 calls for the assumption that the residuals ε_{it} vary both over time and across individuals and are serially uncorrelated. However, the individual specific component α_i is constant over time for each individual. It does not have a time subscript but it varies across individuals. Thus if the equation is estimated in OLS levels, the individual component will go into error term, such that if an error term is uncorrelated with the regressor it becomes another unobserved factor making up the residual.

4.3.2.1 Motive behind employing panel data

Biased estimates can result from time series and cross-section studies as they do not seem to control for individual heterogeneity. This study employed panel data since they have a variation increase in the data and there is efficiency improvement in the estimates (Hurlin, 2010; Knust, 2010). This increases their ability to consider and make right conclusions on the complicated behavioural hypothesis such that they reduce aggregation biases (Lockwood and McCaffrey, 2007).

The study employed eight economic sectors whose outputs are affected by various factors such as business practices which are hardly observable. Therefore, the use of panel data handled unobserved or missing variables, and unrestricted dynamic relations. In addition, operational activities vary across economic sectors and therefore the use of the panel data in this study allowed control of heterogeneity in the data, measurement errors and non-stationary panel series. This is consistent with Sibanda, Mishi and Tsegaye (2015) who suggested that the panel data techniques allow less collinearity amongst variables, and control of unobserved heterogeneity among variables. Additionally, Sheytanova (2014) also proposed that the use of individual specific component α_i controls individual heterogeneity in panel data. More so, the component helps to explain correlation between the observation variables over time.

In this research, the use of panel data was desirable in the sense that it compares changes over time in a group of economic sectors (such as mining, manufacturing, agriculture, construction, communications) that are either affected or treated by policy change, to control groups that are affected. In doing so, the study inferences will assist the policymakers, the power industry and electricity regulators to focus on the electricity price determination process that emphasises cost-reflective electricity prices and economic development concurrently. This will enhance efficient distribution and use of electricity and thereby improve economic output growth in a sustainable environment. This will augment power industry expansion and improvise sustainable output performance within different sectors of the economy in South Africa.

Söderbom (2011) suggested that working with panel data is looked-for, in the sense that it controls for individual specific, time invariant, within variables. In addition to that, panel data techniques enlarge the sample size such that it becomes easy to obtain more precise estimates with lower standard errors. The framework addresses the endogeneity problem within the regression model, hence allowing to solve an omitted variable problem (Hun, 2011; Söderbom, 2011; Hurlin, 2010). Unlike the time series or cross-sectional, the panel data are able to control for state and time invariant variables (Baltagi, 2008).

Myoung (2011) stated that panel data models are desirable in the sense that they provide further informative data and promote variability. The technique allows the researcher to identify dynamic changes in behaviour of different sector output with regards to electricity price changes. Panel data provides additional information that allows for more accurate estimates. They are less problematic and they require fewer assumptions unlike the time series and cross-sectional data analysis.

In addition to that, the individual specific component limits the unexplained variability and thus the mean square error which makes the model more efficient than the time series and cross-sectional which do not include the specific component. Indeed, they do not require long series. The model can be inferred by making observations on the series for all the individuals. That is, by finding what is common among the individual one can construct a model accurately without having to rely on long time series – such that the available data across sectors in this study could compensate time series. Despite that, data gathering control and traceability of the sampled individuals is one of the limitations of the panel data technique. The panel data techniques as noted in Torres-Reyna (2010) consider variables at different levels such as sectoral output, inflation and exchange rate.

In this study, the economic sectors real output and their sector specific variables (such as unit labour cost, sector imports and real gross fixed stock) were repeatedly measured. There could be group (individually) or time effects which were thus analysed by fixed or random effect. To cater for this type of bias, the panel data analysis was employed. The analysis technique is desirable as it explores more issues than time series and cross-sectional since panel data have more variability.

Among the three basic panel data estimators, Guajarati (2004) indicated that the pooled data regression is heavily biased because of unobserved heterogeneity. The three basic panel data models are presented in Chapter Five of this study to show some comparisons between the results and to identify the requirements of the latter estimators. More so, the status of the data set determined the suitable methods in this study since all the estimators could not be used at one time. Tests such as the Hausman tests, BP/LM and the stationarity tests (such as LLC, Im Pesaran, Breitung, Hadri and Harris) were conducted to decide the appropriate estimator for the study.

4.3.2.2 Pooled regression

The problem with pooled estimation technique for this study is that it does not distinguish between the various sectors (Podestà, 2000). By pooling, the model denies the heterogeneity or individuality that may exist among eight economic sectors. Pooled regression can provide results that tally with the economic theory. However, the researcher assumed that all eight economic sectors (mining, manufacturing, trade, agriculture, government services, transport and communications, banking and construction) are the same when running this model but that normally does not happen. As a result, this study was unable to accept the outcome of the pooled regression. The estimator can only be used if the BP/LM test for random effects approves the model as appropriate to use. Notwithstanding its potential biases, pooled ordinary least of squares (OLS) estimation is often used as a starting point in applied analyses. Thus the results were compared to results from models that are better suited for the analysis of panel data. The other two models considered for this study were the random effects estimator and the fixed effects estimator which are presented in the following sections.

4.3.2.3The random effect technique

This estimator assumes that the individuals are random and uncorrelated, unlike the fixed effect estimator. The random regression results for this study are presented in the following chapter for comparison and to implement the Hausman test. The random effect (RE) allows the time invariant variable to be included rather than be absorbed by the intercept. The model is illustrated below as:

$$Y_{it} = \omega + \beta X_{it} + (\alpha_i + \mu_{it} + \varepsilon_{it}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .. (4.7)$$

In this equation, the inclusion of ε_{it} is the error term associated with the variables within each individual. More so, the μ_{it} is the error term which only represents the errors associated with variables that occur between individuals which will change with time and does not depend on individual characteristics. The RE model allows all of the variable relationships to be determined providing additional insight from the model.

The RE follows the assumption that $E(\varepsilon_{it}; X_{it}, \alpha_i) = 0$ $t = 1,2 \dots. T \dots. \dots\dots\dots\dots\dots\dots .. (4.7.1)$

Where:

ε_{it} , X_{it} and α_i are error term, explanatory variables and unobserved effect respectively. The assumption holds if the regressor is strictly exogenously conditional on the unobserved. Thus the X_{is} has no partial effect on Y_{it} for $s \neq t$ once the explanatory variables and unobserved effect are controlled for (Söderbom, 2011). Therefore, the RE differs with the pooled OLS in the sense that the expected value of the dependent variable does not depend on the regressor but also on the unobserved effect. This assumption holds that the RE method undertakes that the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables (because no time invariant invariables are omitted or because the variables that are omitted are not correlated with the variables that are in the model) included in the model (Williams, 2015).

Therefore, the unobserved effect is called a random effect when there is no correlation between unobserved effect and the regressor. The random effect is thus applicable and consistent if the error term is not correlated with the regressor. Söderbom (2011) indicated that the random effect requires correlation to be zero in order to be consistent. The method explores differences in error variance components across individuals or time periods. The hypothesis test for a random effect is estimated by the BP/LM test in the following chapter. Again to check the appropriate estimator between the pooled and random effect, the researcher utilised the BP/LM test for random effects to choose the appropriate estimator between the RE and the pooled regression.

4.3.2.4 Fixed effect estimator

The estimation technique allows for heterogeneity or individuality among eight economic sectors (mining, manufacturing, banking, construction communication, trade and catering, wholesale and trade and agriculture) by allowing its own intercept value. Although the fixed effect method examines individual difference in intercepts, it assumes constant slopes and variance across individuals or sectors. The term fixed effect defines the fact that although the intercept may differ across economic sectors, the intercept does not vary over time. Hence, it is time-invariant. Williams (2015) suggested that if the error term is correlated with the regressor, the fixed effect will be the appropriate method to use. Thus the assumption of exogeneity is not violated. When using the fixed effect the error term is allowed to be correlated with other regressors. Thus the assumption of exogeneity is not violated.

Therefore, the estimator can correct for biases arising from the correlation between the constant and the regressor. The estimation method is an alternative to first difference. Furthermore, the fixed effect method examines individual differences in intercepts, assuming the constant slopes and variances across individuals (Torres-Reyna, 2010).

The fixed effect model can be expressed in Equation 4.8 as

$$\boldsymbol{Y_{it} = +\beta X_{it} + \alpha_i + \varepsilon_{it}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(4.8)}$$

Where:

Y_{it} is the dependent variable, *i* and *t* represent the individuals and time period respectively.

X_{it} is the independent variable which varies over time.

α_i is the individual specific component; this is the unknown intercept for each sector (mining, banking, manufacturing, construction, trade and agriculture) that will absorb the impacts of time invariant variables in the model as well as heterogeneity in the data. Equation 4.8 assumes that the individual specific component is freely correlated with the regressor. $E(X_{it}\varepsilon_{is}) = 0. Thus\ for\ s = 1,2 \ldots T$ which is strictly exogeneity. Hence the fact that if the error term is correlated with the explanatory variables, it shows that there is a problem of endogeneity which would bias the estimates. By doing so, if the data set in this study fitted in with these assumptions, the researcher considered the fixed effect method to obtain consistent estimates of β allowing the error term and regressor to correlate.

Hatz II, (2011) and Torres-Reyna (2010) stated that the fixed model is used to analyse the impact of variables that vary over time The researcher assumed that all the eight sectors are different. Therefore, some unobserved factors (such as business practices, degrees of risk aversion) within these economic sectors may affect electricity prices and other regressors in the model or the sectoral output. Hence there was the need to control that. That is, the justification behind the assumption of correlation between the predictors (electricity prices, sector specific and macroeconomic variables) and the error terms. In doing so, if the fixed effect became the appropriate estimator for this study, it would have removed those time invariant characteristics so as to evaluate the net effect of explanatory variables on sectoral output in South Africa.

Apart from that, the FE models can be estimated by the least squares dummy variables (LSDV) regression within the effect estimation method. The dummy variable absorbs the effects particular to each economic sector so as to control for the unobserved heterogeneity, thus identifying individuals and additional N-1 parameters. Schmidheiny (2015) noted that the LSDV is fundamentally base on OLS in terms of estimation. The fixed effect model is just a standard OLS model with dummies for the groups, with one modification that the OLS baseline dummy sets the coefficient to zero. However, in fixed effects, the dummy coefficients are summed on all groups to zero. In doing so, the coefficients of the explanatory variables of both the fixed effect and LSDV become the same with different constant coefficients. Thus the fixed effect becomes the standard equation in a dummy variable form as:

$$Y_{it} = +\beta X_{it} + \alpha_i + D_i + \varepsilon_{it} \ldots\ldots\ldots\ldots i = 1 \ldots\ldots N \ldots\ldots t = 1 \ldots\ldots T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.9)$$

Where:

Y_{it} is the dependent variable with *i* and *t* representing the individuals and time period respectively. The X_{it} is the independent variable which varies by subject (i) and time (t). Again, α_i is the individual specific component; this unknown intercept for each sector (mining, banking, manufacturing, construction, trade and agriculture to mention but a few) will absorb the impacts of time invariant variables in the model as well as heterogeneity in the data. The D_i signifies the dummy variable if the observation belongs to that cross-sectional unit and zero if not. This implies that the fixed effect model can also be expressed using the LSDV estimator. The standardisation of the intercepts does not make any difference regardless of whether the constant and N-1 dummies are contained, and hence the estimate will still be the same in terms of significance.

As mentioned earlier, the fixed effect models eliminate and control the biasing effects of time invariant and undetectable variables in order to assess the impact of the changing variables. Mcmanus (2011) also noted that the FE estimator also transforms the model to remove unobserved heterogeneity components. Both fixed and random estimators take into account individual heterogeneity. The two methods differ in the sense of whether the individual specific time invariant effects are correlated with the regressor or not. If the random effect is valid, the fixed effect estimators still produce consistent results of the identifiable parameters. Therefore, if individual specific effects are uncorrelated with the covariates, the fixed effect is the preferable estimator over the random effects estimators. Fixed effects assume that the individual group or sector in this case have different intercepts in the regression equation. And so, presenting all models sounds illogical. Therefore, to choose whether to use the pooled, FE or RE, the researcher conducted two statistical tests, namely the BP/LM and Hausman tests. The tests were used to decide on the appropriate model following the fact that if one model is right, then all other models are inappropriate (Torres-Reyna, 2010; Park, 2011).

4.3.2.5 Breusch Pagan/Lagrange (BP/LM)

The study utilised the BP-LM test to check if there are individual specific effects or not within variables. Thus when deciding on whether to rely on the results from the pooled OLS estimator, or somewhat more likely when using panel data, whether random effects exist. The Breusch Pagan Lagrange Multiplier test for random effect tests whether the pooled or random effect is an appropriate estimator to use. The guideline of the tests suggests that if the probability value of the BP/LM test statistic is less than the 0.05, the researcher should reject the null hypothesis that the pooled estimator is appropriate. Hence the random effect becomes the appropriate method. In contrast, if the p-value is greater than 0.05, then the pooled estimator will be the appropriate method to use. However, Schmidheiny (2015) posited that the random effect regression is only consistent and efficient when the errors are not correlated with the explanatory variables. Thus to detect whether the errors are correlated or not correlated with the regressor, the study used the

Hausman test. This tool is used to identify the reliable estimator between the fixed and random effect models.

