CAUSALITY ANALYSIS BETWEEN ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH: EVIDENCE FROM ZAMBIA

By

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A Dissertation Submitted to the University of Zambia in Partial Fulfilment of the Requirement for the Degree of

Master of Arts in Economics

The University of Zambia

Lusaka

July, 2016

DECLARATION

I, Chitumbo Bupe S, declare that this dissertation:

(a) Represents my own work;

(b) Has not previously been submitted for a degree at this or any other University; and

(c) Does not incorporate any published work or material from another dissertation.

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Date……………………………………………………...

APPROVAL

This dissertation of **Chitumbo, Bupe** has been approved as a partial fulfilment of the requirements for the award of the degree of Master of Arts in Economics by the University of Zambia.

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ABSTRACT

Zambia's economic history has, to some extent, been greatly influenced by the early 1970s energy oil crisis precipitated by the steep adjustment of the international oil prices following the Arab-Israeli war of 1972. Globally, energy is arguably one of the major determinants of economic growth. The international community, through the United Nations, have increasingly recognized universal access to clean, affordable and reliable energy services as a prerequisite to sustainable poverty reduction and improved shared prosperity. For a country like Zambia experiencing excessive electric shortages, it is important to empirically demonstrate that a well-developed energy sector is expedient in social and economic development. This paper attempted to establish the causality between electricity consumption and economic growth over the period 1971 to 2013. It employed the Johansen Maximum Likelihood Procedure and the Error Correction Model (ECM) to estimate both the short and long run causality between electricity consumption and economic growth. The application of the Johansen Maximum Likelihood procedure to the Zambian data from the World Development Indicators (WDI) indicates one co-integrating equation. The ECM results show a short-run and long-run unidirectional causality running from economic growth to electricity consumption without feedback. However, the Variance Decomposition Analysis (VDC) indicates that electricity consumption contributes more to economic growth than economic growth contributes to electricity consumption. In the short-run, the government should utilise all the possible avenues to avert the current electric energy poverty. This is because addressing an energy infrastructure bottleneck is one of the major strategies for unlocking the country's shared growth potential.

Key Words: Causality, electricity consumption, economic growth, error correction model, Johansen co-integration, Zambia.

DEDICATION

To my family and friends

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr. Mushiba Nyamazana for his constructive comments, guidance, patience and mentorship as my supervisor. I am also thankful to all members of staff in the Department of Economics for broadening my academic knowledge, as well as the Bank of Zambia for their financial support. And finally, I owe everything to the omnipotent God.

LIST OF ACRONYMS AND ABBREVIATIONS

ADF	Augmented Dickey Fuller test
AGDP	Agricultural Gross Domestic Product
ARDL	Autoregressive Distributed Lag
CEC	Copperbelt Energy Corporation
EAZ	Economics Association of Zambia
ECM	Error Correction Model
ECT	Error Correction Term
ERB	Energy Regulation Board
Eq	Equation
GDP	Gross Domestic Product
IEA	International Energy Agency
KWh	Kilowatt Hour
LR	Likelihood Ratio
LM	Likelihood Multiplier
MDGs	Millennium Development Goals
MMEWD	Ministry of Mines, Energy, and Water Development
NGDP	Non-Agricultural Gross Development Program
OECD	Organisation for Economic Corporation and Development
PP	Phillips-Perron
SDGs	Sustainable Development Goals
UNDP	United Nations Development Program
U.S.A	United States of America
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WSSD	World Summit for Sustainable Development (WSSD)
ZESCO	Zambia Electricity Supply Corporation
ZRA	Zambia Revenue Authority

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0: INTRODUCTION

1.1.0: Background

As a sector, energy is often overlooked in most developing countries, but its importance in any given economy cannot be overstated. Energy is like blood in the veins. An individual is more likely to be productive the greater the amount of blood in the body. As a corollary, a country is very unproductive given inadequate supply of energy. Simply put, the supply of modern energy such as electricity is a necessary requirement for social and economic development (IEA, 2002). Many institutions such as the United Nation, governments, and non-governmental organizations have recognized the need for reliable, sustainable and affordable energy for all. For instance, in 2002, at a World Summit for Sustainable Development (WSSD) in Johannesburg it was concluded that access to reliable and affordable energy services facilitates the eradication of poverty (World Energy Council, 2014). Furthermore, in 2012, the Rio+20 United Nations Conference paved the way for the development of Sustainable Development Goals (SDGs) recognising the need for energy equity, security and the environment in the development process of all countries.

Policymakers in both the developing and developed countries are at pains to find an optimal balance of energy security, energy equity and environmental sustainability. This problem is referred to as an *Energy Trilemma* across the globe (World Energy Council, 2014).However, this trilemma is more pronounced in developing countries where policymakers are faced with high levels of unemployment and poverty (Wolde-Rufael, 2006).In a quest to improve energy security and equity, most countries are constrained with the need to preserve the environment. That is, apart from experiencing erratic electric energy supplies and low electric access rates, environmental sustainability is a major challenge in Africa. However, an all-inclusive energy policy need not preclude the environment. This also entails that energy efficiency programs on both the supply and demand side be employed, as well as the need to improve the share of clean and modern energy in the energy mix of most countries across the globe. Incorporating energy equity, security and environmental sustainability is in line with United Nations advocacy for a green economy. Without a doubt, few can argue against the need for a sustainable energy framework in achieving sustainable development.

Empirical evidence, however, suggests that an optimal balance of these three aspects of a sustainable energy system cannot be implemented with ease in all countries (World Energy Council, 2014). This is because the effects of such a policy on economic growth vary depending on a country's unique characteristics (Binh, 2011). Therefore, many researchers have sought to establish the causality between energy or electricity consumption and economic growth to assess the possibility of implementing energy conservation policies.

An oil supply shock of the early 1970s precipitated by the Israeli-Arab War of 1972 prompted an interest on the role of energy in economic growth. In particular, Kraft and Kraft (1978) pioneered the work on the causal relationship between energy consumption and economic growth. The oil crisis triggered a recession in the global economy, thereby supressing the demand for copper on the international market. For the Zambian economy, it was the start of the beginning of the end. An increase in international oil prices coupled with tumbling copper prices on the international market in 1973s transformed Zambia into one of the poorest countries in Africa. Before then, Zambia was the second richest country in Sub-Saharan Africa (Whitworth, 2014).

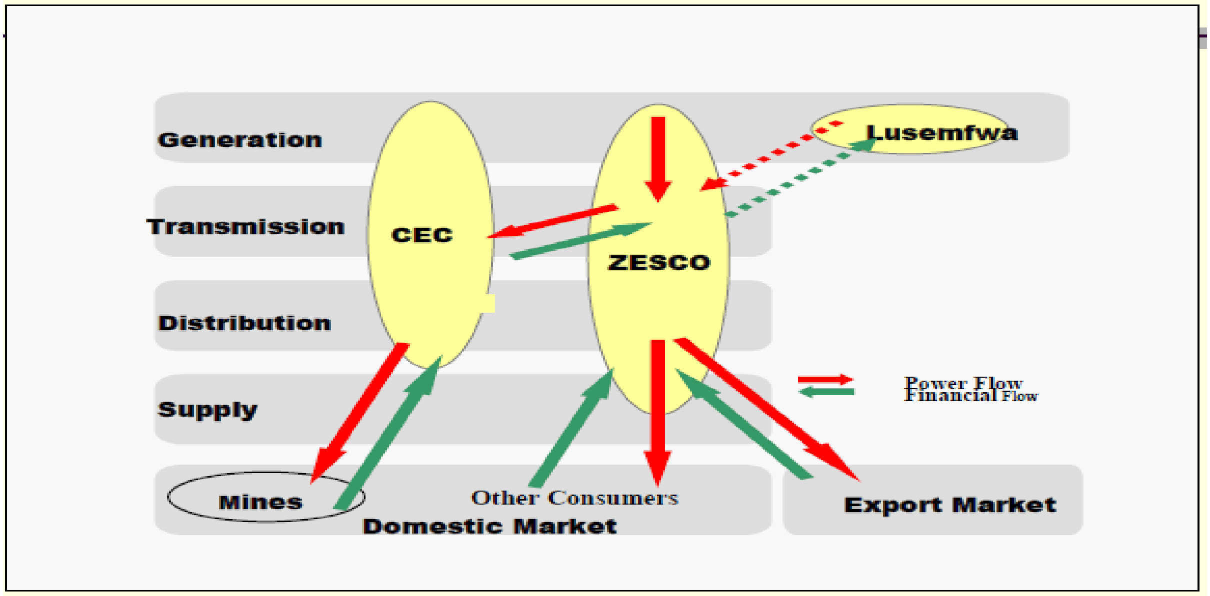
Today, the Zambian economy is experiencing one of the worst energy crisis ever experienced via electric energy shortages (Energy Regulation Board, 2014).Is it possible to implement energy conservation policies in Zambia given the impending electric energy insecurity combined with an electric national access rate of 25 percent? In Zambia, the institutional and legal incentives are well developed for implementing energy efficiency strategies and technologies. However, the economic and financial incentives, as well as the social and political incentives are non-existent (United Nations Economic Comission for Europe, 2015). Therefore, the major aim of this paper is to empirically examine the electricity-growth nexus to establish the possibility of implementing energy conservation policies in Zambia.

1.2.0: Overview of the Zambian's Electricity Sector

The total installed capacity of electric energy generation in Zambia is about 2,398 MW; hydropower is the most important energy source with 2,259 MW which accounts for over 94 percent. The second important source of electric energy is gas-contributing about 3.3 percent to the national supply. Zambia has huge hydroelectric potential as she possess 40 percent of water bodies in the Southern African Development Community (SADC) (Energy Regulation Board, 2014). This endowment is sufficient for the country to meet its own electric energy demand and can export the surplus to generate revenue. However, an immense potential of 6,000 MW of hydropower remains unexploited. Therefore, the state owned power utility company, ZESCO, and other private producers are heavily dependent on water for electricity generation.Aside from the hydropower potential, the country has an average, 2001-3000 hours of sunshine per year, albeit solar penetration has remained relatively low due to high initial cost. Similarly, wind energy potential in Zambia is relatively low due to low wind speed of 2.5m/s at 10 meters above sea level. With regard to geothermal, the country has about 80 hot springs (Zambia Development Agency, 2014). Failure to capitalize on the huge hydropower potential, as well as to diversify to other clean energy sources such as solar has resulted into acute electric energy shortages in Zambia.

Figure 1 below shows how the electrical power supply is structured in Zambia. The power supply is dominated by ZESCO, the vertically integrated state-owned utility. The other important sector participant is Copperbelt Energy Corporation (CEC), a private company that purchases bulk power from ZESCO and supplies the copper mines. CEC used to provide power to the mines under long-term agreements at an exceptionally favourable price (Vagliasindi & Besant-Jones, 2013).However, this has since changed due to the electric energy poverty the country is experiencing.

Figure 1: Electricity Industry Structure

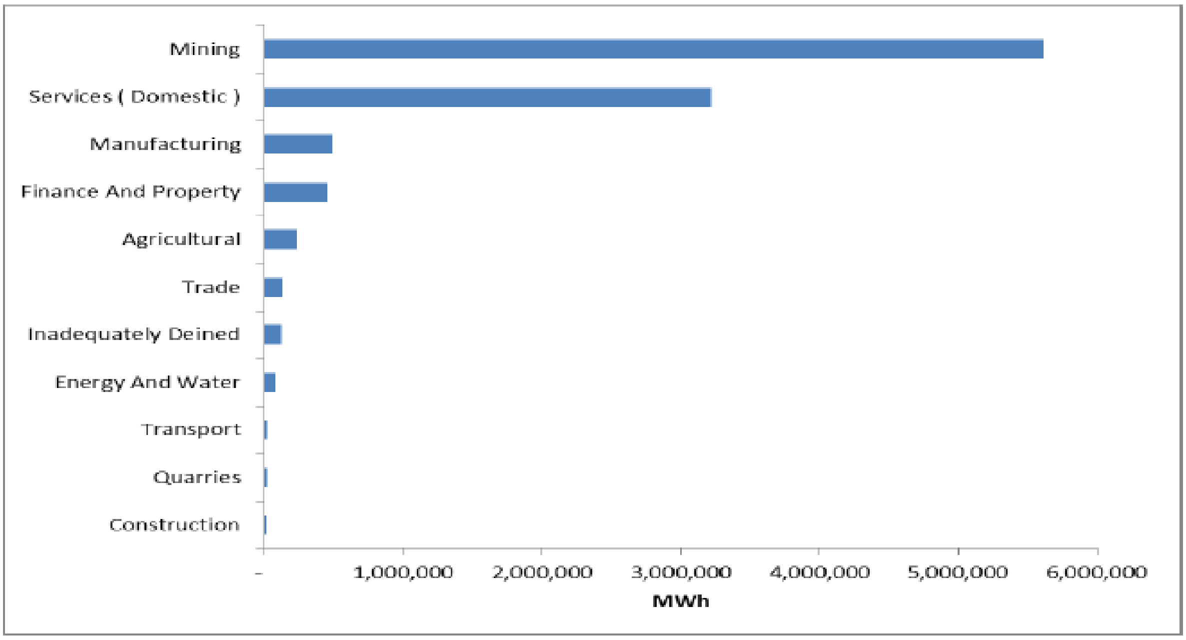


Source: (Vagliasindi & Besant-Jones, 2013)

As a consequence, the government advised mining companies to get used to high electric tariffs. This is because high power tariffs are paramount in promoting increased participation of independent power producers to help resolve the problem of erratic power supply. Electricity is a key input for mining—more than 50 percent of electricity generated in Zambia is used up by the mining sector (Energy Regulation Board, 2014). Policy analysts have also advised the government to unbundle the electric energy sector into separate units of transmission, distribution and generation and have cited independent power producer such as Maamba, and Lunsemfwa as good examples in achieving this. Lunsemfwa Hydro Power Company operates a plant of 40 MW of capacity and is connected to ZESCO's transmission system. Lunsemfwa provides electricity to a nearby manganese mine and to ZESCO (Vagliasindi & Besant-Jones, 2013).

Figure 2 below shows consumption of electricity by sector in 2013. The major consumer of electricity in Zambia in 2013 was the mining sector with about 55% (5,600,000 MWh) of the total national consumption. Services (including residential customers) consumed about 31% (3,200,000 MWh) while the rest of the sectors shared 15% (1,600,000 MWh) of the national consumption.

Figure 2: Electricity Consumption by Sector



Source: (Energy Regulation Board, 2014)

1.4.0: Statement of the Research Problem

One objective of the Zambian Sixth National Developmental Plan (SNDP) is to achieve universal access to clean, reliable and affordable energy at the lowest total economic, financial, social and environmental cost consistent with national development goals (Ministry of Finance and National Planning, 2014).In order to help design an appropriate energy policy there is need to understand the prevailing causal relationship between electric energy consumption and economic growth in Zambia. However, this causal relationship varies from country to country.Empirical evidence shows that the nature of this causality has been a point of disagreement. The variability in this causal relationship can be attributed to the differences in the methodology used, study duration, sources and availability of data, sample size and the level of development of a country under study (Wolde-Rufael, 2006).

In some countries, a one-way causal relationship from economic growth to electricity consumption holds. With such an outcome, implementing energy conservation polices that restrict electricity consumption can have little or no impact on economic growth (Jumbe, Yoo, 2005). On the contrary, when this causality runs from electricity consumption to economic growth, an interruption in electricity supply or electricity consumption can have serious adverse effects on economic growth (Chen, 2007; Bellouni, 2009; Kouakou, 2006; Bildirici, 2013). Other countries exhibit a two-way causal relationship which depicts the importance of a reliable and sustainable supply of electricity in promoting and sustaining economic growth. To this effect, an inadequate power infrastructure can constrain national development goals from being met (Yoo, 2006; Shahbaz, 2011).If no causality between them exists, then any constraints to electricity consumption does not pose any serious negative effects on economic growth.Against this backdrop, it is very dangerous to design future energy policy of one country based on experiences of another (Binh, 2011).*The purpose of this paper is to ascertain the causality between economic growth and electricity consumption in Zambia over the period 1971 to 2013*.

1.5.0: Significance of the Study

To the best of our knowledge, this is the first study in Zambia to undertake a country specific approach on the electricity–growth nexus for a period of 1971–2013. There are several studies in literature on the causal relationship between electricity consumption and economic growth across the globe. Most of these were carried out in the developed world whilst very few have been done in Zambia and Southern Africa. In this paper, we focused not on the causal relationship between economic growth and the broad spectrum of energy use per se but rather between electricity consumption and economic growth. This is because time series data on electricity consumption and real GDP per capita are readily available at the World Bank (Wolde-Rufael, 2006).

A country-specific study on the causal relationship between electric energy consumption and economic growth provides deep insights into the design of an energy policy. Such kind of studies tend to be more focused and are better able to provide policy guidelines by providing explanations of the dynamics of energy use and economic development for a particular country. Furthermore, results from a country specific study are useful in finding a win-win situation between economic growth and the environment. Particularly for those economies like Zambia that are facing constrained electric energy supply, electric energy efficiency can help address energy shortages in addition to safeguarding the environment (Mozumder, 2006; Jamil et al, 2010).Given that no study has attempted to empirically estimate a country specific causal relationship between electricity consumption and economic growth in Zambia. This paper, therefore, attempts to supplement this gap.

1.6.0: Objectives

1.6.1: General Objective

- To establish the causal relationship between economic growth and electricity consumption per capita

1.6.2: Specific Objectives

- To investigate both the short and long run causal relationship between electricity consumption per capita and economic growth.

1.7.0: Hypotheses

Our hypotheses listed below were drawn from the electricity-growth nexus literature (Payne, 2010).

- A one-way or unidirectional causality from electricity consumption per capital to economic growth. This is referred to as the growth hypothesis.

- A one-way or unidirectional causality from economic growth to electricity consumption per capita is known as a conservation hypothesis. This implies that economic growth causes the development of the energy sector and indicates an economy which is less electric energy dependent.
- The neutrality hypothesis refers to a situation where the causality between electricity consumption and economic growth does not exist.
- A two-way or bi-directional causality between per capita electricity consumption and economic growth. This is what is known as the feedback hypothesis.

The remainder of the paper is organized as follows: Section 2 reviews the existing literature, that is, studies on Africa and Zambia, and those outside Africa. The methodology and data sources are discussed in Section 3. Section 4 discusses data management, and modelling. The discussion of findings will be done in Section 5, and Section 6 concludes the paper with policy recommendations.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: Introduction

This section reviews relevant theoretical models and empirical studies in the field of energy economics. It will start by highlighting the role that energy plays in economic growth as outlined by the mainstream, biophysical and ecological models of economics. Thereafter, we review some important empirical studies on the causal relationship between electrical energy consumption and gross domestic product for both Zambia and other countries.

2.2.0: Theoretical Literature Review

The field of macroeconomics is riddled with many debates. It is no surprise that the importance of energy as a determinant of economic growth is one such example. There are primarily two conflicting arguments. On the one hand, some growth theories insist that energy consumption is not paramount in achieving economic growth such as the Neo-classical growth model. On the contrary, others contend that energy consumption is a significant factor in determining economic growth.

Mainstream economics and Neo-classical growth models downplay the importance of energy use in in social and economic development. The Neo-classical growth theories argue that economic growth is premised on technological advancement (Romer, 2010). For example, the Solow growth theory postulates that anything short of advancement in technology is just a mere disturbance to the growth path which eventually restores itself to an equilibrium known as the steady state. The idea is that technological advancement and innovations enhance the productivity of inputs or factors of production. The only factors of production that the Neo-classical growth theories identify are labour and capital. That is, the gross domestic product of a country is solely determined by these two factors of production (Mankiw, 2001). Therefore, a change in energy prices or electric energy use has only a negligible impact on economic growth.

Consequent development of the Neoclassical theories such as endogenous models still insist on the irrelevance of electric energy use as a determinate of economic growth (Romer, 2010). This line of thinking gives support to the *neutral* and *conservation hypotheses*. Similar to the

Solow growth model, the endogenous growth theory deduct that the role of energy is negligible in economic development. Contrary to the Solow growth theory, this model explains technological change within its framework. That is, it maintains the premise of the Solow growth model including the role of energy in economic growth except for the explanation of the technological change (Mankiw, 2001).

On the other hand, non-Neoclassical growth theories such as the biophysical, ecological, and natural resource economics and physical theory refute the irrelevance of energy as a primary factor in economic growth (Mallick, 2007). They argue that the absence of energy constrain social and economic development.More specifically, Biophysical economics begins with a conceptual model that sees the economy connected to, and sustained by, a flow of energy, raw materials, and ecosystem services.It focuses on the central role of energy flows through the economic system and therefore the role that entropy and depletion play in its functioning and prospects. Energy is not the only thing which provides value in an economic system. But it is the master resource without which nothing else gets done (Cobb, 2010). Unlike the Neoclassical models,a variant of Biophysical models treats capital and labour as flows of capital consumption and labour services rather than as stocks (Stern & Cleveland, 2004).Under this model, the analysis of energy and material flows is central to current issues about sustainability, environmental quality, and economic development (Cleveland, 2010). Therefore, this model can be used to analyse the effects of energy use on the environment and the consequential impact on the overall economy.

Contrary to the Neo-classical model that assumes that prices including energy prices are fixed in the long run, changes in the price of oil and electricity can have adverse effect on the economic prospects of a country (Mallick, 2007). As shown earlier, the oil supply shocks of 1970s greatly influenced direction of the Zambian and the global economy. Therefore, many economists are rethinking their earlier stance on the irrelevance of energy as a factor in economic growth models. However, most of them are ecological economists and not mainstream (Stern, 2004). This school of thought gives support to the *feedback and growth hypothesis*. Ecological economics models draws on the tenets of Biophysical economics. Many ecological economists have a fundamentally different version of the economic process than that presented in neoclassical economics. Mainstream growth theory focuses on institutional limits to growth. When mainstream economists address the technical limits to growth they tend to not take these possible constraints very seriously. Ecological economists tend instead to focus on the material basis of the economy. The criticism of mainstream growth theory focuses on limits to substitution and limits to technological progress as ways of mitigating the scarcity of resources. If these two processes are limited then limited resources or excessive environmental impacts may restrict growth (Cleveland, 2010).To this end, energy use should be considered as a significant factor in sustaining and achieving higher economic growth.