4.3.2.6 Hausman test

This research adopted the Hausman test to identify the appropriate model to use (Torres-Reyna, 2007). The test is used to test for the exogeneity of the unobserved error component (Mcmanus, 2011) – thus determining an appropriate method which specifies whether the fixed or random effect should be employed or not. The test detects whether the error terms are correlated with the explanatory variables or not. If the error terms are correlated with the regressors, the researcher needs to employ the fixed effect model, and if they are not, the researcher must employ the random effect. According to Gujarati (2004), the random effect method is considered more efficient than the fixed effect when it is correct and appropriately used. This is because it gives best linear unbiased estimates (BLUE). However, if the specific individual component is correlated with the regressor in the random model and if there are omitted variables, then the fixed effect becomes consistent and efficient. The Hausman test hypothesis is defined as follows:

$H_0: Cov(\alpha_i, X_{it}) = 0$

$H_1: Cov(\alpha_i, X_{it}) \neq 0$

For the null hypothesis (H_0), the appropriate estimator is the random effect which is efficient and consistent if the individual specific component and the regressor are uncorrelated, that is equal to zero. In contrast, the alternative hypothesis does fits for fixed effects which are consistent and efficient if there is correlation between the error term and the explanatory variables (Söderbom, 2011). The rule of thumb is that, if the H-statistic is bigger than its critical value, the null hypothesis will be rejected. Another guideline concerning the Hausman test is that the null hypothesis shall be rejected or accepted if the p-value is less than or greater than 0.05. Therefore the researcher of this study used the results to select the appropriate estimator to use.

4.3.3 Seemingly unrelated regression model

This study used the dataset of 22 years and eight economic sector outputs to investigate the impact of electricity prices on sectoral output in South Africa. Generally, different economic sectors have different production processes and operations. Indeed, they differ in their behaviour towards the use of electricity usages as illustrated in Figure 2.3 of Chapter 2. Therefore, if the

Hausman test detects the fixed effect model as the appropriate estimator of the study, this means that there is a high possibility of misleading inferences due to individual heterogeneity. In doing so, the study opted for Zellner's (1962) seemingly unrelated regression (SUR) model estimable in the Stata package.

According to Zellner (1962), the SUR regression is a fixed model in that each individual (sector output) has its own equation with its own intercept, set of slopes and standard deviations. The SUR is a generated least estimator that estimates individual effects. The SUR models are efficient and standard when the cross-sectional units are less than the time dimensions. Therefore, in this study, the SUR captured the impact of the explanatory variables on each of the outcome variables (sectors) separately, considering that the sample is characterised by heterogeneity in its behaviour towards electricity consumption and other factors such as business practices Inglesi-Lotz and Blignaut (2011), Lee and Lee (2009), and Zellner (1962). According to Inglesi-Lotz and Blignaut (2011), the SUR methodology is preferred because it can account for the presence of cross-sectoral correlations. The seemingly unrelated regression model is a brainchild of Zellner (1962) which can be presented in line with the model of this study as follows:

Let

$$\boldsymbol{SY_k = \beta_k X_k + \varepsilon_k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \boldsymbol{(4.11)}$$

Thus, the k^{th} equation of the M equation regression system with SY_k being the $T \times 1$ vector of observations on the dependent (economic sectors) variable. The X_k is the $T \times l_k$ matrix with rank l_k of observations on the independent (electricity prices, sector specific and economic variables) variables. β_k, is the $l_k \times 1$ vector of regression coefficients and ε_k is the $T \times 1$ of random error terms, each with a mean zero. Therefore, the above system is an equation which may be written as

$$\begin{bmatrix} SY_1 \\ SY_2 \\ SY_k \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 \\ 0 & X_2 & 0 \\ 0 & 0 & X_k \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_k \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_k \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \boldsymbol{(4.12)}$$

Zellner (1962) formulated the seemingly unrelated regression models as dependent correlated equations. In addition to that, Ghazal and Hegazy (2015) confirmed that the SUR model considers a joint modelling where idiosyncratic terms are correlated in a system of multiequation regression estimation. The model allows each of the outcome variables to have different design matrices with the explanatory variables being the same. The model also allows for a variable to be both in the dependent and independent matrices. The estimation method is used when there are several equations that appear to be unrelated; however, they may be related in the sense that some coefficients are the same and are assumed to be zero. The disturbances are correlated across the equation with the subset of the right hand variables being the same. Zellner (1962) stated that the basic idea for SUR is that the error terms of different equations are correlated amongst each other, such as demand of different forms or different products. It has the same number of explanatory variables in each equation not being necessarily the same. More so, the SUR model allows each of the sectoral outputs to have a different design matrix with some of the predictor variables being the same. If one uses the SUR, individual fixed effects are already being estimated.

4.3.4 Diagnostic tests

The panel data model can be robust on the condition that the six assumptions of the classical model are met. According to Gujarati and Poter (2009) and Brooks (2008), the classical regression assumptions are described as follows: the model should be correct where $(\Sigma(\varepsilon_{it}; X_{it}) = 0. where\ t = 1,2 \ldots\ldots T$. This implies that the assumption holds if the error terms are correlated with the explanatory variables in the respective time period. The latter does not imply an association of the regressor and disturbance terms. Hence, contemporaneous exogeneity and not strict exogeneity exists where the error term at each time is uncorrelated with the explanatory variables in each time period. The latter condition is required to obtain unbiased and consistent estimates. There should be no autocorrelation. Exogeneity and homoscedasticity are some of the assumptions that have to be met when analysing panel data. Also, there should be no cross-sectional or time series correlation within variables. The sixth assumption entails that the idiosyncratic stochastic terms should be normally distributed in order to conform to these abovementioned assumptions. The researcher conducted the diagnostic checks such as heteroscedasticity, normality, and serial and cross-sectional correlation tests to avoid biased and spurious regression that leads to paltry economic inferences.

4.3.4.1 Heteroscedasticity test

Heteroscedasticity in panels is pretty severe for the model inferences due to misspecification of the model. Antonie, Cristescu Cataniciu (2010) also noted that heteroscedasticity is a restrictive assumption for panels, which follows that

$\mathrm{E}(\varepsilon_{it}; X_{it}) = \sigma^2 t = 1,2 \ldots T \; where \; \sigma^2 \; E(\varepsilon_{it}^2)$ For all *it*.

For this assumption to hold, the errors have to be homoscedastic. That means $Var(\mu_{it}; X_{it})$ cannot depend on X and $Var(\varepsilon_{it})$ has to be constant over time. The null hypothesis entails that there is no heteroscedasticity whilst the alternative one calls for existence of unequal variance. Therefore, when it is present in the panel regression model, the standard errors of the coefficient estimates will be inclined. Again, best linear unbiased estimates are obtained if the assumption of homoscedastic is met. That is if the errors are heteroscedastic, the estimators may be unbiased and consistent, but they will no longer have minimum variance (Brooks, 2008).

In order to circumvent misleading inferences, this study used the Wald and White test. The resulting test statistic is the distributed chi-squared under the null hypothesis of homoscedasticity. If the probability (p) value of the test statistics is less than 0.05, the researcher has to reject the null hypothesis of homoscedasticity. This follows that the residuals are heteroscedastic. If the p-value is more than 0.05, then the tests indicate homoscedastic residuals in the regression model. The study controlled the presence of unequal variance within the fixed effect model by employing the standard error estimators such as the FGLS, panel corrected standard errors (PCSE) and SCC estimators to correct the presence of heteroscedasticity.

4.3.4.2 Normality test

According to Baltagi and Kao (2000), one advantage of using panel data is that the addition of time series to cross-sectional dimension can act as recurrent draws from the same distribution. Therefore, as the time and cross-section dimensions increase, the panel set statistics and estimators can be derived and they converge in distribution to normally distributed random variables. The panel data analysis is consistent and efficient if the residuals of the model are normally distributed. If the residuals are not distributed normally, the violation of the assumption will result in the *t* and *F*-statistic being null and void. One of the most commonly used tests for normality which test for residual normality is the Jarque-Bera test. The JB normality test compares the scores in the sample to a normally distributed set of scores with the same mean and standard deviation (Gujarati, & Poter, 2009).

The guideline for the normality test is that if the residuals are normally distributed, the JB statistic would not be significant. Thus a p-value of the normality test should be bigger than 0.05 to not neglect the null hypothesis of normality at the 5% level of significance. If the p-value is greater than the usual significance level (such as 0.10; 0.05; 0.01), there will be no evidence to reject the null hypothesis of normal distribution.

4.3.4.3 Autocorrelation test

Phillips and Moon (2000) reckoned that panel data with large T dimensions are likely to suffer serial correlation. Again, if the values lagged, one or more are dependent of one another, then autocorrelation or serial correlation occurs. This correlation occurs between residuals at a different point of time. Serial correlation in linear panel data models causes the standard errors of the coefficients to be smaller than they actually are. Therefore, a higher R-squared and the square estimators will be less efficient and will be no longer be the best linear unbiased estimators (Drukker, 2003). Symbolically, autocorrelation means$\sum(\varepsilon_i, \varepsilon_j) = 0, i \neq j$ Gujarati and Poter (2009). That is, the expected value of the product of two different error terms is zero. Therefore, the researcher needs to check for serial correlation in the error term in the panel data model.

Gujarati and Poter (2009) posited that the use of incorrect functional forms and the excluded variable are likely to cause autocorrelation. The researcher of this study examined cross-section (sectoral) output over a period of time. This also shows that the past values of the variables have an effect on the dependent variable and other regressor. Hence there are always expectations of autocorrelation.

For this study, there was a great need to identify the presence of autocorrelation in the model so as to decide on the proper standard error estimate to use. For serial correlation test, Antonie *et al.* (2010) stated that the new Woodridge test is more attractive and easy to implement. This study therefore utilised the new Woodridge (2002) autocorrelation test and the Breusch Pagan LM test to compare the results of the serial correlation in the regression model. The guidelines for the tests suggest that if the test statistics are insignificant, the study fails to reject the null hypothesis of no autocorrelation. If the contemporaneous correlation happens to exist within the residuals, the study employs the PCSE or FGLS which only changes the coefficients but only the standard errors depending on the time and cross-section dimensions status.

4.3.4.4 Cross-sectional dependence test

Another violation of the linear panel regression model assumption is the presence of the cross-sectional dependence (CD) within residuals. Therefore it is important to examine the cross-sectional dependence to avoid bias inferences which may be caused by correlated residuals. Cross-sectional correlation can lead to bias test results also called contemporaneous correlation. Cross-sectional dependence may be due to common shocks, unobserved components and spatial dependence (De Hoyos & Sarafidis, 2006). Torres-Reyna (2010) also added that cross-sectional dependence is a problem in macro panels with long time series (over 20-30 years).

De Hoyos and Sarafidis (2006) cited three tests for CD which include the Pesaran(CD) (2004), Friedman (FR) (1937) and Frees (1995) tests. Therefore, to test whether the residuals from a fixed effect estimation model are cross-sectionally dependent or not, the researcher employed the cross-sectional dependence (CD) Pesaran (2004) test. The null hypothesis of the CD test deduces that the residuals are cross-sectionally uncorrelated and the alternative posits that the residuals are cross-sectionally correlated. Thus if the p-value is less than 0.05, the researcher must reject the null hypothesis, meaning that the residuals are cross-sectionally dependent. Given that, the researcher applied the Driscoll-Kraay (SCC) standard error estimator control for general forms of cross-sectional correlation within the fixed effect regression model. As mentioned earlier, if heteroscedasticity, serial and cross-sectional dependence happen to exist within the residuals, the study should employ the SCC, PCSE or FGLS robust estimators. These models slightly change the coefficients but only the standard errors depending on the time and cross-section dimension status.

4.3.5 Justification for using the robust standard error estimators

As stated in the previous section, spherical errors such as heteroscedasticity, serial and cross-sectional correlation are normally present within panel data models. Presence of non-spherical errors can lead to inefficient coefficient estimation and bias in the standard errors of the model. Reed and Webb (2010) posited that the Parks model (FGLS) remains the most commonly used estimation procedure for simultaneously handling cross-sectional and serial correlation. Beck and Katz (1995) and Reed and Ye (2011) recommended the FGLS or PCSE to get rid of the non-spherical errors within the panel models. In addition to that, Hoechle (2010) suggested that the use of PCSE, SCC and FGLS control heteroscedasticity cross and serial correlation in panels. Thus, if the model happens to suffer unequal variances and serial autocorrelation, the researcher should opt for the standard error estimators which will change only standard errors with some slight changes on the coefficients. Furthermore, Williams (2015) postulated that robust regression models control problems of outliers in a regression model

In order to ensure valid statistical conclusions when some underlying regression model assumptions are violated, Hoechle (2010) suggested that it is common to rely on the robust standard error estimators such as the feasible generalised least of squares (FGLS), panel corrected standard errors (PCSE) and the SCC estimators. For all t, $var\ (\varepsilon_{it}|X_{it}) = \sigma^2$and $var\ \left(\varepsilon_{it,}\varepsilon_{is}\middle|X_{it}X_{is,}\right) = 0$. That is, residuals should be homoscedastic with no serial correlation respectively. More so, there should be absence of cross-sectional dependence. The estimators are commonly determined by the diagnostic test results and the status of the data employed in the study. For instance, it is more efficient to use the FGLS than the PCSE when the time (T) dimensions are greater than their cross-sectional units (N) (Reed & Ye, 2011). More so, the Driscoll-Kraay (SCC) estimator is most appropriate when the error structure is assumed to be heteroscedastic, auto correlated up to some lag, and possibly correlated between sectors. The SCC estimator is suitable for both balanced data and is capable of controlling missing values.