2.3.0: Empirical Literature Review

As earlier discussed, there are no country-specific studies in existence that have been conducted to ascertain the causal relationship between electricity consumption per capita and economic growth in Zambia. Presently, there are only five cross-country studies on Zambia (Wolde-Rufael 2005, 2006, 2009; Nondo, 2012; Bildirici 2013). However, there are a lot of studies on the subject outside Zambia. Studies on the electricity-growth nexus highlights the importance of investment and environment in the energy sector. For example, in Zambia, there is need to optimise the level of investment and preserving the environment in addressing the electric energy poverty. Furthermore, as will be evidenced in literature, the employment of energy efficiency strategies and adequate investments on both the demand and supply side can reduce effect of load shedding or power blackouts (Shahbaz, 2011;Yoo, 2005; Wolde-Rufael, 2005, 2006, 2009).

Among the first researchers to ascertain the nexus between economic growth and energy consumption were (Kraft and Kraft, 1978; Akarca and Long, 1980; Yu and Hwang, 1984). More recent studies include (Zhang and Cheng, 2009; Belloumi, 2009; Soytas and Sari, 2009; Nondo, 2012; Bildirici, 2013). It is important to recall that the results in literature are mixed and inconclusive. The direction of the causal relationship between electricity consumption and economic growth could be categorized into four types; each of which has important implications for energy policy (Ozturk, 2009). In case of country specific and panel studies surveyed, some found that there was a one-way causality from economic growth to electricity consumption called the *conservation hypothesis* (Chen, 2007; Shahbaz, 2011; Bildirici, 2013; Yoo, 2005; Yoo, 2006; Jumbe, 2004) while others estimated a one-way causality from electricity consumption to economic growth referred to as the *growth hypothesis* (Chen, 2007; Bellouni, 2009; Kouakou, 2006; Bildirici, 2013). Another camp observed a two-way causality. That is, electricity consumption and economic growth complement each other known as the *feedback hypothesis* (Chen, 2007; Yoo, 2006; Shahbaz, 2011; Kouakou, 2006; Jumbe, 2004, Nondo, 2012; Bildirici, 2013). The last case is where there is no causal relationship at all between these two variables (Chen, 2007; Bildirici, 2013).

The conflicting results are attributed to differences in the econometric methodologies, different data sets employed by various studies and different country characteristics (Ozturk, 2009). For country specific studies, Payne (2010) estimated that in literature 31 percent supported the neutrality hypothesis; 28 percent the conservation hypothesis; 23 percent the growth hypothesis; and 18 percent the feedback hypothesis. However, the causality in the same country may differ in the short-run from its long-run one. Thus this paper will help in establishing the causality between electricity consumption and economic growth in Zambia.

2.3.1: Studies outside Zambia and Africa

2.3.1.1: Cross Country Studies

Chen (2007) estimated the relationships between GDP and electricity consumption in 10 Asian countries using both single data sets and panel data procedures. The results in these 10 Asian countries were mixed. The results of the panel causality tests indicated that a bi-directional long-run causality exists between electricity consumption and economic growth and that a uni-directional short-run causality runs from economic growth to electricity consumption, while the reverse relationship was not found to exist. The panel results of long-run causality showed that an expansion in real GDP increased electricity consumption. The findings on the long-run relationship indicate that a sufficiently large supply of electricity can ensure a higher level of economic growth. Furthermore, he suggested that to avoid giving rise to an adverse effect on economic growth, these Asian countries must make the necessary efforts to increase their investment in electricity infrastructure, and enforce electricity conservation policies to reduce the unnecessary wastage of electricity.

Yoo (2006) using time-series data for the period 1971 to 2002 investigated the causal relationship between electricity consumption and economic growth in Indonesia, Malaysia, Singapore, and Thailand. He found a bi-directional causality between electricity consumption and economic growth in Malaysia and Singapore. This implies that electricity consumption and real GDP reinforce each other. In order not to adversely affect economic growth, he suggested that government and industry must be encouraged to increase electricity supply investment and overcome the constraints on electricity consumption. On the contrary, a one-way causality was established running from economic growth to electricity consumption in Indonesia and Thailand and not the other way round. He concluded that energy conservation policies can be implemented without any adverse effects on economic growth in these two countries. Put differently, strategies that reduce the use or wastage of electric energy can be employed at both household and national level without having any negative effects on these economies.

2.3.1.2: Country Specific Studies

As earlier noted Chen (2007), also carried out causality test for a single country data set. Results reveal that in Hong Kong and Korea, a long-run causality was found to run from real GDP to electricity consumption, but without feedback effects. In Indonesia, on the contrary, there was a uni-directional long-run causality from electricity consumption to real GDP. In India, Singapore, Taiwan and Thailand, evidence showed that there was no long-run causality between real GDP and electricity consumption. A uni-directional short-run causality was however found in the case of Hong Kong, India and Singapore. Furthermore, there was no evidence of a two-way causality in the short-run in Indonesia, Korea, Taiwan and Thailand. However, the causal relationship in China was not clear. Lastly, there was a causality running from economic growth to electricity consumption in Malaysia and the Philippines.

A study by Yoo et al (2005) in Indonesia investigated the causal relationship between electricity generation and economic growth by using time-series data between 1971 and 2002. The unit root and co-integration tests were applied before Granger's-causality tests and several models were estimated to test for the direction of Granger-causality. The results of the study showed that uni-directional or one-way causality running from economic growth to electricity exists. However, there was no feedback effect. That is, there was no causality running from electricity consumption to economic growth. Thus due to load shedding it was suggested that Indonesia required large-scale investment to be injected in the electricity sector. Furthermore, through rationalizing the tariff structure, efficiency improvement and demand side management can be initiated without inflicting damaging effects on the economic growth of the country.

Shahbaz et al (2011) re-examined the relationship among these variables; electricity consumption, economic growth, and employment in Portugal. This study covered the sample period from 1971 to 2009 using the co-integration and Granger causality frameworks. The findings suggested that there was a unidirectional short-run causality running from economic growth to electricity consumption, while there was a bi-directional causality in the long-run. Thus in the short-run environmental friendly policies which aim to reduce the wastage of electricity cannot adversely affect the economic activity. However, the continuous electricity conservation policies may weaken the process of economic growth and development for the economy in the long-run.

2.3.2: Studies on Zambia and Africa

2.3.2.1: Cross Country Studies

Wolde-Rufael (2006), sought to investigate the causal relationship between per capita electricity consumption and per capita real GDP in about 17 African countries including Zambia. He adopted the ARDL (1999) and Toda-Yamamoto (1995) Approach for Granger Causality Test by using annual time series data between 1971 and 2001. The ARDL results showed that there was evidence of a long run relationship between electricity consumption and economic growth for only9 countries. More specifically, there was a positive causality in Cameroon, Morocco and Nigeria which indicated that energy consumption acted as a stimulus to economic growth running from energy use to economic growth. For the Toda-Yamamoto (1995), only 12 out of 17 countries indicated presence of causality. In particular, there was positive long run causality from economic growth to electricity consumption for 6 countries which included Zambia. For 3 countries there was an opposite causality running from electricity consumption to economic growth, while Bi-directional causality was detected for 3 other countries. In Gabon, the results revealed a negative bi-directional causality. He argued that the negative relationship could have been due to the very low level of energy efficiency and suggested that increasing the efficiency of electricity supply and utilisation should be a priority for social and economic development.

Bildirici (2013), investigated the causality between economic growth and electricity consumption in 10 African countries and Guatemala. These African countries included Cameroon, Cote d’Ivoire, Congo, Ethiopia, Gabon, Ghana, Kenya, Senegal, Togo and Zambia for the period 1970-2010. The paper employed the ARDL (1999) or bounds testing approach and Vector Error-Correction Model (VECM) using panel data. The data was sourced from World Bank World Development Indicators, IEA, OECD and U.S. Energy Information

Administration. The results showed that in the long run, there was bi-directional causality in all the countries except for Cameroon in which the causality was neutral. The results reveal income elasticities of electricity consumption; electricity consumption is a luxury good for Gabon and Guatemala, necessity good or Engel's good for Senegal and inferior good for Zambia. Furthermore, in the short-run, it was discovered that in Zambia and Senegal the causality run from economic growth to electricity consumption. This implies that conservation polies can be implemented without having any adverse effects on the economy or economic growth.

Nondo et al (2012), employed a panel Granger causality test to explore the causality relationship between energy consumption and GDP in COMESA from 1980 to 2005. For a panel of all 19 member states of COMESA, the paper established that there was no short-run transitory relationship between GDP and energy consumption, but in the long-run, there was a long-run bidirectional relationship between energy consumption and GDP. The study concluded that that energy is an important input in the production system; this suggests that low access to energy in COMESA member countries may constrain growth prospects. As a consequence, they suggested that policymakers should focus on developing policy frameworks that are aimed at stimulating economic growth and increasing energy accessibility for COMESA member countries. Furthermore, in an effort to address the energy poverty problem, COMESA countries should harmonize and coordinate energy policies within the context of regional economic integration.

2.3.2.2: Country Specific Studies

Jumbe (2004) investigated the causality between electricity consumption, and overall GDP, agricultural GDP (AGDP) and non-agricultural GDP (NGDP) in Malawi. He utilised annual time series data from 1970 to 1999 and Standard Granger Causality (GC) test, and the Error Correction Model (ECM). He found, based on the Granger causality test, that there exist a bi-directional causality between GDP and electricity consumption. The error correction model, however, showed a uni-directional relationship running from GDP to electricity consumption.

Kouakou (2006) examined the causal relationship between the electric power industry and the economic growth of Cote d'Ivoire. The paper employed annual data between 1971 and 2008 whilst the normal Granger causality tests were performed within the Error Correction Model. The result revealed a two-way relation or causality between per capita electricity consumption and per capita GDP in the short-run. Conversely in the long run, there was evidence of causality running from electricity consumption to economic growth. In other words, a shortfall in the supply of power supplies will certainly result in reduced economic activity.

Belloumi (2009) discovered a one way causality from energy consumption to gross domestic product (GDP) in the short-run. This study employed the Johansen co-integration technique to examine the causal relationship between per capita gross energy consumption (PCEC) and per capita gross domestic product (PCGDP) for Tunisia during the 1971 to 2004 period. In order to test for Granger Causality a Vector Error Correction Model (VECM) was employed.

A study by Ankilo (2009), investigated the causality relationship between electricity consumption and economic growth for Nigeria during the period 1980–2006. This paper used a cointegration model and co-feature analysis to establish the causality between electricity consumption and economic growth. The results indicated that there was cointegration between the variables and that a unidirectional from electricity consumption to real gross domestic product existed. The test of the Hendrick–Prescott filtered series shows that there existed not only co-trend but also co-feature relationship between electricity consumption and economic growth. The paper suggests that investing more and reducing inefficiency in the supply and use of electricity can further stimulate economic growth in Nigeria. However, it was argued that results of the study be interpreted with caution because of the possibility of loss in power associated with the small sample size and the danger of omitted variable bias due to a bi-variate model.

CHAPTER THREE

3.0: RESEARCH METHODOLOGY

3.1.1: Research Design

The aim of this paper is to investigate the causality between economic growth and electricity consumption in Zambia from 1971 to 2013 by employing a classical or traditional regression methodology. That is, it employed an analytical quantitative approach within the confines of a non-experimental design.

3.1.2: Empirical Framework

To investigate the causal relationship between electricity consumption and economic growth, we adopted an empirical model used by Lorde (2010). In this model capital, labour, and energy, and technology were used as separate inputs in a conventional neo-classical one-sector aggregate production function. The model was fitted as follows:

$$Y = AK^{\alpha}L^{\beta}E^{\gamma} \quad \ldots\ldots \quad (1)$$

Where Y is aggregate output; A denotes the level of technology; K is the physical capital stock; L is the labour; and E is energy consumption. Taking the logarithmic time derivative of Eq. (1), the model takes on the form:

$$\dot{Y}_t = \dot{A} + \alpha\dot{K} + \beta\dot{L} + \gamma\dot{E} \quad \ldots\ldots \quad (2)$$

The dot above a variable indicates that it is now in growth form. The constant parameters α, β, and γ are the elasticities of output with respect to capital, labour and energy, respectively (Lorde, et al., 2010). However, due to data constraints for the Zambian economy the model will take on the following form. In particular, our preferred model, the ARDL could not stabilise due to the different order of integration among our variables of interest. The proxy for capital, gross fixed capital formation only becomes stationary at second difference. In such a case, the ARDL is ruled out. To use the Johansen Maximum Likelihood Procedure, the proxy for capital has to be dropped as it requires the same order of integration among the variables (Shahbaz, et al., 2011). Furthermore, the use of Labour Force as a proxy for Labour introduces serial correlation into the model, and has a different order of integration from electricity consumption per capita and per capita GDP. Therefore, the model only becomes dynamically stable only when two variables, electricity consumption and per capita GDP are utilised.

$$\dot{Y}_t = \gamma \dot{E} \quad \ldots\ldots (3)$$

Where $\dot{Y}_t$ and $\dot{E}$ are growth rates of per capita gross domestic product and electricity consumption respectively. This is what is referred to as a Bivariate Model employed by Ankilo (2009), Jamil (2010), Bildirici (2013), Wolde-Rufael (2006), and Nondo et al (2012).

3.1.3: Data Sources

This paper employed annual time series data for the period 1971 to 2013. The dataset used was sourced from the World Bank, World Development Indicators 2015. This metadata was downloaded from the World Bank website compiled by IEA Statistics © OECD/IEA 2015, subject to IEA terms and conditions.

3.1.4: Data Collection Techniques

The metadata was easily downloadable from the World Bank website.

3.1.5: Issues of Reliability and Validity

Most dataset on economic variables in developing countries like Zambia tend to be incomplete and not reflective. This may therefore affect the validity of our findings. Wolde-Rufael (2005) argues that the dataset he employed in 19 African countries in examining the causality between energy use and economic growth did not adequately reflect the level of energy used. This might also be the case for our empirical study on Zambia.

3.1.6: Definitions of key terms, concepts and variables

This study used data from the World Bank; corresponding to annual observations and covered the period 1971 to 2013. All variables were transformed into their natural log for analysis to avoid problems of heteroscedasticity (Jamil 2010). It is important to note that National accounts data were rebased to reflect the January 1, 2013, introduction of the new Zambian kwacha at a rate of 1,000 old kwacha = 1 new kwacha. Zambia reports using SNA 2008 (World Bank, 2015).

Table 1: Definition of Variables

Variable	Definition	Units
The end-use electricity consumption is denoted by $\boldsymbol{PCEC_t}$	The World Bank defines electricity consumption per capita as a measure of the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.	measured in kilowatts (KWh) per capita
The natural logarithm of real Gross Domestic Product per capita($\boldsymbol{PCGDP_t}$) was used as a proxy for economic growth denoted by**,** $\boldsymbol{LPCGDP_t}$	$PCGDP_t$ defined as GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.	Data are in constant 2010 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates

CHAPTER FOUR

4.0: DATA MANAGEMENT

4.1.0: Type of Data Analysis and Transformations

In this paper, we employed the following statistical packages, Microsoft-Excel, E-views 9 and Stata-13. The data was entered directly into excel, and all necessary adjustment were made to the data and thereafter transferred to Stata-13 and E-views 9 for analysis. However, the main statistical package for this paper was E-views.

4.1.1: Modelling

In this study, a bivariate model was employed to ascertain the economic growth–electricity consumption nexus in Zambia. As one of the most famous techniques in literature, the Johansen maximum likelihood approach was adopted (Shahbaz, et al., 2011). To start with, the stationarity of all the variables was tested to avoid spurious regression results that are associated with the use of time-series data. Similar to (Jamil & Eatzaz, 2010), the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests have been employed to identify the order of integration of each series as specified in the following equation:

$$\Delta y_t = \beta_0 + \delta y_{t-1} + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + \ \dots . + \gamma_p \Delta y_{t-p} + u_t \ \dots\dots\dots\dots\dots\dots\dots\dots \ (4)$$

Source: (Jamil & Eatzaz, 2010)

Where Δ and $u_t$are the first difference operator and the white noise term respectively. Similarly,y_t represents a series. Sufficient lags are included in the order to whiten the errors. The optimum number of lags was chosen using Akaike Information Criterion (AIC) after testing for first and higher order serial correlation in the residuals. The null hypothesis that was tested in Eq. (4) is that δ is equal to zero against the one-tailed alternative that it is negative. If δ is found to be significantly negative, the stationarity of y_t cannot be rejected.

In the next step, we investigated whether the two series are co-integrated; that is, whether a linear combination of the two non-stationary series is stationary. The concept of co-integration can be defined as a systematic co-movement among the two or more economic variables over the long-run. That is, whether a linear combination of the two non-stationary series is stationary. The co-integration methodology was used to help correct for any non-stationary problem that was encountered in the time series data employed in this paper. According to Jamil (2010), modelling relationships among non-stationary variables essentially require their differencing to induce stationarity. Since most of the economic long-run relationships are lost in their differences, there was need to conserve the long-run information contained in level variables and at the same time avoid spurious regressions.

The Johansen Maximum likelihood was used for co-integration. Under this technique the same order of integration is required for finding a long-run relationship among the variables (Shahbaz, et al., 2011). Johansen maximum likelihood procedure to cointegration provides two likelihood ratio (LR) tests based on trace statistic and maximum eigenvalue statistic. Although co-integration confirms the existence of Granger causality, it does not point out its direction. The vector error correction model (VECM) is therefore, specified to detect the direction of causality in the co-integrated vectors (Jamil & Eatzaz, 2010). Since the series were cointegrated, the Granger causality relation was specified as a VECM. The advantage of using an error correction model to test for causality is that it allows testing for short-run causality through the lagged difference explanatory variables and for long-run causality through the lagged $ECT_{r,\ t-1}$term (Bildirici, 2013). The VECM in two variables can be written as follows:

$$\Delta LPCEC_t = \alpha_1 + \sum_{i=1}^{l} \beta_{1i} LPCEC_{t-1} + \sum_{i=1}^{m} \gamma_{1i} \Delta LPCGDP_{t-1} + \phi_1 ECT_{r,\ t-1} + u_{1t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5a)}$$

$$\Delta LPCGDP_t = \alpha_2 + \sum_{i=1}^{l} \beta_{2i} LPCEC_{t-1} + \sum_{i=1}^{m} \gamma_{2i} \Delta LPCGDP_{t-1} + \phi_2 ECT_{r,\ t-1} + u_{2t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6a)}$$

Source: (Jamil & Eatzaz, 2010)

Where;

- $LPCEC_t$ represents the growth of electricity consumption per capita,
- $LPCGDP_t$ representsthe growth of real gross domestic product per capita,
- $u_{i,t}$ (for i=1, 2) are serially uncorrelated random error terms.
- $ECT_{r,\ t-1}$denotes an error correction term, represents a cointegrating vector
- ϕ_i, represents an adjustment coefficients showing how much disequilibrium is corrected.

The deviation from long-run equilibrium is gradually corrected through series of adjustments. The size and statistical significance of ECT is a measure of the extent to which the left hand side variable in each equation returns in each short-run period to its long-run equilibrium response to random shocks. Thus the error correction model through the ECT, brings in another channel for identification of Granger causality.

According to Binh (2011), equation (5a) and (6a) could include dummy variables in order to take into account the existence of the possible structural breaks during the study sample. He argues further that it is necessary to employ non-linear techniques for testing co-integration if the economic data has structural breaks such as the threshold cointegration test proposed by Gregory and Hansen (1996). This is because the Johansen cointegration has a tendency of rejecting the hypothesis of cointegration. Taking the first difference of the series with structural breaks to achieve stationarity may lead to spurious results. That is, in the presence of structural breaks stationarity can only be obtained by detrending the series by taking the estimated breakpoints into considerations through a proper VECM as follows:

$$\Delta LPCEC_t = \alpha_1 + \alpha_2 T + \sum_{i=1}^{l} \beta_{1i}\, LPCEC_{t-1} + \sum_{i=1}^{m} \gamma_{1i}\, \Delta LPCGDP_{t-1} + \phi_1 ECT_{1,\ t-1} + u_{1t} \quad \ldots\ldots\ldots\ldots \text{(5b)}$$

$$\Delta LPCGDP_t = \alpha_3 + \alpha_4 T + \sum_{i=1}^{l} \beta_{2i}\, LPCEC_{t-1} + \sum_{i=1}^{m} \gamma_{2i}\, \Delta LPCGDP_{t-1} + \phi_2 ECT_{2,\ t-1} + u_{2t} \ldots\ldots\ldots\ldots \text{(6b)}$$

Source: (Binh, 2011)

Where, $ECT_{1,\ t-1}$, and $ECT_{2,\ t-1}$ are equilibrium errors lagged one period, obtained from the threshold co-integrating equations. Equation (5b) and (6b) can be estimated using the OLS since all the variables are stationary.

4.1.2: Estimation and Statistics

The causation from $LPCGDP_t$ to $LPCEC_t$ was tested using Eq. (5a). Causality from $LPCEC_t$ to $LPCGDP_t$was tested likewise using Eq (6a). As discussed earlier, although cointegration indicates the presence of causality, it does not point the direction of causality among the variables. Granger causality will be examined in two ways in this paper. Firstly, short run or weak Granger causalities are tested by $H_O: \gamma_{1i} = 0$ and $H_O: \beta_{2i} = 0$ in Eq. (5a) and (6a). Second, long run Granger causalities are tested from the $ECT_{r,\ t-1}$ in those equations. Long-run causalities are tested by $H_O: \phi_1 = 0$ and $H_O: \phi_2 = 0$.