According to Hoechle (2010), PCSE perform better when there is cross-sectional dependence in the data. PCSE are robust to every general form of cross-sectional and temporal dependence. PCSE address the problem of errors that are not independent and identically distributed. However, they produce accurate estimates when the cross-sectional units (N) are greater than the time dimensions (T). Thus, the use of generalised least of squares uses a weighting scheme that reduces the impact of outliers on the estimates of the regression coefficients.

In their study, Antonie *et al.* (2010) hypothesised that the SCC estimator is a robust estimator and nonparametric covariance matrix estimator which produces heteroscedasticity consistent with standard errors that are a strong to very general form of spatial and temporal correlation with cross-sectional units. As recommended in Hoechle (2010), the researcher implemented the SCC and FGLS to control certain violation of the underlying econometric models. The researcher also used the least square dummy variable (LSDV) to control for omitted variables and overstated coefficient of determination within the model.

4.4 CHAPTER SUMMARY

The use of energy-output theories and the empirical literature in the previous chapter helped the researcher in specifying the panel data model of the electricity impact on sectoral output in South Africa. Employing panel data was desirable for this study since panel data allows control of unobservable variables and heterogeneity within variables. The chapter presented the three basic methods of panel data analysis as well as the common and individual panel unit root tests. The chapter also demonstrated that the sectoral output is the outcome variable whilst electricity prices are the main explanatory variable of the study. Again, other regressors include the sector-specific (unit labour cost, remuneration, and import prices and the macroeconomic (inflation, exchange rates and interest rates) variables. The chapter also presented the data sources, an explanation of variables and their expected priories. Furthermore, this chapter discussed a number of diagnostic checks (such as heteroscedasticity, serial and cross-sectional correlation) in order to identify the appropriate robust standard error estimator to use if the model suffers violation of the assumption of the panel linear regression. All the techniques mentioned in this chapter were practically performed in Stata, so as to attain the research objective stated in the first chapter. Following this, the estimation, presentation and assessment of the research outcomes of the impact of electricity prices on sectoral output are presented in the following chapter.

CHAPTER FIVE
ESTIMATION, PRESENTATION AND DISCUSSION OF EMPIRICAL RESULTS

5.1 INTRODUCTION

The previous chapter outlined the methodology framework of the study. Following the model developed in the previous chapter, this chapter presents, interprets and analyses all estimation results. Estimation results in this chapter provide answers to the objectives stated in the first chapter of this dissertation. In line with the analytical considerations, the chapter is segmented into different sections. The first section provides the guidelines for the interpretation of the regression results. This will be followed by the stationarity test results. The third section evaluates results on pooled, fixed, random effect, and identifies the appropriate estimator using the BP/LM and Hausman test. The fourth section presents estimation and diagnostic tests results. The fifth section presents the appropriate estimator for the study, as well as the robust standard error model results if the heteroscedasticity, serial and cross-sectional correlation are present within the appropriate basic panel data model of this research. The sixth section also provides the results for LSDV, SCC, FGLS and SUR estimators for sectoral analysis. A summary of the chapter is presented in the last section.

5.2 GUIDELINES FOR THE INTERPRETATION OF THE MODEL

This section reviews the guidelines or rule of thumb which determines whether the model is fit or correct. In their work, Gujarati and Porter (2010) proposed that if the p-value is less (<) than 0.05 then the model is fit. More so, 0.01 and 0.1 can also be used as probability values (Gujarati and Poter, 2009). The F-test shows whether all the coefficients in the model are different from zero. The R^2 is the coefficient of determination. Anukoonwattaka and Beverelli (2013) stated that it shows the amount of variance of the dependent variable explained by the explanatory variable. The closer it is to one (1) the better the model, and the closer it is to zero the worse the model. Again, the $\bar{R}^2$ shows the same an R-squared but is adjusted by the number of cases and number of variables. Torres-Reyna (2010) posited that when the number of variables is small and the number of cases is very large, the adjusted R-squared will be closer to R-squared.

More so, the t-value tests the hypothesis to determine that each coefficient is different from zero. To reject this, the t-value has to be higher than 1.96 (for 95% confidence) (Brooks, 2008). If this is the case, then one can suggest that the variable has a significant influence on the dependent variable (sectoral output). The higher the t-value, the higher the relevance of the variable (Anukoonwattaka & Beverelli, 2013). Furthermore, Torres-Reyna (2010) indicated that the two-tailed probability values have a substantial role in interpreting the fitness of the model. Therefore, if the two-tailed p-values test the hypothesis to determine that each coefficient is different from zero, then to reject the null hypothesis, the probability value has to be lower than 0.05 (95% confidence). A probability value of 0.10 can be an alternative. If that is the case, the researcher can posit that the variable has a significant influence on the dependent variable. The other parameter that had to be taken into consideration in this study was the "rho" or "r" that is the correlation coefficient. A non-parametric test is used to measure the strength of association between two variables. When the value of r =1 then there is a perfect positive correlation. However, if r = -1, there is perfect negative correlation.

5.3 UNIT ROOT TESTS

Table 5.1 presents the results from both the common and individual LLC in the Pesaran and Breitung unit root tests. For sample unit root tests (see Appendix A), the researcher's decision on the appropriate stationarity was based on the majority methods. The panel cointegration model preconditions on the unit root suggests that the variables at levels must have a unit root but be stationary at first difference. As mentioned, the table below shows the results for three unit root tests (LLC, Im Pesaran and Breitung). The researcher selected these tests since they perform better when T (22) grows at a faster rate than N (8) as mentioned earlier in the previous chapter.

Table 5.1 Common and individual unit root tests

Method	IM Pesaran		LLC		Breitung	
Order of integration	1(0)	1(1)	1(0)	1(1)	1(0)	1(1)
Variable	t-stat	t-stat	t-stat	t-stat	t-stat	t-stat
Sectoral output (SY)	1.3659	-3.9977**	-1.3724*	3.4003**	1.5237	-2.7122**
Electricity prices (EP)	14.7257	2.3680	16.873	1.9538	5.5483	3.2373**
Unit labour cost (Ulc)	9.0807	0.6722	7.4168	-1.0425	4.8335	-2.4454**
Remuneration (Rem)	7.6745	-0.9133	4.6095	-0.9888	-3.5555	-1.3344**
Sector imports (Ipt)	1.8337	-5.488**	0.0093	-5.6603**	0.3637	-6.0455**
Intermediate input price (Iip)	6.4245	-6.2566**	3.6066	-6.2806**	3.8211	-2.7435**
Real gross fixed capital stock (Rs)	1.5623	-0.3085	-1.3941*	1.3645*	- 2.0893***	- 1.6649***
Labour productivity (Lp)	0.3150	-3.1317**	-1.5521*	-2.4600**	0.3597	-4.6933**
Expenditure on health (Exh)	- 4.33349**	0.6135	-6.5666**	7.2765	-7.2513**	-4.0328**
Inflation (Inf)	-6.5637**	-8.6128**	-7.6262**	-9.3986**	- 4.24400**	-7.3747**
Exchange rate (Ei)	-3.6408**	-6.0631**	-4.2982**	-6.8365**	- 1.9571***	-5.5044**
Interest rate (Ir)	-1.0524	- 7.02773**	-3.7870**	-7.5887**	-0.9056	-5.8769**
p<0.1*, p<0.05***, p<0.01**						

Source: *Author's own compilation from Stata panel unit root tests*

Table 5.1 shows the unit root results from both the common (LLC, Breitung) and individual Im Pesaran (ImP) panel unit root tests. The researcher employed the three panel unit root tests to identify the benchmark unit root test. The LLC, ImP and the Breitung unit root tests indicate that the p-values for expenditure on health, inflation and the exchange rate are less than 5%, meaning that the variables are stationary at levels. The LLC and Breitung also indicate that sectoral output, labour productivity and real gross fixed capital level data are stationary. Nonetheless, electricity prices, unit labour cost, remuneration, sector imports and intermediate input prices data have a unit root at levels and stationary first difference. The Breitung unit root test shows that all the variables included in the study had a unit root at levels. However, the p-values of the variables are less than 5% at first difference, meaning that the variables do not have a unit root. This implies that the Breitung common unit root test fulfils the pre-conditions of the panel cointegration which suggests that the test must have a unit root at levels or before differencing but be stationary at first difference. Correspondingly, this research also tested the correlation between the dependent variables and the explanatory variable to identify the strength of the relationship between those variables. The following section illustrates the correlation results.

5.4 CORRELATIONS BETWEEN SECTORAL OUTPUT AND OTHER VARIABLES

According to Frees (2003), correlation shows the degree of association between two variables. However, it does not imply causation between variables. Therefore as one variable changes, the other one seems to change in an expectable way with the same magnitude. Additionally, Gujarati and Porter (2010) noted that correlation ranges from (+1) which is perfect positive correlation, through zero which implies no correlation, to negative (-1) which is a perfect negative correlation. This section presents the correlation between the dependent (sectoral output (SY)) and the regressor (electricity prices (EP), sector specific variables (SE) and macroeconomic variables (ME)) at overall and individual sectoral level. The eight sectors included in this study were agriculture (Agric), transport and communication (Comm), construction (Cons), banking and finance (Fin), general government service (Govern), manufacturing (Manu), mining (Min) and wholesale and trade (Trade). The intention was to illustrate whether there is correlation and whether the correlation is significant or not. The Stata pairwise correlation is presented in the following table below.

Table 5.2 Correlation matrix

Variable	Overall	Agric	Comm	Cons	Fin	Govern	Manu	Min	Trade
SY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Ep	0.2662*	0.790*	0.713*	0.861*	0.790*	0.824*	0.579*	0.242	0.730*
Ulc	0.2178*	0.978*	0.673*	0.975*	0.978*	0.966*	0.748*	0.116	0.924*
Rem	0.4970*	0.972*	0.989*	0.991*	0.972*	0.985*	0.814*	0.048	0.970*
Ipt	0.7174*	0.868*	0.933*	0.431*	0.868*	0.889*	0.894*	0.016	0.780*
Iip	0.3147*	0.791*	0.967*	0.960*	0.791*	0.954*	0.900*	0.093	0.958
Rs	0.4468*	0.986*	0.905*	0.991*	0.986*	0.940*	0.838*	0.177	0.976
Lp	0.3842*	0.820*	0.847*	0.913*	0.820*	0.906*	0.941*	0.391	0.763*
Exh	0.3259*	0.936*	0.884*	0.969*	0.936*	0.959*	0.788*	0.080	0.902
Inf	-0.1065	-0.290	-0.340	-0.202	0.291	-0.255	-0.315	0.400	-0.306
Ei	-0.1692*	-0.459*	-0.532*	-0.381	0.459*	-0.414	0.507*	0.199	-0.481*
Ir	-0.2797*	-0.778*	-0.808*	-0.716*	-0.778*	-0.758*	-0.759*	0.081	-0.734*
(*) denotes that the Pearson's correlation coefficient is significant at **5% level (p<0.05).**									

Source: *Author's own compilation from Stata (13) results*

Table 5.2 shows that there is a statistically significant correlation between sectoral output and its explanatory variables. More so, intermediate input price and remuneration have a high correlation coefficient with overall sectoral output. However, there is no correlation between the dependent variable (SY) and inflation rate on overall sectoral analysis. All independent variables have high correlation coefficients with sectoral output at individual sector output levels except for inflation and exchange rate. Table 5.2 also illustrates that there is no correlation between inflation and sectoral output at overall and individual levels. Thus, if the variables in the model correlate then it is possible to examine the impact between them.

5.5 REGRESSION RESULTS

The broader objective of the study was to investigate the impact of electricity prices on sectoral output (mining, manufacturing, construction, finances, trade wholesale and catering, agriculture and communication). The variables included sectoral output, electricity prices and other macroeconomic and sector-specific variables such as exchange rate, inflation, interest rate, labour productivity, remuneration and unit labour cost. In order to answer this objective, the study employed the different estimation methods presented in Chapter Four. The panel data analysis has three basic regression methods. Among them, one estimator should be appropriate whilst others are not, depending on the status or the type of the data or N and T dimensions employed in the study. The diagnostic checks and the status of the data assisted the researcher in identifying the correct robust standard errors estimators for the research.