CHAPTER FIVE

5.0: DATA ANALYSIS AND DISCUSSION OF RESULTS

5.1: Introduction

This section illustrates the descriptive characteristic of our annual time series, and thereafter discusses the causal relationship between the two series. The descriptive part highlights salient statistical features of the series.

5.2: Descriptive Statistics

The logarithmic per capita gross domestic product (LPCGDP), and logarithmic per capita electricity consumption (LPCEC) are our variables of concern. Table 2 presents some key summary statistics for these two annual time series variables.

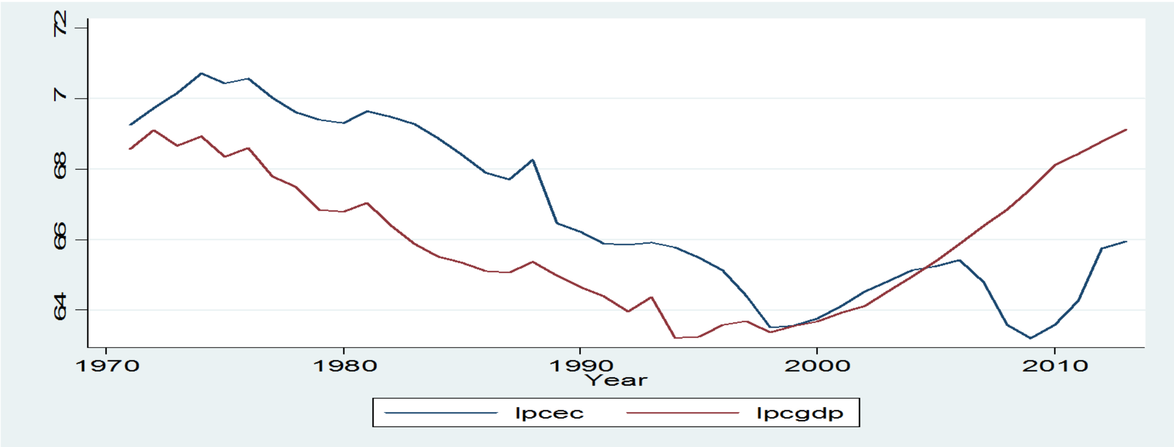
Table 2: Summary Statistics

Variable	LPCGDP	LPCEC
Mean	6.599116	6.677374
Median	6.551677	6.591694
Maximum	6.912459	7.072255
Minimum	6.321609	6.320986
Std. Dev.	0.191737	0.242271
Skewness	0.206484	0.195203
Kurtosis	1.695215	1.567563
Jarque-Bera	3.355805	3.949356
Jarque-B Prob*	0.186765	0.138806
Sum	283.7620	287.1271
SumSq. Dev	1.544047	2.465193
Observations	43	43

The summary statistics above reveal some key characteristics of the variables. With over 30 observations, the dataset is large enough for making inferences as regards to the general operation of the economy. In particular, there are 43 annual observations ranging from 1971 to 2013. As discussed earlier, the choice of the period of study was dependent on the availability of data from our only source, the World Bank. Since the two variables have significantly non-zero standard deviations our estimates will be efficient. It can also be observed from the Jarque-B probability value that our time series is normally distributed.

Figure 3 below shows the evolution of real GDP per capita (LPCGDP) and electricity consumption per capita (LPCEC) from 1971 to 2013. It can be observed that both economic growth and electricity consumption in the middle 1970s embarked on a downward trend not until the late 1990s. The two series exhibited an upward trend after 1998. However, it can be observed that between 2007 and 2008, electricity consumption drastically falls reflecting the onset of load shedding or electric power blackouts in Zambia.

Figure 3: Evolution of LPCGDP and LPCEC



5.3: Analysis and Results

5.3.1: Unit Root Test

The Augmented Dickey Fuller (ADF) and Phillips-Perron testing methodologies were employed to test for the presence of unit root in our series of interest at 5 percent level of significance. Both tests were conducted by considering a deterministic linear trend and a constant. Table 3 and Table 4 summaries the results as shown below, as is normally the case, the two series are non-stationary, I(0), at level, but become stationary after first difference, I(1).

Table 3: ADF Unit Root Test Results

Variable	*P-value: Level*	*P-value: First Difference*	*Significant lag Based on AIC*	*Order of Integration*
1. LPCGDP	0.9998	.0000***	0	I (1)
2. LPCEC	0.7656	0.0041***	1	I (1)

Note: The optimum lag lengths are determined using Akaike's Information Criterion. The P-values are calculated under the null hypothesis of nonstationarity. The asterisk *** denotes significance at 1 percent.

Table 4: PP Unit Root Test Results

Variable	*P-value: Level*	*P-value: First Difference*	*Order of Integration*
1. LPCGDP	0.9999	0.0000***	I (1)
2. LPCEC	0.8996	0.0047***	I (1)

Note: The optimum lag lengths are determined using Akaike's Information Criterion. The P-values are calculated under the null hypothesis of nonstationarity. The asterisk *** denotes significance at1 percent.

The Zivot and Andrews (1992) null hypothesis is that the series has a unit root against an alternative that the series has trend stationary process with a structural break. The results of the Zivot and Andrews test are presented in table 5 where it has been demonstrated that the series has trend stationary process with structural break at first difference. Put simply, LPCEC and LPCGDP becomes stationary, I (1) at first difference with a break.

Table 5: Zivot and Andrews Unit Root Test Results

Variable	*t-Statistic: Level*	*t-Statistic: First Difference*	*Order of Integration*
1. LPCGDP	-0.792 (0)	-8.947 (0) ***	I (1)
2. LPCEC	-3.693 (1)	-5.105 (0) **	I (1)
1% Critical Value	-5.34	-5.34	
5% Critical Value	-4.80	-4.80	
10% Critical Value	-4.58	-4.58	

Note: The numbers in parentheses are the lag order. The lag parameters are selected based on AIC. ***and ** indicate significance at the 1% and 5% levels respectively.

5.3.2: Cointegration Test Results

Before employing the Johansen test of co-integration, the number of lags to be included in the model should be determined. The Akaike Information Criterion was used to estimate an optimal number of lag of 1. The number of co-integrating vectors is denoted by r based on two testing systems, the trace and maximum eigen value. Both tests indicated the existence of a co-integrating relationship between LPCEC and LPCGDP at respective levels of significance. If the test statistic is greater than the critical value at a given significance level, we can reject the null hypothesis, and vice versa. The Johansen co-integration model uses the intercept, but no trend in the test. Table 6 shows that the null hypothesis of no co-integration can be rejected, but we fail to reject the alternative of one co-integrating relationship between the LPCEC and LPCGDP at 5 percent significance. That is, both the trace and maximum eigen values are below the 5 percent level of significance. The co-integrating equation shown in Table 7 indicates that electricity consumption and economic growth are positively related. The normalized cointegrating coefficient is 0.688 and it is significant as shown by the *p-value* in parentheses. Therefore, we can conclude that there is a long run positive relationship between electricity consumption and economic growth in Zambia.

Table 6: Johansen Cointegration Results

	Null Hypothesis	**Trace Statistics (trace)**	**05% Critical Value**	**Max Eigen Value Statistics (eigen)**	**05% Critical value**
Electricity Consumption and Economic growth rate	$r = 0$	25.97258	15.41	23.46931	14.07
	$r \leq 1$	2.503278**	3.76	2.503278**	3.76

Note: ** indicates we fail to reject the null hypothesis at 5 percent level of significance

Table 7: Estimates of Cointegration Vector

LPCEC	**LPCGDP**
1.00	0.688 (0.000)***

Note: p-value is in parentheses. ***, **, and * Indicates significance at 1, 5 and 10 percent level

5.3.3: Vector Error Correction Model

Given the presence of a co-integrating equation between the variables, an error correction model was estimated as can be illustrated by equation (7) and (8) for per capita electricity consumption and per capita gross domestic product respectively as outlined below. As mentioned earlier, the optimum number of lags was calculated using the Akaike Information Criteria (AIC). According to the Criterion, the optimum lag length is 1. Using the lag of 1, it was noted that only the coefficient of $\mathrm{ECTt}-1$ in equation (7) is negative and significant. As such, it confirms the long-run relationship in the model between our variables of interest. On the other hand, equation (8) is significant but the sign of $\mathrm{ECTt}-1$ is contrary to the expected sign, it is positive (see Appendix). In other words, it does not confirm the long run causal relationship from electricity consumption to economic growth.

$$\mathbf{D(LPCEC) = -0.005441 + 0.411280 * D\big(LPCEC(-1)\big) - 0.509889 * D\big(LPCGDP(-1)\big) - 0.15216 * ECTt - 1}$$

…………..……………………………….………..…….(7)

$$\mathbf{D(LPCGDP) = 0.000596233671334 - 0.240767356281 * D(LPCGDP(-1)) + 0.0515793065947 * D(LPCEC(-1)) + 0.109547846106 * ECTt - 1}$$

……………………………….……………………….. (8)

It can be noted from Table 8 that there is a unidirectional causal relation from the growth of per capita gross domestic product to the growth of the per capita electricity consumption in the long run. Similarly, the growth of the per capita gross domestic product Granger causes the growth of the per capita electricity consumption in the short run. However, we fail to reject the null hypothesis that economic growth does not Granger cause growth of electricity consumption per capita in the short run. That is, the long run causal relationship from the growth of the per capita electricity consumption to economic growth cannot be accepted despite being statistically significate. As discussed earlier, the coefficient of the error correction term is positive.

Table 8: Results of Granger causality tests based on the VECM

Null Hypothesis	Sources of Causation				
	Short run		Long run	Joint(Longrun/Shortrun)	
	$\Delta LPCEC$	$\Delta LPCGDP$	ECT_{t-1}	$\Delta LPCEC,$ ECT_{t-1}	$\Delta LPCGDP,$ ECT_{t-1}
	F-statistics		t-statistics	F-statistics	
Economic growth does not cause electricity consumption		4.75786 (0.0358)**	-3.227190 (0.0026)***		5.23584 (0.0099)***
Electricity consumption does not cause economic growth	0.229417 (0.6348)		4.603269 (0.0000)***	10.6112 (0.0002)***	

Note: The value in parentheses represents the associated p-values. ***and ** indicates rejection of the null hypothesis at 1% and 5% significance level

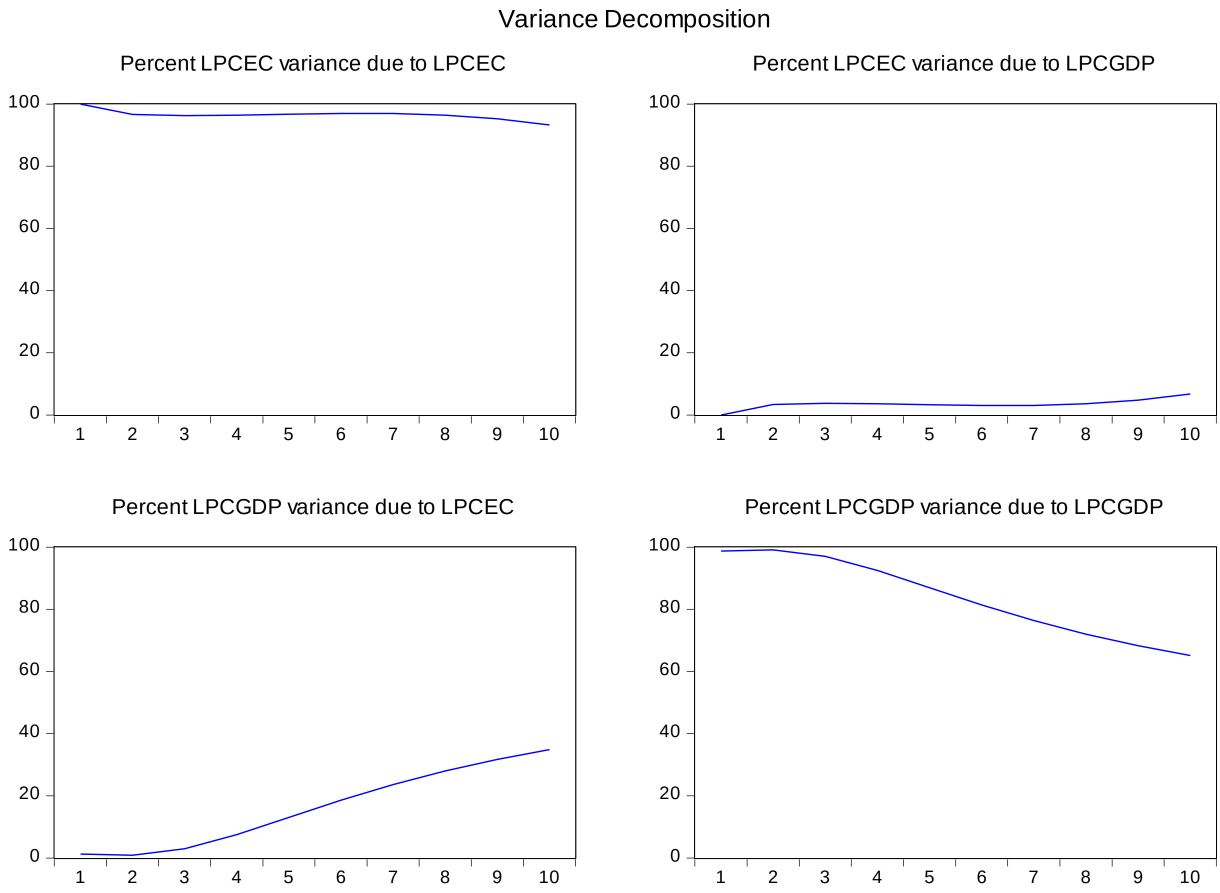
5.3.4: Dynamic Causality Models

5.3.4.1: Variance Decomposition Analysis

The variance decomposition analysis (VDC) can be employed to check for the robustness of our empirical findings. Granger-causality can only test causality within the sample period; therefore we use variance decomposition analysis (VDC) as an out of sample causality test and as a robust analysis of the ECM. The analysis of the dynamic interactions among the variables in the post-sample period is conducted through variance decompositions (VDCs) and impulse response functions (IRFs).The VDC indicates the amount of information each variable contributes to the other variables in the autoregression. It estimates the actual amount by which electricity consumption contributes to economic growth or economic growth to electricity consumption (Akinlo, 2009).

Our results from the VDC and ECM term are consistent in the short run, but not in the long run. Figure 3, shows the variance decomposition of real GDP per capita (LPCGDP) and electricity consumption per capita (LPCEC). In the long run, a shock or an impulse to electricity consumption accounts for more than 30 percent fluctuation to real GDP per capita. However, an innovation in real GDP per capita explains less than 10 percent variation in electricity consumption in the long run. Within a year, a shock to electricity consumption causes a 1.3 percent variation in real GDP per capita. On the contrary, a shock to real GDP per capita does not appear to explain the variation in electricity consumption in the short-run. It can therefore be concluded that the VDC indicates that electricity consumption contributes more to economic growth than economic growth does to electricity consumption. This is contrary to our Granger causality results of a one-way causality from economic growth to electricity consumption. That is, in this dynamic model, evidence indicates a one-way or unidirectional causality from electricity consumption to economic growth in the long run. This implies that the effect of reduced electric energy consumption is more pronounced in the long run than in the short run.

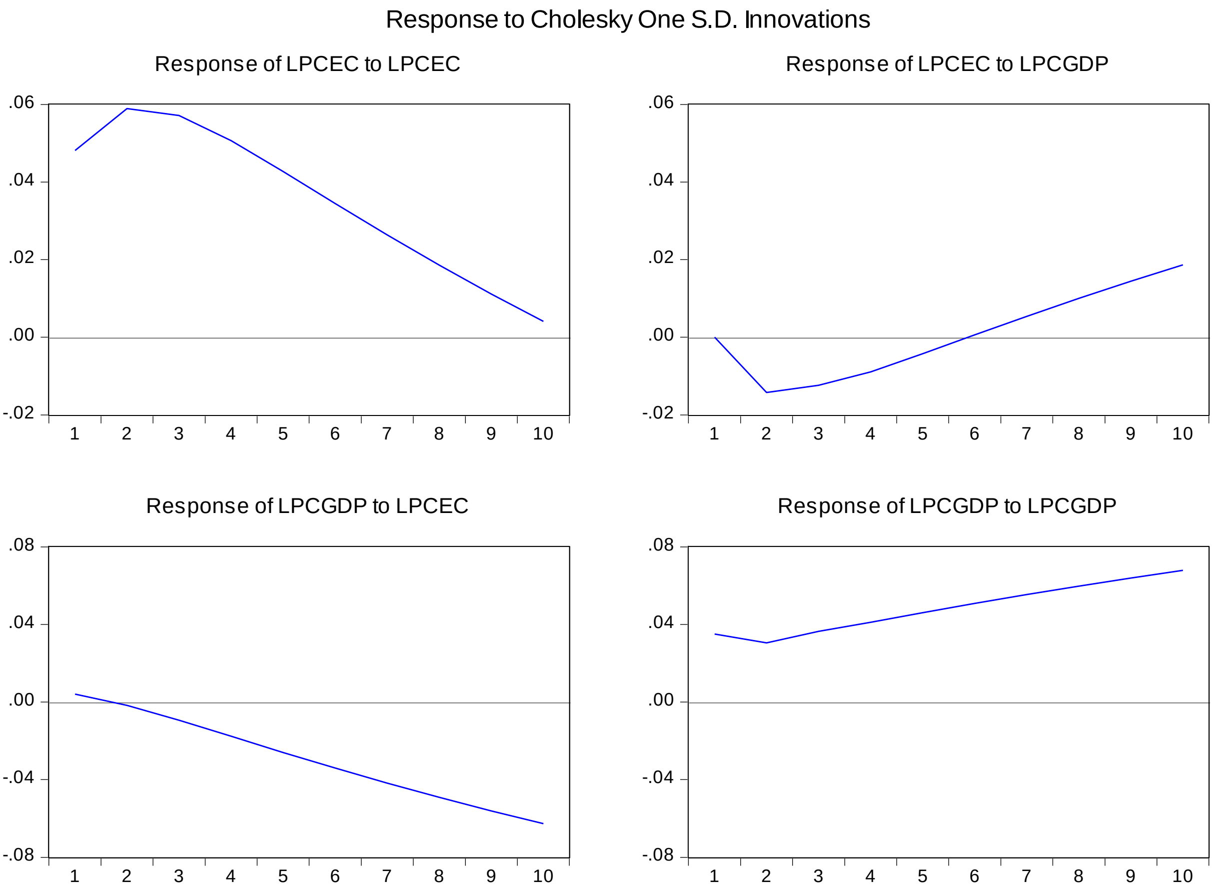
Figure 4: Variance of Decomposition Analysis



5.3.4.2: Impulse Response Functions (IRFs)

An impulse response function traces out the response of the dependent variable in the VAR system to shocks in the error terms. In other words, it traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables (Polemis & Dagoumos, 2013). The IRF derived from the VECM are presented in Figure 5. This diagram reports the response of each variable of the VECM to its own innovation and to the innovations of other variables. From Figure 5 it is evident that the response of electricity consumption to its own innovation is positive, but after year 2 decreases, albeit remaining positive in the long run. The response of electricity consumption to a one standard deviation shock of per capita GDP is negative for the first six years and then becomes positive. That is, it takes approximately 6 years for electricity consumption to normalise after an upswing in economic activities. Increased economic activities lead to an onset of power blackouts as the demand for electricity outstrips supply. In the first 2 years the problem of electric power blackouts worsens, before it starts reducing in severity. At year 6 the demand for electricity starts to increase.

Figure 5: Impulse Response Functions



5.3.5: Diagnostic and Stability Tests

The robustness and validity of the estimated model depends on whether it is free from any statistical problems such as the presence of serial correlation as well as model stability. Table 8 and 9below shows a result summary of various Diagnostic tests. For both models, the LM test for autocorrelation could not reject the null hypothesis of no autocorrelation. Similarly, the test for heteroscedasticity could not reject the assumption of homoscedasticity. However, in model 1 the assumption of normality could not be accepted, but this is not a serious problem because the number of annual observation of 43 is large enough. We also conducted the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM SQ) to assess the stability of the model as shown by Figure 6 and 7 respectively, along with critical bounds at 5 percent significance level. From the figures, the stability of the regression coefficients is established.

Table 9: Summary of Diagnostic Tests for VECM 1

Test for:	***Diagnostic Test***	***Test statistic***	***p-value***	***Conclusion***
Model Significance	F-test significance	F = 5.481578	0.003217	Model is significant
Autocorrelation	Breusch-Godfrey LM	F = 1.383574	0.2641	No Autocorrelation
Heterescedasticity	ARCH	F = 1.962886	0.1693	No Heteroscedasticity
Normality	Jarque-Bera Test	J-B =11.35	0.0034	Residuals are not normal

Note: Conclusions are made at 1% percent level of significance.