Table 5.3 below demonstrates the results from the basic (pooled, fixed and random effect) estimation methods. By doing so, the researcher assessed the biases of the pooled, fixed and random effect estimations so as to determine how their magnitude varies with characteristics of the data set. The researcher implemented the Breusch Pagan/Lagrange Multiplier for the random test to detect the appropriate estimator between pooled and random effect estimators. From the pooled and random effect model estimations shown in Table 5.3, the Breusch Pagan Lagrange Multiplier test for the random effect test shows a test statistic of 710.88 and a p-value of 0.000. This implies that the researcher had to reject the null hypothesis that the pooled estimator is appropriate. Thus from the BP/LM test the random effect is the appropriate method. The results for the random effect may appear similar to that of the fixed effect in Table 5.3. However, the random effect regression is only consistent and efficient when the errors are not correlated with the explanatory variables. Given that, the researcher used the Hausman test to detect whether the errors are correlated or not correlated with the regressors This follows the estimation results from the Hausman test which suggests 0.002, a p-value of less than 0.05 with the test statistic of 28.54. Thus the p-value is small enough to reject the null hypothesis. Therefore the study rejected the null hypothesis, meaning that the fixed effect estimator was the appropriate method to use in the study. This is consistent with Reed and Ye (2011) who stated that if one estimator is appropriate then the alternative models are likely to be inapplicable.

The results from the basic panel data models presented the relationship between sectoral output and electricity prices as well as other sector-specific and macroeconomic variables. The results of the three basic methods in Table 5.3 reflect some similarities on the coefficient signs, nonetheless some estimators suffer violation of the assumptions of the panel linear regression. Thus the pooled estimator may show good results, but the estimator suffers heterogeneity bias and thereby inefficient estimates. Again, it assumes that all individuals are the same, and in doing so, the pooled regression results could not be relied on for this study.

The results in Table 5.3 are consistent with Judson and Owen (1996) who posited that the fixed effect model is a common choice for macroeconomists. The estimator is regarded as more appropriate than the random effect method. This is because the individual effect represents the omitted variables, and thus it is highly likely that these sector-specific characteristics are correlated with the other explanatory variable. More so, it is likely that a typical macro-panel will contain most of the sectors of interest and thus will be less likely to be a random sample from a much larger universe of sectors. For instance, a sectoral panel is likely to contain all of the economic sectors and not just a random sample of them.

Table 5.3 Estimation results

Variable	Pooled	Random	Fixed
Electricity prices	-1247.32	-3464.616**	-3115.867**
	(2015.75)	(888.7806	(828.458)
Unit labour cost	473.8625	4771.315**	5137.803**
	(1726.811)	(984.8434)	(918.2302)
Remuneration	-2.157245**	-1.621669**	-1.906637**
	(0.4555984)	(0.4099039)	(0.3932026)
Sector imports	2.357348**	1.453996**	1.480232**
	(0.1237340	(0.1766701)	(1.716616)
Inter-input price	-2797.743*	-4925.084**	-4540.395**
	(1457.317)	(715.4166)	(668.2467)
Real-G -Stock	0.3044912**	0.7175568**	0.9023485**
	(0.0227485)	(0.0623129)	(0.0694299)
Labour productivity	31337.617**	2964.355**	3440.963**
	(1039.05)	(557.2815)	(525.3324)
Exp on health	3.212795***	2.113624**	1.2548*
	(1.449507)	(0.7201906)	(0.6900455)
Inflation	-3270.422	-2291.547	-1558.684
	(9534.873)	(4102.106)	(3801.203)
Exchange rate	-2862.735*	-2766.655**	-2415.87**
	(1790.77)	(781.2096)	(726.496)
Interest rate	-5640.594	-5321.8	-5397.781
	(010283.74)	(4457.346)	(4130.962)
Constant	372387.8	65151.65	-142064.1
	(235297.4)	(144094.6)	(12093.6)
R-squared (R^2)	0.8147	0.8507	0.8571
F-statistic	65.57		85.63
Wald (chi)	-	80355	-
Probability value	0.0032	0.010	0.0001
Corr (u_i-,Xb)	-	-	0.7528
Rho	-	0.8739475	0.97832908
Observations	176	176	176
Sectors	8	8	8
Time periods	22	22	22
P< 0.01**, p< 0.05***, P< 0.1*			

Source: *Author's own compilation, Data from Quantec (2016) and Department of Energy (2016)*

Regarding the fixed effect regression as the appropriate estimator, electricity prices show a negative and significant impact on sectoral output in South Africa. The third column in Table 5.3 indicates that for a 1% increase in electricity prices, sectoral output is expected to decline by 3.1%, holding other variables constant. The variable coefficient is consistent with the study a priori proposition. The significant relationship between electricity prices and sectoral output is consistent with the KLEC (Kummel, 1982) theory which opines that electricity is a substantive factor of production which can be treated separately as an input of production. More so, a negative relationship is also in accordance with the substitution and technical change theory (Rosenberg, 1983; Schurr & Netschert, 1960) which posits that sectoral outputs are determined by input (electricity, labour, capital, non-electrical) prices. Furthermore, a negative and significant relationship is also consistent with Masuduzzaman (2013), Kohler (2013), Bildirici *et al.* (2012), Electricity Supply Commission (Eskom) (2011), Adebola (2011) and Ciarreta and Zarraga (2010) who confirmed that hikes in electricity prices have adverse effects on output growth.

The unit labour cost, sector imports, real gross stock and labour productivity are positive and significant to explain changes in sectoral output. Thus for one percentage increase in unit labour cost, imports, real gross stock and labour productivity, sectoral output is expected to increase by 5.1%, 14.8%, 9% and 3.4% respectively.

The unit labour cost has a positive coefficient and it is significant at 1% level. This variable is not consistent with the research a priori proposition. However, a positive relationship is consistent with Herman and Fulco (1969) who posited that if gains in hourly compensation do not exceed those of productivity, growth in output per hour permits an increase in labour compensation without raising the cost of production. Thus if these two factors remain constant, then the additional labour only changes to aggregate total labour output and not labour costs per unit.

Remuneration and intermediate input prices show a negative and significant effect on sectoral output. This implies that one unit increase in remuneration and intermediate input prices is expected to decrease sectoral output by 19% and 4.5% respectively. A negative coefficient of intermediate input prices is consistent with Lee (2002) who reported that intermediate input prices have a significant effect on output prices which hinders aggregate demand, thereby decreasing output growth. Consistently, Bruno and Sachs (1982) reported that input intermediate input prices caused a fall in the UK manufacturing output. Expenditure in health has a positive impact on sectoral output. This implies that if the government increases its expenditure on health, sectoral output will be expected to increase by 12.5%. However, an appreciation in the South African rand will cause sectoral exports to become expensive which in turn will decrease the sectoral output. Inflation and interest rate under the fixed effect estimator indicates a negative and insignificant effect over the period of study.

These results appear to be the best and unbiased since the probabilities and the coefficients of determination are justifiable for correct models. Table 5.3 shows that among all the estimators (pooled, random and fixed), the variance of sectoral output explained by predictor variables are very high (more than 80%). However, according to the BP/LM and Hausman test, the fixed effect is the appropriate estimator. The other two models do not indicate any correlation between the regressors and the idiosyncratic error term. Contrariwise, column three indicates that the error terms are correlated with the predictor variables. Given that, the fixed effect estimator becomes more favourable than the random effect. The fixed effect estimator in column three in Table 5.3 illustrates that 97.8% of the variance is due to heterogeneity across economic sectors. However, to obtain efficient and consistent inferences, the models should be best and unbiased. Thus, the models should be free from heteroscedasticity, with the omission of variable, serial and cross-sectional correlation. The following section presents the diagnostic tests results to detect the appropriate robust standard error estimators for the study.

5.6 DIAGNOSTIC TESTS

For this study, the researcher employed the White and Wald test for heteroscedasticity, the Woodridge Lagrange Multiplier test to diagnose serial autocorrelation, the CD Pesaran test for cross-sectional correlation, and the Jarque-Bera test for normality tests. These tests and results are listed in Table 5.4; with the results showing that the p-value of the test statistic for heteroscedasticity, serial and cross-sectional correlation are less than 0.05. This implies that the residuals are heteroscedastic, auto correlated and cross-sectionally dependent. The Jacque-Bera test posits that the residuals are normally distributed since the test statistic is insignificant. Given that, the researcher employed the robust standard error estimators to control for the violations of the assumptions of the panel linear regression model which are also presented in Table 5.4.

Table 5.4 Summary of the diagnostic test results

Test	Order of integration		Logged values
	1(0)	1(1)	
Woodridge	928.172***	5.467*	15.844***
	(0.0010)	(0.0520)	(0.0053)
B-P/LM	110.424***	47.351**	96.379***
	(0.000)	(0.0126)	(0.000)
White	155.37	164.90*	174.38
	(0.1404)	(0.09995)	(0.493)
Wald	100.06***	241.20***	597.56***
	(0.000)	(0.000)	(0.000)
Pesaran	1.677*	1.837*	4.676***
	(0.0935)	(0.0662)	(0.000)
Absolute(pesaran)	[0.355]	[0.241]	[0.335]
Jacque Bera	0.4678	413.9	413.9
	(0.7914)	(0.7149)	(0.7149)
p>0.05**, p>0.01*** p>0.1*			

Source: *Author's own compilation from Stata result with data from Quantec and SARB (2015)*

The diagnostic test results above show that heteroscedasticity, serial correlation and cross-sectional dependence are present in the panels. The study applied the robust estimators to control for the violation of the assumptions of the linear panel regression. These robust regressions only change the standard error of the model so that it gives accurate p-values for the estimates. The time dimensions (T) for this research are greater than the (N) cross sectional units. Chen, Lin and Reed (2010) posited that the FGLS produce efficient estimates compared to PCSE when T >N. The Hausman test results suggest that the fixed effect model is the appropriate estimator for the given data. The heteroscedasticity coefficient is greater than 1.67 and the cross-sectional units are less than the time dimension. In this regard, Reed and Ye (2011) stated that panel data, fixed effect (within estimator), FGLS estimator control non stationarity, heteroscedasticity, cross and serial correlation (Hoechle, 2010). Following a small n and a large

T, this study considered the FGS as the appropriate robust estimator to rely on. By so doing, the results in the third and fourth columns of Table 5.5 are free of unequal variance, non-stationarity, cross-sectional and serial correlation. The findings in Table 5.5 answer the third objective of this study.

5.7 ROBUST STANDARD ERROR ESTIMATION RESULTS

The researcher also employed the least square dummy variable (LSDV) to control for omitted variables and overstated coefficients of determination within the model. Schmidheiny (2015) and Park (2010) noted that the estimator is fundamentally based on OLS in terms of the estimation. Thus, it includes a set of N-1 dummy variables which identifies the individuals (sectoral output) and additional N-1 parameters. Apart from that, one of the individual dummies is dropped because of the constant variable that is included in the regression. According to the Hausman test results, the fixed effect is the appropriate estimator. Thus the research included the model as part of estimation results since the robust estimators only change the standard errors of the appropriate model of the study. Given that, the results in Table 5.5 change the standard errors, with a slight difference among the coefficients. In their study, Chen *et al.* (2010) posited that the FGLS and SCC estimator allow control of autocorrelation, heteroscedasticity and cross-sectional dependence when T is greater than N. According to Reed and Ye (2011) and Hoechle (2010), the FGLS estimator controls heteroscedasticity, serial and cross-sectional correlation. Again the estimator is regarded as the best overall estimator with respect to efficiency. The results of the current study are thus presented based on the FGLS robust estimator.

The LSDV, FGLS and the SCC regression results in Table 5.5 indicate that electricity prices have a negative and significant impact on sectoral output. The individual analysis for the LSDV regression results is presented in Table 5.6 of this chapter. The FGLS, however, in Table 5.5 indicates a negative and insignificant relationship between electricity prices' impact on sectoral output. The variable of the electricity prices is the main explanatory variable of the study. The study expected the electricity price coefficient to be either negative and significant as recommended in the theory of technical changes of Rosenberg (1983) and Schurr and Netschert (1960). The theory recommends that the electricity input price is negatively related to sectoral output. Generally, if the prices of input such as electricity or labour goes up, the firms will reduce their usage of that input, thereby decreasing output. The fixed effect, LSDV and the SCC show that electricity prices have a negative and significant impact on sectoral output in South Africa. This is consistent with the works of Ciarreta and Zarraga (2010); He, Zhang, and Hao (2015); Adebola (2011); Boonzaaier *et al.* (2012); and Blignaut *et al.* (2015) who suggested that electricity prices have a significant impact on consumption and economic growth.

In addition, the results are consistent with Blignaut *et al.* (2015) who indicated that electricity prices have statistically significant and negative elasticities for nine of 11 sectors considered. Thus the popular economic sectors have turned out to be much more sensitive to changes in electricity prices following 2007/2008. Although Blignaut *et al.* (2015) examined electricity tariffs and consumption at industrial level, their main concern was consumption rather than output. Table 5.5 presents analysis of output, electricity prices' sectoral and other sector-specific variables (such as remuneration, intermediate input prices, labour productivity) and macroeconomic variables which include expenditure on health, inflation, interest rate and exchange rates.

Table 5.5 Robust estimation results

Variable	Fixed	LSDV	SCC	FGLS
Electricity prices	-3115.867**	-3115.867**	-3115.867***	-1247.32
	(828.458)	(828.458)	(1122.95)	(1945.818)
Unit labour cost	5137.803**	5137.803**	513.803**	473.8625
	(918.2302)	(918.2302)	(1717.597)	(1666.903)
Remuneration	-1.906637**	-1.906637**	-1.906673**	-2.157245**
	(0.3932026)	(0.3932026)	(0.42289)	(0.4397925)
Sector imports	1.480232**	1.480232**	1.480232**	2.357348**
	(1.716616)	(1.716616)	(0.3328135)	(0.119446)
Inter-input price	-4540.395**	-4540.395**	-4540.395**	-2797.743***
	(668.2467)	(668.2467)	(1204.059)	(1406.759)
Real-G -Stock	0.9023485**	0.9023485**	0.9023485**	0.3044912**
	(0.0694299)	(0.0694299)	(0.0526343)	(0.0219593)
Labour productivity	3440.963**	3440.963**	3440.963**	3137.617**
	(525.3324)	(525.3324)	(718.0474)	(1003.002)
Exp on health	1.2548*	1.2548*	1.2548*	3.212795***
	(0.6900455)	(0.6900455)	(0.7207831)	(1.399219)
Inflation	-1558.684	-1558.684	-1558.684	-3270.422
	(3801.203)	(3801.203)	(4153.071)	(9204.083)
Exchange rate	-2415.87**	-2415.87**	-2415.87**	-2.862.735*
	(726.496)	(726.496)	(688.2858)	(172.643)
Interest rate	-5397.781	-5397.781	-5397.781	-5640.594
	(4130.962)	(4130.962)	(4212.918)	(9926.996)
Constant	-142064.1	-134946.3	-142064.1	37287.8*
	(12093.6)	(114748.6)	(12544.6)	(277134.3)
R-squared (R^2)	0.8571	0.9722	0.871	-
F-statistic	85.63	304.71	467.85	-
Wald (chi)	-	-	-	774.01
Probability value	0.0001	0.0000	0.0010	0.000
Corr (u_i-,Xb)	0.7528	-	-	
Rho	0.97832908	-	-	
Observations	176	176	176	176
Sectors	8	8	8	8
Time periods	22	22	22	22
P<0.1*, p< 0.01**, p<0.05***				

Source: *Author's own compilation, Data from Quantec (2016) and SARB (2015)*

From the results above, the model of the study becomes

$$Y_{it} = \beta_0 - \beta_1 EP_t \pm \beta_2 SR_{it} \pm \beta_3 ME_t + \varepsilon_{it}, i = 1, \ldots . N, t = 1 \ldots . T \ldots\ldots\ldots\ldots\ldots\ldots . (5.1)$$

Regarding electricity prices, a negative effect in the first, second and the third column implies that as electricity prices rise, investors will move plants to the neighbouring countries, or invest in other sectors within. This shows that high electricity prices reduce investments within various sectors. Again, increasing electricity prices at some point reduces demand and consumption of electricity by end users (such as mining, agriculture, transport and communications, finance and government services). Hence, for those sectors to attain profit in such conditions, they have to forego other operational activities, such as closing down parts of their operations which will reduce their output growth. These results are consistent with those of the Electricity Supply Commission (Eskom, 2011) which suggests that a 72% increase in electricity price hikes will cut investment by 2.1% as the cost of capital investment tends to rise, thereby reducing output by 0.5%.

The sector specific variables such as import, real gross stock and labour productivity have a positive impact on the sectoral output in South Africa. A positive and significant impact of sectoral imports and sectoral output implies that the value of the import penetration has increased. This shows that imports account for almost all of the total domestic demand for the production in the agriculture, mining, manufacturing, wholesale and trade, transport and communication and construction. Moreover, a positive impact entails that the aforementioned economic sectors have improved competitiveness through imports of cheaper, quality raw materials and advanced technology. This results in cheaper imports reducing production costs, enriching production capabilities and improving output quality as recommended in. Importation can be result due to the non-existence of the required goods or services, lack of quality and cheaper goods and new innovations in the importing country. This confirms Rahardja and Varela (2015) who suggested that economic sectors import for various reasons such as value, quality and variety, and that the availability of imported input has contributed to improved product quality in Indonesian manufacturing.

Table 5.5 indicates that a unit increase in the gross capital formation increases sectoral output by 3% at 1% significant level. This implies that high capital formation boosts sectoral output in South Africa. Indeed, the results are in accordance with Uneze (2013) who propounded that increases in capital formation result in higher economic growth in the Sub-Saharan countries.

Apart from that, the results indicate that if the sectoral employers increase their investment capacity utilisation, managerial skills and the efforts of the workforce, sectoral output will increase by 3.1%. The positive coefficient confirms Highfill (2002) who opined that the two easiest ways to increase economic output are to increase both labour participation and labour productivity

However, sectoral output is expected to increase if remuneration rises. The findings from the empirical results in Table 5.5 show that remuneration has a negative and significant impact on sectoral output. Thus, for a one percent increase in remuneration, sectoral output falls by 2.2% while holding other things constant. The variable coefficient is not consistent with the a priori proposition of the study. This is consistent with Brauer (1997) who suggested that an increase in the rate of compensation growth accelerates cost push inflation which may compromise output growth in the long run. This posits that real remuneration increases are likely to show signs of high costs of production within economic sectors. In other words, the results show that the economic sectors incur more costs on employee salaries, wages and bonuses, as well as pensions and provident funds. A negative impact also implies that if the remuneration increases at a rate higher than inflation, the sectoral output levels go down as the cost of production goes up.

Regarding intermediate input prices, a negative effect connotes that, as the cost of raw materials rises, the cost of production follows the trend. In fact, the sectoral output will go down. Sectors such as the manufacturing, mining and agriculture, communications, and construction are adversely affected since they depend on each other. For instance, the agriculture sector supplies raw materials to the manufacturing sectors. A negative coefficient of intermediate input prices is consistent with Lee (2002) who indicated that high intermediate input prices hamper output growth.

The study recommends the government of South Africa to increase expenditure in health so as to improve sectoral output performances since a healthy nation is a working nation. This is evident in Table 5.5 which shows that healthy employees boost sectoral output in the country. Thus, for a one unit increase in government expenditure on health, sectoral output increases within a range of 1.2% - 6%. The results are consistent with Babatunde (2014) Bakare and Sanmi (2011) who posited that the increase in health expenditure has boosted national income in Nigeria. Regarding exchange rate, a negative impact entails that, as the South African rand evaluates, the domestic exports become expensive, thus detracting sectoral output. If the domestic currency depreciates, the South African exports will be cheaper, as production costs go down, thereby increasing output in the mining, agriculture, manufacturing, wholesale and trade, communication and the finance sectors. In other words, the empirical results posit that for a one unit increase in the appreciation of the rand, the sectoral output is expected to decrease by 2.8%. The empirical results are consistent with Eather and Frawley (2015) who suggested that the South African economy deteriorated as a result of currency weakness which put upward pressure on inflation.

However, interest rate levels seems to be ineffective on sectoral output following an average interest rate of 8.03% since 1994 to 2015. An insignificant effect shows that sectoral output is not responsive to interest rates. This is an indication of lower interest rates where economic sectors can invest without being interrupted by the interest rate changes. Although the average inflation (6.3%) over the period 1995 to 2015 was above the inflation target (3%-6%), the empirical results in Table 5.5 for inflation indicate that inflation has a negative but weak significant impact on sectoral output. Correspondingly, an insignificant impact may mean that the impact of inflation output decisions may be small relative to sectors' adjustment technology. These empirical results are consistent with Talan and Osberg (1998) who stated that inflation effects on output variability are determined by the level of inflation, change in level of inflation or trend in recurrent components that matter for output decisions.

According to Inglesi-Lotz and Blignaut (2011), electricity prices have been low and declining in South Africa. The industries and economic sectors that were vulnerable to high electricity tariffs include manufacturing, transport and trade. Most studies (Inglesi-Lotz, 2014; Amusa *et al*., 2013) have been devoted to energy prices, consumption and GDP. Less have been said pertaining electricity prices and output at sectoral level. Again, numerous works on electricity and output, particularly in South Africa (Inglesi-Lotz, 2014; Amusa *et al.,* 2013; Inglesi & Pouris, 2010), cover a time period when electricity was very low which made it difficult to detect its real impact on the economy and the sectoral output in particular.

Empirical results in Table 5.5 indicate that electricity prices in South Africa have a negative and significant impact on sectoral output. The regression results provide an analysis of the effect of electricity prices on overall sectoral output. However, the analysis of the effect of electricity prices (in Table 5.5) on aggregate sectoral output does not clearly indicate how electricity prices affect each and every selected sector in the study. Again, the use of a fixed effect estimator in this research allowed sectoral differences in terms of the business practices and day-to-day operation which could determine their effect on electricity usage. Hence, this research assumed that the impact of the electricity prices may not be the same across sectors.

Having looked at the impact of electricity prices on aggregate sectoral output in Table 5.5, there is the need for individual analysis in order to understand the real impact of electricity prices on sectoral output at sectoral level. To achieve this, the study employed LSDV and the seemingly unrelated regression model (SUR) to examine the various impacts of electricity prices on each of the economic sector's output separately. This followed an assumption of the study that the sample was characterised by heterogeneity due to sectoral behaviour towards use of electricity for their production processes. The following section looks at the output responsiveness to electricity price changes at sectoral level in the South Africa.

5.8 SEEMINGLY UNRELATED REGRESSION RESULTS

According to Zellner (1962), if one uses SUR models, then they are already estimating fixed individual effects. The SUR estimates several equations that appear to be unrelated. Nonetheless, Ghazal and Hegazy (2015 and Zellner (1962) suggested that they may be related in the sense that some coefficients are the same and are assumed to be zero. Thus, the disturbances are correlated across the equation with the subset of the right hand variables being the same. Economists and analysts have been utilising the SUR models. For instance, Inglesi-Lotz and Blignaut (2011) used the dataset of five economic sectors for the period 1993 to 2006 to examine the elasticity of demand for electricity in South Africa. Lee and Lee (2009) used the SUR to investigate the stationarity properties per capita carbon dioxide and GDP for 109 countries. Likewise, previous studies such as Beierlein, Dunn and McConnon (1981) employed the dataset from 1967 to 1977 to estimate six equations describing the demand for electricity and natural gas by residential, commercial and industrial sectors in the USA; whereas Verbon (1980) used the SUR model to estimate a set of four labour demand equations. This study also employed the seemingly unrelated regression model to examine how electricity prices affect the selected economic sector output separately. This is consistent with Inglesi-Lotz and Blignaut (2011), Lee and Lee (2009) and Zellner (1962) who posited that the SUR regression models capture the impact of the explanatory variables on each of the outcome variables (sectors) separately, considering that the sample is characterised by heterogeneity.

Table 5.6 presents LSDV and SUR results from different estimation techniques for robustness where the coefficients are basically the same but with slight differences across variation techniques. In this scenario, it is specifically the impact of electricity prices on sectoral output and not with other regressors. These results present and retort the broad objective of this study. Previous and recent literature on electricity prices and output in developed and developing countries, including South Africa, has been devoted to the relationship between the aggregated output and energy consumption or prices. In this regard, numerous studies found that low electricity prices reflect a weaker impact on output and sectoral output. Numerous studies have been devoted to electricity and output at overall levels. Again, use of time series which suffers heterogeneity bias was also one of the challenges in energy and output literature.

Table 5.6 presents the results of the LSDV and SUR panel data analysis implemented in the Stata package. More so, Table 5.6 illustrates that each equation is estimated separately using the fixed effect, FGLS and SCC models to illustrate the impact of electricity prices on economic sector output separately, using the SUR. The Stata package and the SUR models arrange the sector number in ascending order and the selected sectors were grouped from one to eight – thus, agriculture (1), transport and communication (2), construction (3), finance and banking (4), government and personal services (5), manufacturing (6), mining (7) and trade and catering (8). Table5.6 also shows the results for the LSDV and the two standard error estimators, the FGLS-SUR and the SCC-SUR. The FGLS was used instead of PCSE because the T>N. The SCC control for cross-sectional correlation within the model as indicated by the CD tests previously.

Table 5.6 SUR and LSDV Sectoral Analysis results

Sector/Equation number	Sector name	LSDV	FE-SUR	SCC-SUR	FGLS-SUR
1	Agriculture	-134946.3*	-465.264*	-465.264***	-505.777**
		(114748.6)	(230.7749)	(197.6459)	(160.276)
2	Transport and communication	-200791.4**	-2370.97*	-2370.97	-2616.489**
		(38125.36)	(1120.147)	(1943.474)	(756.6552)
3	Construction	367976.4**	(163.0826)	163.0826	143.7302
		(28781.16)	433.9	(495.1424)	(183.4828)
4	Finance	-919189.4**	- 4357.438**	-4357.438**	-4761.761**
		(114033.7)	(1093.001)	(1068.829)	(4398.452)
5	Government	-213640.6**	- 4484.962**	-4484.962**	-5141.911**
		(68077.21)	(929.1625)	(1109.435)	(558.3897)
6	Manufacturing	400668.1**	-4145.991	- 4145.991***	- 4353.817***
		(61615.8)	(2740.148)	(1575.48)	(187.125)
7	Mining	91259.52***	-661.3479	-661.3479	-377.0078
		(44828.89)	(1057.962)	(1334.891)	(655.5079)
8	Trade	416775.4**	-1051.478*	- 1051.478***	-800.921*
		(24547.58)	(635.9641)	(481.0097)	(435.2123)
R-Squared		0.9722	0.9885	0.9717	0.9991
observations		176	176	176	176
P< 0.01**, p< 0.05***, P< 0.1*					

Source: *Author's own compilation with data from Quantec (2016) and SARB (2015)*

The LSDV regression results as illustrated in Table 5.6 dropped the agriculture output since the constant is included in the regression process. The results indicate that the transport, finance and government sector outputs respond negatively to electricity price changes. However, electricity prices have a positive and significant impact on the manufacturing, construction, mining and trade sector output. According to the researcher's observation on the LSDV empirical results, the individual effects are only presented in one column. Unlike the SUR model, the LSDV coefficients of the individual outputs are not specifically presented as per electricity price changes. For this reason, the researcher opted for the SUR regression results which indicate the effect of electricity prices for each and every selected sector output in the study.