Table 10: Summary of Diagnostic Tests for VECM 2

Test for:	***Diagnostic Test***	***Test statistic***	***p-value***	***Conclusion***
Model Significance	F-test significance	F =8.271750	0.000245	Model is significant
Autocorrelation	Breusch-Godfrey LM	F = 0.571924	0.5696	No Autocorrelation
Heteroscedasticity	ARCH	F = 0.195904	0.6606	No Heteroscedasticity
Normality	Jarque-Bera Test	J-B =1.754675	0.415889	Residuals are normal

Figure 6: CUSUM test

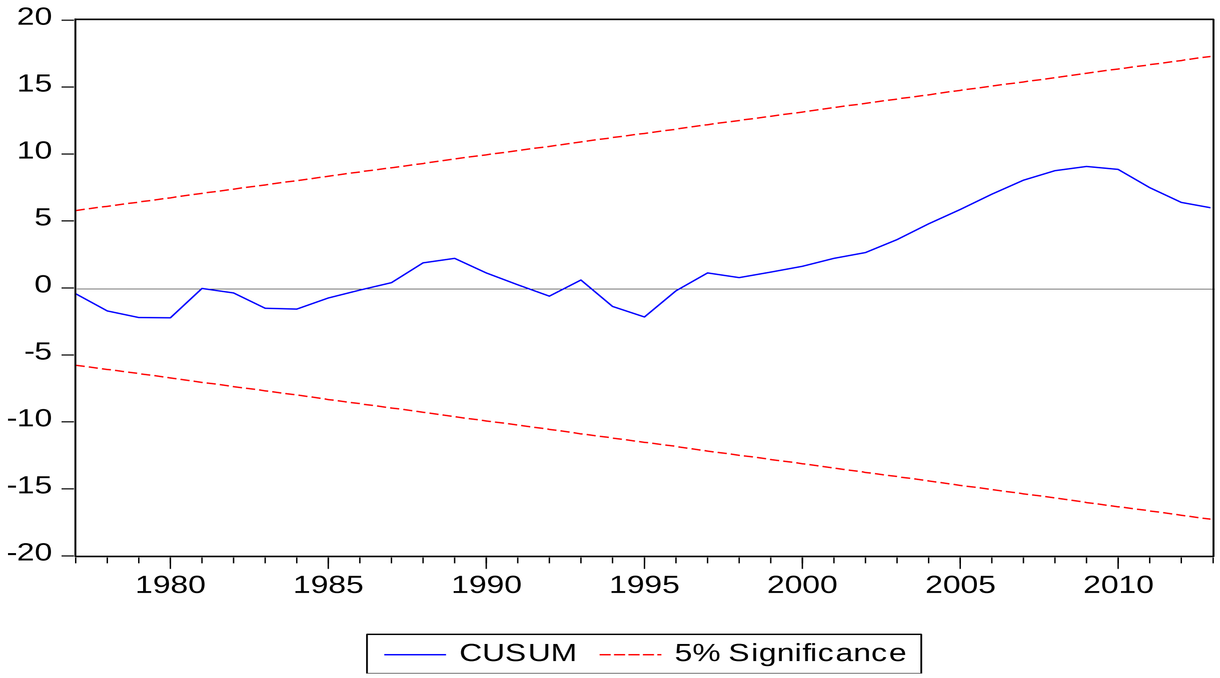


Figure 6: plot of cumulative sum of residuals. The straight lines represent critical bounds at 5% significant level.

Figure 7: CUSUM Squares test

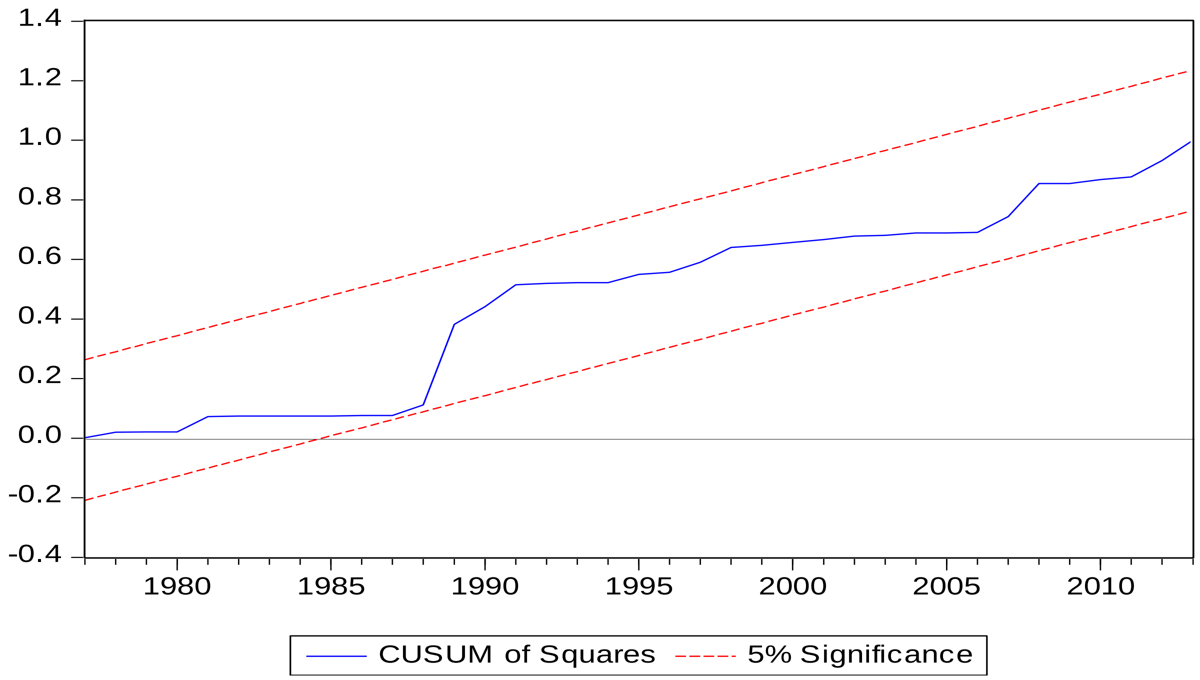


Figure 7: Plot of cumulative sum of squares residuals. The straight lines represent critical bounds at 5% significant level.

Table 11 and Table 12 both show that the estimated VECM model is valid with regard to the presence of structural break. If the VECM has any structural breaks, necessary adjustment are necessary to reflect them. One way to make sure that there are no structural is through the use of tests such as the Quandt-Andrews breakpoint tests. Using the optimal lag length chosen by the Akaike Information Criterion, we established that there are no significant breakpoints in the series. That is, we failed to reject the null hypothesis of no breakpoints within 15 percent trimmed data. Therefore, the causality test based on the error correction model, as shown in Table 8 does not suffer from any problems caused by structural breaks. The results of the Quandt-Andrews breakpoint tests are summarised in Table 11 and Table 12 below.

Table 11: Quandt-Andrews unknown breakpoint results for VECM 1

Dependent Variable	**Statistic**	**Value**	**Prob**
LPCEC	Maximum LR F-statistic (1989)	3.574289***	0.0998
	Maximum Wald F-statistic (1989)	14.29716***	0.0998
	Exp LR F-statistic	0.658559***	0.4022
	Exp Wald F-statistic	4.093863***	0.1265
	Ave LR F-statistic	1.191811***	0.2753
	Ave Wald F-statistic	4.767243***	0.2753

Note: probabilities calculated using Hansen’s (1997) method. *** indicates rejection of null hypothesis at 1 percent level of significance

Table 12: Quandt-Andrews unknown breakpoint results for VECM 2

Dependent Variable	**Statistic**	**Value**	**Prob**
LPCGDP	Maximum LR F-statistic (1989)	3.948333***	0.0586
	Maximum Wald F-statistic (1989)	15.79333***	0.0586
	Exp LR F-statistic	0.958470***	0.1575
	Exp Wald F-statistic	5.453715***	0.0378
	Ave LR F-statistic	1.630453***	0.0965
	Ave Wald F-statistic	6.521814***	0.0965

Note: probabilities calculated using Hansen’s (1997) method. *** indicates rejection of null hypothesis at 1 percent level of significance

Note all three of the summary statistic measures fail to reject the null hypothesis of no structural breaks at the 1% level within the 28 possible dates tested.

5.4: Discussion of Results and Findings

This paper attempted to establish whether economic growth explains electricity consumption or electricity consumption explains economic growth in Zambia over the period 1971 to 2013.In short, the objective of this paper was to establish the causality between economic growth and electricity consumption in Zambia. The empirical analysis in our study began with assessing the stationarity condition of the variables of interest. Results indicated that the null hypothesis of a unit root in the series at level cannot be rejected at a 5 percent level of significance, but both variables become stationary after first difference. Thereafter, it was established that there were no structural breaks and that the model was stable by using the Quandt-Andrews breakpoint and CUSUM tests respectively.

After establishing an order of integration of a unit for both series, I(1), the Johansen Maximum Likelihood Procedure was employed to identify the presence of co-integration. The Akaike Information Criterion (AIC) suggested that a one lag interval be employed in the Johansen testing procedure. The Johansen cointegration test demonstrated presence of one cointegrating equation. This confirmed the existence of one long term relationship between the logarithm of per capita electricity consumption and the logarithm of per capita gross domestic product. As a consequence of the presence of cointegration, estimation of the VECM to establish the direction of causality was paramount. Within the VECM, the short-run and long-run causal relationship were established at different significant levels.

Based on the VECM, a unidirectional causal relationship from economic growth to electricity consumption exists in both the short-run and long-run. On the contrary, the unidirectional causal relationship from electricity consumption to economic growth does not exist. The results from our study are contrary to panel study results by Wolde-Rufael (2005) and Nondo et al (2012), but consistent in the long-run with (Wolde-Rufael 2006; Wolde-Rufael 2009) and in the short-run with Bildirici (2013). An error correction term of -0.152 implies that disequilibrium is restored in the short-run by 15.2 percent every year to achieve long-run equilibrium. Put differently, a disturbance or shock in the model will restore itself or converge to equilibrium by correcting for 15% of disequilibrium every year. Results from this paper imply that the energy *conservation hypothesis* holds for the Zambian economy.

Given our empirical results, the growth of the Zambian economy is less dependent on the development of the electric energy sector ceteris paribus. That is, in promoting environmental sustainability, the government can implement policies that reduce electricity consumption without having any serious negative effects on economic growth. However, in practice the conservation hypothesis cannot hold well in an economy that is experiencing erratic supply of electric energy. In such an environment, the development of the economy should be in tandem with the development of an electric energy sector. This implies that as the economy expands the demand for electricity increases significantly. If the demand for electricity is not met by an equal increase in supply, then this constrains the Zambian economy from expanding further. Therefore, implementation of energy conservation in an economy with power blackouts might prevent a smooth expansion of the economy.

Contrary to our findings, it is generally argued that the prevailing situation is that of a unidirectional causal relationship from electricity consumption to economic growth. That is, the postulated causal relationship supports the *growth hypothesis*. This prevailing notion contradicts our research findings in both the short-run and long-run based on an in-within sample causality testing framework, the VECM. Thus the results may not be very surprising considering the fact that the electric energy poverty is a recent phenomenon in Zambia, but our study period stretches as far back as the 1970s. This implies that our results cannot adequately represent the current inadequate electric energy infrastructure in the country. To account for this limitation, we used an out of sample causality testing framework; the Variance Decomposition Analysis (VDC) and Impulse Response Functions (IRFs).