In addition, Table 5.6 demonstrates the SUR regression results as confirmed by Inglesi-Lotz and Blignaut (2011), Lee and Lee (2009) and Beierlein *et al.* (1981). It is evident from the table that the SUR estimators indicate that electricity prices are negative and significant to explain output changes in the agriculture, transport and communication, finance, government, manufacturing and trade sectors. Thus, for a one percent increase in electricity prices, agriculture, transport and communication, finance, government, manufacturing and wholesale and trade output are expected to fall by 5%, 2.6%, 4.7%, 5.1%, 4.3% and 8.0% respectively. These empirical results are consistent with Ciarreta and Zarraga (2010), Adebola (2011), Boonzaaier *et al.* (2012) and Jorgenson (1984) who suggested that sectoral output or GDP and electricity consumption are sensitive to electricity prices. Looking at the six sectors where electricity prices show a negative and statistically significant impact, the greatest effect is seen in the wholesale trade, government and agriculture.

In addition to that, the empirical results of this research are also consistent with the theories of Kummel (1982), Rosenberg (1983) Schurr and Netschert (1960) which posit that energy and electricity in particular and productivity/output are related. The negative impact of electricity prices on the six economic sectors also confirms the hypothesis of Schurr (1960) and Rosenberg (1983) that a decline or increase in electricity prices induces or hampers output growth respectively. This suggests that the share of electricity in the value of output increases with technical change while the rate of technical change increases with a decrease in the price of electricity in six (agriculture, transport and communication, finance, government, manufacturing and wholesale and trade) out of the eight economic sectors employed in this study.

Numerous studies (Blignaut, Inglesi-Lotz, & Weideman, 2015; Inglesi-Lotz, 2014; Polemis &Dagomous, 2013; Altinay, 2005; Gosh, 2002) supported the idea that electricity prices have an insignificant impact on GDP in South Africa. This follows Table 5.6 results which also indicate that electricity prices are negative but weakly significant in explaining mining output. The insignificant impact of electricity prices on the mining levels sectors shows that some mining sectors are affected whilst others are not. For instance, the surface mining which relies more on diesel is less affected than the deep shaft mining (Montmasson-Clair & Ryan, 2014). The negative and insignificant impact of electricity prices on the mining sector output is also consistent with Inglesi-Lotz and Blignaut (2011) and Boonzaaier *et al.* (2012) who stated that sectors such as mining show an insignificant response to electricity prices since they are engaged in a process of co-generation whereby mines generate their own electricity or create smaller power units. According to Montmasson-Clair and Ryan (2014), the mining sector has embarked on new innovations around the implementation of new energy efficient technologies and renewable energy. Hence, the sector appears to be one of the least affected sectors by increases in electricity prices. This implies that electricity prices are still significant but the mining sector may be using their own source of electricity instead of Eskom electricity.

Table 5.6 shows that electricity prices have a positive but not significant impact on construction. Therefore, a positive and insignificant impact of electricity prices on the construction sector output is consistent with Deloitte Touche's (2012) proposition that the sector does not rely much on electricity. The sector may be using other forms of energy such as diesel and petrol in their production processes and operation. Hence, the electricity price changes may not have an effect on the construction sector output.

The use of panel data in this study allowed the researcher to investigate the impact of electricity prices on both aggregated and disaggregated sectoral output in South Africa. Unlike the time and cross-sectional data analysis, the panel data allowed the researcher to examine the sectoral output movements in response to electricity price changes at sectoral level. Moreover, the use of the fixed effect estimator as the appropriate estimator of the study allowed sectoral differences considering sectoral behaviour towards the use of electricity in their production processes and operations. This suggests that economic sectors are different in terms of operations, business practices, consumption and use of electricity. Indeed, the electricity price impact on these sectors is also expected to vary across economic sectors. Table 5.6 shows that although electricity prices have a negative and significant impact on agriculture, transport, finance, government and service, manufacturing, and trade, the degree of impact is not the same for the economic sectors. The

SUR empirical results in Table 5.6 thus confirm the alternative hypothesis of this study, that the impact of electricity prices on real output varies across different sectors in South Africa.

5.9 CHAPTER SUMMARY

This chapter estimated the effect of electricity prices on sectoral output using the basic panel data and robust standard estimation techniques. The common and individual unit root tests results were also presented in this chapter. The Breitung test is the benchmark test which indicates that most on the variable have a unit root at levels and become stationary at first difference. Furthermore, the correlation matrix was presented in this chapter. All the results for this study were obtained by means of the Stata package. The chapter divided the estimation, presentation and discussion of results into three categories. Firstly, the chapter presented the three basic panel data models so as to identify the appropriate estimator. The Hausman and BP/LM tests were used to determine the appropriate estimator (fixed effect) for the study which is the fixed effect estimator. The second table (5.5) was presented after the diagnostic tests. Thus the results from the diagnostic checks with the help of data status (T>N) were employed to identify the appropriate robust standard error estimators (FGLS and SCC). Table 5.5 also presented regression results from the basic estimator as well as the robust estimators free from heteroscedasticity, non-stationarity, and omitted variables, overstated coefficient of determinant, serial and cross-sectional correlation. The third category also employed SUR models to present results of the impact of electricity prices on economic output at sectoral level. The above discourse on the estimation and presentation of results has provided a clear picture indicating that there are differences within each economic sector. Such inferences are substantive for the policy recommendations and implementation to be presented in the following, final chapter.

CHAPTER SIX
SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

6.1 INTRODUCTION

This chapter draws conclusions from the results of the study and also puts forward recommendations for future policy formulation. The chapter summarises the findings and conclusions as well as some policy implications and recommendations for South Africa, based on the results of the study. Areas of further studies and delimitations are also presented in this chapter. The main objective of this study was to examine the impact of electricity prices on sectoral (which include agriculture, mining, manufacturing, construction, finance, trade and wholesale, trade and catering and communication) output in South Africa over the period 1994-2015. The reason for this is to cast some light and provide a clearer picture on how the economic output is being affected at sectoral level.

The second chapter of this research provided an assessment of trends in electricity prices, sectoral output and other macroeconomic variables of concern in the study. These trends revealed that when electricity prices were declining, sectoral output was increasing promptly. The sectoral output trends increased at a decreasing rate as electricity prices were increasing. This implies that high electricity prices hinder economic output whilst low electricity tariffs expand sectoral output in South Africa. The said outcomes are in accordance with the findings of Lim and Yoo (2013), Kohler (2013), Electricity Supply Commission (Eskom) (2011), Ciarreta and Zarraga (2010) and Altman, Mather and Harris (2009) who posited that electricity price changes have adverse effects on output. The study reviewed an overview of trends in electricity prices, the exchange rate, interest rate and inflation. In addition, theories and empirical literature from previous studies were also reviewed.

Energy prices and output have been a matter of excessive attention that has generated much debate in the theoretical literature ever since nations came into being. However, most of the studies on this subject have been concerned with electricity consumption and overall output. Thus, reactions by individual economic sectors with regards to electricity prices were a minor concern to most analysts and economists, since electricity prices have been regarded as an input of low cost share as a proportion to GDP. The empirical literature (Blignaut, Inglesi-Lotz & Weideman, 2015; Adebola, 2011; Odhiambo, 2010; Ghali & El-Sakka, 2004) shows that the energy and growth literature was more concerned with energy consumption and GDP analysis than energy (electricity) prices and economic growth at sectoral level. Therefore, to achieve the main objective of this study, it was necessary also to take account of other variables in the production model as suggested by both theoretical literature and empirical literature. The choice of these variables was informed by an extensive review of literature on both exchange rates and economic growth, and availability of data. The explanatory variables in this study included the sector specific (such as unit labour cost, remuneration, labour productivity, real gross capital formation, sector imports) and macroeconomic (interest rate, expenditure on health, inflation) variables.

The study employed the panel data techniques on South African data between 1994 and 2015. This study opted for panel data analysis because it has more sample variability than cross-sectional and time series, thus improving efficiency of econometric estimates. The research made use of the panel data estimation techniques to exploit on their ability to identify and define effects that are not clear in both time series and cross-section analysis together with the fact that panel data analysis allows control for aggregation biases and unobserved heterogeneity, something which is not considered by cross-section or time series data analysis. Apart from that, the panel data regression controls unrestricted dynamic measurement in the data, measurement errors and non-stationary time series. In application of the methodology, the initial step was the analysis of the panel unit root. The study presented the results for both common and individual unit root tests such as (LLC, Breitung and Im, Pesaran) tests. The Breitung test was the benchmark test since it shows that the variables are not stationary at levels but stationary at first difference. Apart from that, the study employed the basic panel data methods, the pooled, random and fixed effects to implement the BP/LM and Hausman tests so as to identify the appropriate basic estimator for the study. The study also performed the diagnostic test to identify the appropriate robust estimators for the study. Further, the study used the robust standard error estimators, FGLS, LSDV and SCC that control violation of the assumptions of the panel linear regression. The SUR model was also employed in this study to analyse economic output responsiveness to electricity price changes at sector level in South Africa.

Chapter Five presented the results from different regression models and tests results. The study tested the panel unit root tests to check whether the variables are stationary before venturing into the actual estimations so as to determine the robust standard error estimation methods to be used in the study. The chapter presented results for pooled, random and fixed effect and the least dummy variable estimators. The Breusch Pagan Lagrange Multiplier (BP/LM) and Hausman test indicated that the fixed effect was the appropriate basis estimator of the study. Indeed, the Hausman test provides a clue on whether there is presence of correlation in panels or not. Diagnostic tests results presented in the Chapter Five also specified the fixed effect mode heteroscedasticity, autocorrelation and cross-sectional dependence. However, the study employed other estimation techniques (SCC, FGLS, LSDV and SUR) to control for violation of the assumptions of the panel linear regression as indicated by the diagnostic test results. The LSDV and the SUR estimators were used for sectoral analysis.

The findings of the study reveal that sudden upturn of electricity prices in South Africa has changed the extent of the impact of electricity prices on sectoral output in South Africa. Previously, electricity has been regarded as having less of an effect on output since the prices were very low (Odhiambo, 2010; Ziramba, 2008; Wolde-Rufael, 2006). More so, the production theory itself considers electricity or energy as an input with less cost of share as a proportion to GDP. However, this study shows that electricity prices have a significant impact on sectoral output and it varies across economic sector output in South Africa.

6.2 THE KEY FINDINGS AND CONCLUSIONS

i) Impact of electricity prices on sectoral output using the fixed effect model

The BP/LM and Hausman tests identified the fixed effect as the appropriate basic estimation method for the study. The fixed effect regression results show that overall sectoral output is negatively related to electricity prices in South Africa. This implies that electricity among other factors (such as labour, capital) is also a substantive and limiting factor of output growth.

ii) Assessing responsiveness of sectoral output with regards to changes in electricity prices using the robust estimators

The empirical findings show that electricity prices have a statistically significant impact on sectoral output in South Africa. The study also shows that sectoral output change movements are not only determined by electricity prices as there are other factors which affect sectoral output. Factors such as remuneration, intermediate input prices and the exchange rate have a negative and significant effect on sectoral output. Apart from that, imports, real gross stock, labour productivity, and expenditure in health and sectoral output are positively related. The study also shows that inflation and interest rates have a weak impact on sectoral output in South Africa

iii) Sectoral output responsiveness to electricity prices at sectoral level in South Africa, 1994-2015

The use of SUR as confirmed by Inglesi-Lotz and Blignaut (2011), Lee and Lee (2009) and Zellner (1962) helped the researcher to examine how each and every selected economic sector output responds to electricity price change. The empirical findings indicate that out of eight economic sectors' output employed in the study, six sectors' (agriculture, transport and communication, finance, government services, manufacturing and trade) outputs are negatively related to electricity prices. Again, the empirical results of this study also indicate that the mining sector output is not sensitive to electricity prices. More so, the results show that the construction sector is positively related to electricity prices. The empirical findings thus confirm the alternative hypothesis of this study that the impact of electricity prices on real output varied across sectoral output in South Africa over the period 1994 to 2015.

6.3 POLICY IMPLICATIONS AND RECOMMENDATIONS

The policy implications and recommendations are made based on the empirical results of this research. The findings of the study have specified that the impact of electricity prices varies across economic sectors. Thus, out of eight economic sectors selected for this study, only six responded negatively to electricity price change. However, electricity prices have an insignificant relationship with the mining sector output. More so, the construction sector output moves in tandem with the electricity prices. Since the research estimation results indicate that most economic sectors are more prone to higher electricity prices, the South African government should be more vigilant in controlling the price level that may damage output growth in some economic sectors (such as agriculture, trade, government service, manufacturing and finance).

The energy regulators, electricity industries and the end users should focus more on the main goals (for both Eskom and the end users), that is on the electricity price determination process that emphasises cost-reflective electricity prices and economic development concurrently. Indeed, the policymakers and government institutions should set and agree on a price that will maintain and improve power capacity and supply as well as enhance sectoral output growth in

South Africa. Cost reflective electricity prices may be a burden to end users but this will assist in maintenance and expansion of the power industry to get rid of electricity supply and demand imbalances which may escalate electricity prices in future. In this regard, the government should work hard to reduce the public resistance towards the cost reflective electricity prices. By doing so, there is a need to keep the electricity end users informed about the economic impacts of such strategies in order for them to make informed choices.

The Eskom Holdings Ltd (2017) endorses that Eskom initially receives subsidies from the government. However, the electricity subsidies are considered as a limiting factor since they encourage the inefficient and wasteful use of energy and unnecessary pollution. Nonetheless, the empirical findings also indicated that each and every selected sector in this study responds disparately to electricity price changes. Some sectors are less sensitive while others have a greater and more significant response. Therefore, this research recommends that the government of South Africa should continue offering electricity price subsidies to the economic sectors that are greatly and adversely affected by price changes so as to minimise production costs. This will induce production processes, hence improving competitiveness and comparative advantages for those exporting sectors (manufacturing and agriculture).

As noted in Blignaut *et al.*,(2015), decreases in electricity consumption appear in two ways with contrasting effects. Some end users will object to consume energy more efficiently while others will turn to alternative and renewable forms of energy. However, the results of this study show that increasing electricity prices adversely affect sectoral output. Therefore, to avoid the adverse effects of high electricity prices on sectoral output, the government should continue supporting the cost-reflective electricity price whilst investing more in renewable energy technologies. As a result, end users can choose to be efficient or to adopt renewable energy without damaging output growth.

In addition to that, increasing expenditure on renewable energy technology is likely to be more sustainable than subsidising the non-renewable energy sector. Alternative renewable energy technologies such as solar water heaters, wind power, and hydroelectricity should be in place to ensure sufficient electricity supply to support output growth and development across economic sectors. The policy implication is also in line with the South African climatic change policy

(Musango and Brent, 2011), which aimed at assisting in the scale-up of the low carbon technology market in South Africa.

Policymakers, the electricity regulator and Eskom should ensure maintenance and stability of electricity prices. More so, the electricity prices should reflect a true economic cost of supplying power to improvise investment decisions and gross allocation of electricity to the South African citizens and economic sectors (such as mining, agriculture, finance, manufacturing, wholesale and trade, communication, trade and catering).

An interesting note is that expenditure in health significantly increases sectoral output. A healthy nation is productive nation. This implies that the government of South Africa should increase expenditure on health services especially for the poor who are deprived of better health facilities. Healthy workers stimulate productivity in different sectors of the economy, leading to higher output.

Empirical results also express that remuneration has a substantially adverse impact on sectoral output in South Africa. Even though remuneration motivates employees, it increases the cost of production. The researcher recommends that the employers within economic sectors should pay remuneration according to output. Thus, if the workers are aware of the incentive, they will work hard to receive more, thereby increasing output growth. In other words, the employees should not be paid to work hard. However, they should work hard to be paid. In doing so, output increases as workers work hard for their shares and incentives.

Another interesting issue in this study is that imports have a positive and statistically significant impact on sectoral output. An increase in importation in South Africa may be due to lack of variety and quality of goods and services and innovation in the country. Again, the domestic producers are likely to suffer supply and demand imbalances. Hence, the goods or services may not exist at a specific level of quality as the sectors can import better products than the domestic ones as far as advertising and packaging is concerned. For this reason, the government should implement policies that encourage innovations by increasing the availability of loans for small and medium sized enterprises. More so, the government should increase access to higher education in science and technology. Thus providing funds for brighter students to take degrees in science subjects. Further, quality goods and services can be enhanced through cleaner and more affordable energy, investment in transport infrastructure and communication. An entrepreneurship ecosystem should be the government's priority to improve sector competitiveness and productivity in South Africa.

6.4 ETHICAL CONSIDERATIONS

The study was based on the quantitative approach and use of secondary data. Therefore, there were no ethical concerns allied with the secondary data gathering. In the course of this study, the researcher was fully attentive of the University of Fort Hare's Policy on study ethics and took every safety measure to observe and remain in keeping with the protocols of the institution. In doing so, the data pooled from secondary bases were properly acknowledged. The researcher referenced other authors' work fully both in text and the reference list.

6.5 DELIMITATIONS OF THE STUDY AND AREAS FOR FURTHER STUDIES

The study analysed the electricity prices bearing on diverse economic sectors' output using panel data in South Africa from 1994 to 2015. Although the research has attained its aims, there were some inevitable limitations. For instance, unlike the time series and cross-sectional data, the panel data was tardily assembled, since the researcher had to gather data for specific variables for each and every selected individual sector. However, this did not compromise the research findings since the panel data from both developed and developing countries is available from sources such as Easy data Quantec.

The study considered the period when electricity prices were low (1994-2007/8) and rising (2007/8-2015). Energy forms include oil, gas, electricity and natural gas. However, this study adopted electricity as the sole form of energy. Numerous studies on the energy-growth relationship have focused on the demand function. This research adopted the production function and not the demand function. Among the three basic panel data methods that were employed in the study, the fixed effect was the appropriate estimator. Panel data allows the use of robust standard error estimators of which this study utilised the FGLS, and SCC. To cater for sectoral analysis, the SUR model was also used. All estimation techniques were implemented in the Stata package. It is important to bear in mind that this study was restricted to the South African economy only and the concern is that the outcomes obtained may not be openly pertinent to other economies. Therefore, applications to the other economies must be done with attention to disparate economic stages of development and structures

The effect of electricity rates was investigated, particularly on the sectoral (agriculture, manufacturing, mining, general government services, construction, trade and finance) output of the South African economy. Put otherwise, there is a possibility that the effects of electricity prices may not be the same at industry levels. For instance, the electricity prices impact on all mining industries such as gold, iron, copper and steel, to mention but a few. Therefore, further research in this regard could include testing the relationship between electricity prices and output at industrial level in South Africa.

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APPENDICES

APPENDIX A: CHAPTER 5 PANEL UNIT ROOT RESULTS

```
. xtunitroot breitung SY, lags(1)

Breitung unit-root test for SY
------------------------------
Ho: Panels contain unit roots           Number of panels  =     8
Ha: Panels are stationary               Number of periods =    22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                 sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------
 lambda              1.5237        0.9362
------------------------------------------------------------------

. xtunitroot breitung D.SY, lags(1)

Breitung unit-root test for D.SY
--------------------------------
Ho: Panels contain unit roots           Number of panels  =     8
Ha: Panels are stationary               Number of periods =    21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                 sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------
 lambda             -2.7122        0.0033
------------------------------------------------------------------

. xtunitroot breitung Ep, lags(1)

Breitung unit-root test for Ep
------------------------------
Ho: Panels contain unit roots           Number of panels  =     8
Ha: Panels are stationary               Number of periods =    22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                 sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------
 lambda              7.9457        1.0000
------------------------------------------------------------------

. xtunitroot breitung D.Ep, trend lags(1)

Breitung unit-root test for D.Ep
--------------------------------
Ho: Panels contain unit roots           Number of panels  =     8
Ha: Panels are stationary               Number of periods =    21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                 sequentially
Time trend:   Included                  Prewhitening: 1 lag
------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------
 lambda             -3.2373        0.0006
------------------------------------------------------------------
```

```
. xtunitroot breitung Ulc, lags(1)

Breitung unit-root test for Ulc
-------------------------------
Ho: Panels contain unit roots               Number of panels  =      8
Ha: Panels are stationary                   Number of periods =     22

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: 1 lag
----------------------------------------------------------------------------
                   Statistic      p-value
----------------------------------------------------------------------------
 lambda               4.8335       1.0000
----------------------------------------------------------------------------
```


```
. xtunitroot breitung Ulc, lags(1)

Breitung unit-root test for Ulc
-------------------------------
Ho: Panels contain unit roots               Number of panels  =      8
Ha: Panels are stationary                   Number of periods =     22

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: 1 lag
----------------------------------------------------------------------------
                   Statistic      p-value
----------------------------------------------------------------------------
 lambda               4.8335       1.0000
----------------------------------------------------------------------------
```


```
. xtunitroot breitung D.Ulc, lags(1)

Breitung unit-root test for D.Ulc
---------------------------------
Ho: Panels contain unit roots               Number of panels  =      8
Ha: Panels are stationary                   Number of periods =     21

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: 1 lag
----------------------------------------------------------------------------
                   Statistic      p-value
----------------------------------------------------------------------------
 lambda              -2.4454       0.0072
----------------------------------------------------------------------------

. xtunitroot breitung Rem, lags(1)

Breitung unit-root test for Rem
-------------------------------
Ho: Panels contain unit roots               Number of panels  =      8
Ha: Panels are stationary                   Number of periods =     22

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: 1 lag
----------------------------------------------------------------------------
                   Statistic      p-value
----------------------------------------------------------------------------
 lambda               3.5555       0.9998
----------------------------------------------------------------------------

. xtunitroot breitung D.Rem, lags(1)

Breitung unit-root test for D.Rem
---------------------------------
Ho: Panels contain unit roots               Number of panels  =      8
Ha: Panels are stationary                   Number of periods =     21

AR parameter: Common                        Asymptotics:  T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included                  Prewhitening: 1 lag
----------------------------------------------------------------------------
                   Statistic      p-value
----------------------------------------------------------------------------
 lambda              -1.3344       0.0910
----------------------------------------------------------------------------
```

```
. xtunitroot breitung Ipt, lags(1)

Breitung unit-root test for Ipt
-------------------------------
Ho: Panels contain unit roots              Number of panels  =      8
Ha: Panels are stationary                  Number of periods =     22

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included                 Prewhitening: 1 lag
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda                0.3637        0.6419
------------------------------------------------------------------------------

. xtunitroot breitung D.Ipt, lags(1)

Breitung unit-root test for D.Ipt
---------------------------------
Ho: Panels contain unit roots              Number of panels  =      8
Ha: Panels are stationary                  Number of periods =     21

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included                 Prewhitening: 1 lag
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda               -6.0455        0.0000
------------------------------------------------------------------------------

. xtunitroot breitung Iip, lags(1)

Breitung unit-root test for Iip
-------------------------------
Ho: Panels contain unit roots              Number of panels  =      8
Ha: Panels are stationary                  Number of periods =     22

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included                 Prewhitening: 1 lag
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda                3.8211        0.9999
------------------------------------------------------------------------------

. xtunitroot breitung D.Iip, lags(1)

Breitung unit-root test for D.Iip
---------------------------------
Ho: Panels contain unit roots              Number of panels  =      8
Ha: Panels are stationary                  Number of periods =     21

AR parameter: Common                       Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included                 Prewhitening: 1 lag
------------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------------
 lambda               -2.7435        0.0030
------------------------------------------------------------------------------
```

```
. xtunitroot breitung Rs, lags(1)

Breitung unit-root test for Rs
------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------
 lambda              -2.0893        0.0183
------------------------------------------------------------------------

. xtunitroot breitung D.Rs, lags(1)

Breitung unit-root test for D.Rs
--------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------
 lambda              -1.6649        0.0480
------------------------------------------------------------------------

. xtunitroot breitung Lp, lags(1)

Breitung unit-root test for Lp
------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------
 lambda               0.3597        0.6405
------------------------------------------------------------------------

. xtunitroot breitung D.Lp, lags(1)

Breitung unit-root test for D.Lp
--------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                   sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------
 lambda              -4.6933        0.0000
------------------------------------------------------------------------
```

```
. xtunitroot breitung Exh, lags(1)

Breitung unit-root test for Exh
-------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda             -7.2513        0.0000
------------------------------------------------------------------------------

. xtunitroot breitung D.Exh, lags(1)

Breitung unit-root test for D.Exh
---------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda             -4.0328        0.0000
------------------------------------------------------------------------------

. xtunitroot breitung Inf, lags(1)

Breitung unit-root test for Inf
-------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda             -4.2400        0.0000
------------------------------------------------------------------------------

. xtunitroot breitung D.Inf, lags(1)

Breitung unit-root test for D.Inf
---------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------------
                   Statistic      p-value
------------------------------------------------------------------------------
 lambda             -7.3747        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot breitung Ei, lags(1)

Breitung unit-root test for Ei
------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------
 lambda               -1.9571        0.0252
------------------------------------------------------------------------

. xtunitroot breitung D.Ei, lags(1)

Breitung unit-root test for D.Ei
--------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------
 lambda               -5.5044        0.0000
------------------------------------------------------------------------

. xtunitroot breitung Ir, lags(1)

Breitung unit-root test for Ir
------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------
 lambda               -0.9056        0.1826
------------------------------------------------------------------------

. xtunitroot breitung D.Ir, lags(1)

Breitung unit-root test for D.Ir
--------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics:  T,N -> Infinity
Panel means:  Included                                  sequentially
Time trend:   Not included              Prewhitening: 1 lag
------------------------------------------------------------------------
                     Statistic      p-value
------------------------------------------------------------------------
 lambda               -5.8769        0.0000
------------------------------------------------------------------------
```

APPENDIX B: SAMPLES FOR LLC AND ImPESARAN UNIT ROOT TESTS

```
. xtunitroot llc D.SY, lags(1)

Levin-Lin-Chu unit-root test for D.SY
------------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        -8.1239
 Adjusted t*         -3.4003        0.0003
------------------------------------------------------------------------------

. xtunitroot llc Ep, lags(1)

Levin-Lin-Chu unit-root test for Ep
----------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     22

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        10.4486
 Adjusted t*         16.8703        1.0000
------------------------------------------------------------------------------

. xtunitroot llc D.Ep, lags(1)

Levin-Lin-Chu unit-root test for D.Ep
------------------------------------
Ho: Panels contain unit roots           Number of panels  =      8
Ha: Panels are stationary               Number of periods =     21

AR parameter: Common                    Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 8.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t        -2.2176
 Adjusted t*          1.9538        0.9746
------------------------------------------------------------------------------
```

```
. xtunitroot ips Exh, lags(1)

Im-Pesaran-Shin unit-root test for Exh
--------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     22

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                       sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -4.3349        0.0000
------------------------------------------------------------------------------

. xtunitroot ips D.Exh, lags(1)

Im-Pesaran-Shin unit-root test for D.Exh
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     21

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                       sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              0.6135        0.7302
------------------------------------------------------------------------------

. xtunitroot ips Inf, lags(1)

Im-Pesaran-Shin unit-root test for Inf
--------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     22

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                       sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar             -6.5637        0.0000
------------------------------------------------------------------------------
```

```
. xtunitroot ips D.Inf, lags(1)

Im-Pesaran-Shin unit-root test for D.Inf
----------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     21

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              -8.6128        0.0000
------------------------------------------------------------------------------

. xtunitroot ips Ei, lags(1)

Im-Pesaran-Shin unit-root test for Ei
-------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     22

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              -3.6408        0.0001
------------------------------------------------------------------------------

. xtunitroot ips D.Ei, lags(1)

Im-Pesaran-Shin unit-root test for D.Ei
---------------------------------------
Ho: All panels contain unit roots           Number of panels  =      8
Ha: Some panels are stationary              Number of periods =     21

AR parameter: Panel-specific                Asymptotics: T,N -> Infinity
Panel means:  Included                                        sequentially
Time trend:   Not included

ADF regressions: 1 lag
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 W-t-bar              -6.0631        0.0000
------------------------------------------------------------------------------
```

APPENDIX C: SAMPLE FOR CHAPTER 5 SUR RESULTS

```
-> sectornum = 1

Seemingly unrelated regression
```

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	2380.961	0.9938	3544.65	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-465.264	155.5884	-2.99	0.003	-770.2117	-160.3164
dlUlc	517.7664	321.118	1.61	0.107	-111.6133	1147.146
dlRem	-2.84996	2.13378	-1.34	0.182	-7.032091	1.332172
dlIpt	-2.434673	.8439683	-2.88	0.004	-4.08882	-.780525
dlIip	517.351	184.5423	2.80	0.005	155.6547	879.0473
Rs	-.7976776	.4519507	-1.76	0.078	-1.683485	.0881295
Lp	1119.632	427.2873	2.62	0.009	282.1638	1957.099
Exh	.5707332	.1567274	3.64	0.000	.2635531	.8779133
Inf	83.07115	546.9738	0.15	0.879	-988.9777	1155.12
Ei	-18.09289	109.0846	-0.17	0.868	-231.8948	195.7091
Ir	2986.871	837.8079	3.57	0.000	1344.798	4628.944
_cons	214937.3	122542.5	1.75	0.079	-25241.65	455116.2

```
-> sectornum = 2

Seemingly unrelated regression
```


Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	6899.439	0.9970	7201.21	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-2370.97	755.2029	-3.14	0.002	-3851.141	-890.7997
dlUlc	-1568.415	964.6078	-1.63	0.104	-3459.011	322.1819
dlRem	1.972031	2.567955	0.77	0.443	-3.061068	7.005129
dlIpt	.248116	.7205705	0.34	0.731	-1.164176	1.660408
dlIip	2478.596	1108.565	2.24	0.025	305.848	4651.344
Rs	.6071863	.3257072	1.86	0.062	-.0311881	1.245561
Lp	-375.0603	2412.182	-0.16	0.876	-5102.851	4352.73
Exh	-.751298	.3590815	-2.09	0.036	-1.455085	-.0475113
Inf	1147.479	1675.512	0.68	0.493	-2136.464	4431.422
Ei	128.6664	537.1458	0.24	0.811	-924.1201	1181.453
Ir	589.8385	2020.367	0.29	0.770	-3370.007	4549.684
_cons	-173055.5	232231.4	-0.75	0.456	-628220.6	282109.6

-> sectornum = 3

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	2947.304	0.9988	17859.43	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	163.0826	292.5527	0.56	0.577	-410.3101	736.4753
dlUlc	3663.013	703.3557	5.21	0.000	2284.461	5041.565
dlRem	-5.194538	2.619897	-1.98	0.047	-10.32944	-.0596331
dlIpt	8.216194	7.131085	1.15	0.249	-5.760475	22.19286
dlIip	-1434.639	382.5444	-3.75	0.000	-2184.412	-684.8654
Rs	5.003774	1.058588	4.73	0.000	2.92898	7.078568
Lp	2757.893	848.2452	3.25	0.001	1095.363	4420.423
Exh	-.4044258	.1874277	-2.16	0.031	-.7717773	-.0370742
Inf	1576.696	626.2298	2.52	0.012	349.3087	2804.084
Ei	51.2082	120.1522	0.43	0.670	-184.2859	286.7023
Ir	-1457.209	803.6681	-1.81	0.070	-3032.37	117.9513
_cons	-142062.3	43494.4	-3.27	0.001	-227309.7	-56814.82

-> sectornum = 4

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	13157.88	0.9978	10068.11	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-4357.438	736.9011	-5.91	0.000	-5801.738	-2913.138
dlUlc	13327.86	4647.516	2.87	0.004	4218.892	22436.82
dlRem	-.7700635	3.941489	-0.20	0.845	-8.495239	6.955112
dlIpt	.1321776	2.828456	0.05	0.963	-5.411495	5.67585
dlIip	-2624.566	715.2862	-3.67	0.000	-4026.501	-1222.63
Rs	.0717136	.1913778	0.37	0.708	-.3033799	.4468071
Lp	4271.902	2575.302	1.66	0.097	-775.5983	9319.402
Exh	-.607942	.6164926	-0.99	0.324	-1.816245	.6003613
Inf	4632.822	3316.111	1.40	0.162	-1866.636	11132.28
Ei	-1764.778	965.1341	-1.83	0.067	-3656.407	126.8496
Ir	-9550.343	3087.134	-3.09	0.002	-15601.01	-3499.672
_cons	-190311.9	238962.6	-0.80	0.426	-658670.1	278046.2

-> sectornum = 5

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	8006.618	0.9981	11350.83	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-4484.962	626.4412	-7.16	0.000	-5712.764	-3257.16
dlUlc	-9850.532	1529.31	-6.44	0.000	-12847.92	-6853.14
dlRem	12.42263	1.699483	7.31	0.000	9.091707	15.75356
dlIpt	2.333609	3.357413	0.70	0.487	-4.2468	8.914018
dlIip	761.825	767.7092	0.99	0.321	-742.8574	2266.507
Rs	.7108816	.1808561	3.93	0.000	.3564102	1.065353
Lp	-9202.467	2727.062	-3.37	0.001	-14547.41	-3857.524
Exh	-.3383294	.3333541	-1.01	0.310	-.9916913	.3150325
Inf	2467.411	1688.655	1.46	0.144	-842.2917	5777.113
Ei	-158.5646	413.2676	-0.38	0.701	-968.5541	651.425
Ir	-361.4923	2046.73	-0.18	0.860	-4373.01	3650.025
_cons	521672.7	373131.5	1.40	0.162	-209651.7	1252997

-> sectornum = 6

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	14783.22	0.9968	6823.69	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-4145.991	1847.407	-2.24	0.025	-7766.843	-525.1394
dlUlc	-19820.51	6033.951	-3.28	0.001	-31646.84	-7994.188
dlRem	12.41269	3.763622	3.30	0.001	5.036122	19.78925
dlIpt	.7344589	.1383295	5.31	0.000	.463338	1.00558
dlIip	9319.782	2130.521	4.37	0.000	5144.037	13495.53
Rs	.8242359	.4326957	1.90	0.057	-.0238321	1.672304
Lp	-7163.959	4713.468	-1.52	0.129	-16402.19	2074.269
Exh	-2.427807	1.312829	-1.85	0.064	-5.000905	.1452909
Inf	875.9655	2945.663	0.30	0.766	-4897.428	6649.359
Ei	-709.1317	601.3687	-1.18	0.238	-1887.793	469.5294
Ir	-7412.207	4419.288	-1.68	0.093	-16073.85	1249.438
_cons	1021373	313650	3.26	0.001	406629.9	1636115

-> sectornum = 7

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	4523.516	0.8816	163.77	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-661.3479	713.2775	-0.93	0.354	-2059.346	736.6503
dlUlc	-2859.425	943.9769	-3.03	0.002	-4709.586	-1009.264
dlRem	1.050525	.4452298	2.36	0.018	.1778909	1.92316
dlIpt	.1169178	.0779102	1.50	0.133	-.0357834	.269619
dlIip	-297.3694	842.8915	-0.35	0.724	-1949.406	1354.668
Rs	-.4115556	.3198578	-1.29	0.198	-1.038465	.2153542
Lp	-221.4952	560.6738	-0.40	0.693	-1320.396	877.4052
Exh	2.278655	.5930393	3.84	0.000	1.11632	3.440991
Inf	665.692	1173.377	0.57	0.570	-1634.084	2965.468
Ei	410.8151	566.0347	0.73	0.468	-698.5925	1520.223
Ir	1031.043	1218.059	0.85	0.397	-1356.308	3418.395
_cons	496411.2	137511.3	3.61	0.000	226894.1	765928.3

-> sectornum = 8

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lSY	22	11	5645.828	0.9983	12612.32	0.0000

lSY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lSY						
dlEp	-1051.478	428.7669	-2.45	0.014	-1891.846	-211.1107
dlUlc	-8322.217	1829.516	-4.55	0.000	-11908	-4736.432
dlRem	27.12035	3.584147	7.57	0.000	20.09555	34.14515
dlIpt	2.551534	1.565111	1.63	0.103	-.5160283	5.619096
dlIip	-563.2232	960.8284	-0.59	0.558	-2446.412	1319.966
Rs	2.745523	.4394282	6.25	0.000	1.884259	3.606786
Lp	-7555.054	1261.618	-5.99	0.000	-10027.78	-5082.329
Exh	-1.4104	.2569214	-5.49	0.000	-1.913957	-.9068438
Inf	-740.552	1302.592	-0.57	0.570	-3293.585	1812.481
Ei	-1423.264	303.5775	-4.69	0.000	-2018.265	-828.2625
Ir	-1300.463	1220.481	-1.07	0.287	-3692.562	1091.637
_cons	563758.3	110571.3	5.10	0.000	347042.6	780474.1

APPENDIX D: PROOF OF EDITING

PROOF OF EDITING CERTIFICATE

TO WHOM IT MAY CONCERN

<u>Language editing</u>

I, Jeanne Enslin, acknowledge that I did the language editing of **Dorcas Gonese's** dissertation submitted in fulfilment of the requirements for the degree Master of Commerce in Economics at the University of Fort Hare.

As agreed with the Dorcas, I did not do the formatting nor did I check or work on the List of references or do cross-referencing; I did however correct some references in text that were not in the correct format.

The title of the dissertation is:

THE IMPACT OF ELECTRICITY PRICES ON SECTORAL OUTPUT IN SOUTH AFRICA

If any major changes are made to the text after I sent the dissertation to **Dorcas Gonese** on 20 November 2017, I cannot be held responsible for any errors that are made. Alternatively, the document needs to be returned to me to check the language of the changes.

Detailed feedback of all the language editing done has been provided to Dorcas in writing and is evident in the dissertation in track changes (with comments).

JHEnslin

Jeanne Enslin
Language editor
082-6961224.

J H Enslin BA (US); STD (US); Hons Translation Studies (UNISA)

APPENDIX E: ETHICAL CLEARANCE

University of Fort Hare
Together in Excellence

Govan Mbeki Research & Development Centre

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22 November 2016

Dorcas Gonese
Department of Economics
University of Fort Hare
East London Campus
South Africa

Dear Dorcas

This is to acknowledge receipt of your application for Ethical Clearance for your research project titled: ***The impact of electricity process on sectoral output in South Africa.***

On behalf of the University Research Ethics Committee (UREC) we have checked your proposal and would like to let you know that there is no need to issue an ethical clearance certificate. Even though in research where secondary data is being reviewed that does not involve collecting data from humans and animals directly, researchers are strongly urged to observe good ethical conduct when using information by others (acknowledge sources and avoid plagiarism).

Yours,

Professor Wilson Akpan
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