The findings from the VECM are not consistent with the results from the out of sample causality testing framework. The VDC indicates that electricity consumption contributes more to economic growth in the long run than economic growth does to electricity consumption. To allow for continuity in the overall expansion of the economy, anything that constrains a sustained and higher economic growth path should be removed. The out of sample causality testing framework gives support to the notion that erratic electric supplies have significant negative effects on economic growth in the long run. Holding other things constant, the VDCs forecasts that in a 10 year period a shock to electricity consumption contributes more than 30 percent variations in economic growth, while economic growth contributes about 6 percent to electricity consumption. Thus, Zambia requires continuous large-scale investments in the electric energy infrastructure to prevent further deteriorations in economic fundamentals.

Given an inadequate energy infrastructure, the government can encourage adoption of energy efficiency[1] tools that are closely related to energy conservation[2] strategies. Unlike energy conservation policies that entail an overall reduction in the level of energy consumption, energy efficiency refers to the reduction in the overall use of electric energy to produce the same level of output. Additionally, households can play a significant role in reducing the adverse effect of loading shedding or power blackouts by utilising electricity efficiently (Yoo & Kim, 2005). Such programs can ease infrastructure bottlenecks and impact of temporal power short-falls, as well as improve industrial and commercial competitiveness through reduced operating costs. Even in a pricing regime like that of Zambia, where tariffs do not reflect costs, energy efficiency come out to be a win-win option costs because it saves utilities from acquiring capacity that is much more(Sarkara & Jas, 2010).Rationalizing the tariff structure, electric energy efficiency improvement and demand side management cannot have negative effects on the economic growth, but removes constraints to Zambia's shared growth potential (Yoo & Kim, 2005).

In interpreting the results of this study, it is important to highlight that the majority of Zambians do not have access to electricity as a modern source of energy. At national level, firewood is the most common source of energy for cooking at 50.7 percent. In rural areas, about 85 percent of Zambian use wood as their main energy source of cooking (Central Statistical Office, 2016). To this effect, our study results should be interpreted within the context of a national electricity access rate of 25 percent. Thus these results cannot provide a satisfactory causal explanation of non-electricity dependent sectors such as the agriculture sector in the rural part of the country. However, the Zambian economy is heavily dependent on mining and related mining activities such as smelting and processing of copper and zinc ore which require a lot of electrical energy. More specifically, over 50 percent of the generated electric power is being consumed by the mining sector (Energy Regulation Board, 2014). It can therefore be argued that electricity consumption is a good proxy for energy consumption for the urban and commercial areas of the country. Moreover, access to electricity can be used as a proxy to

[1]*Energy efficiency* is the use of technology that requires less energy to perform the same function. Using a compact fluorescent light bulb that requires less energy rather than using an incandescent bulb to produce the same amount of light is an example of energy efficiency[www.eia.gov].

[2]*Energy conservation* is any behaviour that results in the use of less energy. Turning the lights off when leaving the room and recycling aluminium cans are both ways of conserving energy [www.eia.gov].

measure the quality of life of individuals in the urban areas. Jamil (2010) suggests that increased income enhance the aspiration of people for an improved quality of life and one of the indices of improved quality of life is the per capita electric energy consumption. Therefore, this study can employ electricity consumption as an indicator of access to modern energy sources and thus as a proxy for energy consumption for the urban and commercial sector of the Zambian economy.

CHAPTER SIX

6.0: CONCLUSION, AND POLICY IMPLICATION

6.1: Introduction

This study used a bivariate model to identify the existence of a causal relationship between the growth of per capita electricity consumption and the growth of real per capita gross domestic product over the period 1971 to 2013. In literature, it was established that there is mixed and inconclusive evidence on the causal relationship between electricity consumption and economic growth for Zambia and the world over. Given an inadequate energy infrastructure, results from our study indicate that it is very difficult for policy makers to achieve an optimal balance of energy equity, energy security and environmental sustainability in Zambia. Simply put, an energy conservation policy cannot be implemented without having any adverse effects on the economy.

6.2: Main Findings of the Study

Based on the error correction model, results indicate that there is a long run unidirectional or one-way causality running from economic growth to electricity consumption. Similarly, in the short-run, economic growth causes electricity consumption. However, the unidirectional causal relationship from electricity consumption to economic growth in both the short-run and long-run does not exist. Thus our results give support to the energy *conservation hypothesis*.

An out of sample causality testing framework was fitted to reflect load shedding in the economy. That is, the Variance Decomposition Analysis indicates that a shock to electricity consumption appears to explain more than 30 percent variation in economic growth in the long run. Furthermore, the Impulse Response Function indicates that an upswing in economic activities in the current year engenders a drop in electricity consumption in the first two years, and eventually normalises in the sixth year given a ten year period. These finding supports the *growth hypothesis* and nullifies the neo-classical school of thought that energy is irrelevant as a critical determinant of national output or GDP.

Given an inadequate electric energy infrastructure, there is need to place a greater emphasis on the out of sample causality testing results than the in-sample causality results.

6.3: Policy Implications

Under the error correction term, our results have serious conservation implication for the electric energy sector as the Zambian economy has been deemed less electric energy dependent. The in-sample results indicate that an energy conservation policy can be implemented with little or no adverse effect on the Zambian economy. As discussed earlier, the implication of the findings should be considered within the confines of the current electric energy infrastructure. Put differently, it is absurd to suggest a reduction in electricity consumption when the economy is in critical need of it. That is, one cannot suggest policies that reduce electricity consumption or electricity accessibility when over 70 percent of the people do not have access to electricity and where demand for electricity outstrips supply to both the residential and commercial customers. Against this backdrop, the country should consider electric energy efficiency strategies that reduce the likelihood of electric energy wastage (Shahbaz, et al., 2011).

As shown by the Variance Decomposition Analysis and Impulse Response Functions, this study provides the empirical evidence that an inadequate electric energy sector retards the growth of the Zambian economy. Thus there is need to continue investing in the electric energy sector. In particular, an inadequate electric energy infrastructure is more problematic in the long-run than in the short-run. Given that economic growth is a long-run phenomenon, this should keep our economic policy makers awake at night. To remove constraints to a higher and sustained economic growth, the government should employ everything at its dispose in the short-run to ensure the development of an adequate energy infrastructure. A reliable, and secure supply of electricity will ensure a sustainable and conducive environment for small, medium and large enterprises.

6.4: Limitations of the Study and Recommendations

The study on causality between electricity consumption and economic growth has become important as the debate on energy as an important factor of production rages on among economists. This study has a number of shortcomings that need to be brought to light. Firstly, energy consumption would have been a better variable than electricity consumption, but was unavailable. Secondly, if it was not due to unavailability of more complete variables such as labour and capital, the study would have been more informative, representative and robust in explaining the variation in economic growth. As such, the use of a bivariate model may present some challenges that future research papers should avoid. Furthermore, the electric power generated by standalone or small grind systems being innovated due to the current electric energy poverty such as solar technologies could not be captured. And finally, many developing countries face serious challenges when computing the official statistics for the economy. With this in mind, the level of economic activity recorded by the World Bank may not reflect the true picture of economic activities in Zambia. Moreover, the high use of inefficient traditional energy that is poorly linked to the economy and the weak industrial sector may affect the causality (Wolde-Rufael, 2005). Therefore, the investigation of the linkage between electricity consumption and official GDP may not give reliable results.

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APPENDICES

Appendix A 1

a.)Descriptive Statistics Table

LPCEC	LPCGDP	PCEC	PCGDP
6.926058	6.857664585113525	1018.47101432879	951.1433477993824
6.972694	6.911009	1067.094009755715	1003.258835226738
7.015754	6.866242	1114.046830015703	959.3364021211026
7.072255	6.893323421478271	1178.803569461276	985.6716002686539
7.043939	6.835198	1145.892137233327	930.0128753734228
7.057300567626952	6.860538482666015	1161.305824744166	953.8804338994758
7.002401	6.778978	1099.269212414967	879.1700618775248
6.961531	6.749778	1055.247769935019	853.8694023718332
6.940292	6.68439245223999	1033.072100121919	799.8245657902716
6.931174	6.67965	1023.695601836041	796.0406017888591
6.964893	6.704932	1058.802043443956	816.4221323808679
6.948993	6.642053	1042.09939896681	766.6671218011634
6.928287506103515	6.588279	1020.744641433011	726.5297572033895
6.887878	6.551677	980.318847969327	700.4177634168919
6.84113	6.53532	935.5460767486945	689.0545867725301
6.789541	6.510945	888.5058410802022	672.4614908915819
6.771372	6.506518	872.5082906361666	669.4914499002018
6.826435565948486	6.53752	921.8990991506056	690.5717223700081
6.646359	6.498421	769.9758162703124	664.0921339039815
6.622631549835205	6.465943	751.9210643753971	642.8706004124769
6.588478	6.43913459777832	726.674218050822	625.8649149697039
6.586121	6.396214485168458	724.963206776459	599.5711797228635
6.591694	6.436983	729.0147293724708	624.5197743988954
6.578462	6.321608543395996	719.4317199086428	556.4673640880866
6.548844	6.324417	698.4363907945586	558.0321191612377
6.512983	6.358211	673.8335985660805	577.2128722136582
6.441622	6.368505	627.4233792740529	583.1852203510519

6.350587	6.337295	572.8287815967692	565.2653458444786
6.356249	6.355721473693848	576.0812314306195	575.7775286835129
6.376709461212159	6.367543	587.9896686134062	582.6245477766825
6.411895	6.393605	609.0465930311075	598.008385223635
6.452651	6.412339	634.3818632316868	609.3173660993042
6.482490539550781	6.454131603240966	653.5967161228518	635.3218914412179
6.514611	6.496208	674.9314642661144	662.6239679340182
6.524941	6.539310455322265	681.9394647327362	691.8094585867098
6.542615413665771	6.587708	694.0995641161349	726.1147033441928
6.47985	6.639488	651.8730831995412	764.7037105364908
6.358884	6.685272	577.6014617015155	800.52835189245
6.320986	6.743923	556.1211115107965	848.884163981082
6.358419418334961	6.812068462371826	577.3332291954001	908.7485909544954
6.426454544067382	6.843369	617.9791496177439	937.6428838648705
6.575549	6.878085	717.3395932433604	970.7657944698404
6.595051	6.912459	731.4664235791402	1004.71532877065

b.) Summary Statistics Table

	LPCEC	LPCGDP
Mean	6.677373641077795	6.599115850289988
Median	6.591694	6.551677
Maximum	7.072255	6.912459
Minimum	6.320986	6.321608543395996
Std. Dev.	0.2422706527325962	0.1917368895666671
Skewness	0.1952028486261346	0.2064844495289288
Kurtosis	1.567563185121825	1.69521483702115
Jarque-Bera	3.949356208075438	3.35580534267119
Probability	0.1388059861388747	0.1867652737181393
Sum	287.1270665663452	283.7619815624696
Sum Sq. Dev.	2.465192905370085	1.544047462469412
Observations	43	43

Appendix A 2

Unit Root Result

1. **Unit Root Results**

ADF Test Results

i.) LPCEC at Level

Null Hypothesis: LPCEC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on AIC, maxlag=1)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.624820	0.7656
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

ii.) LPCEC at First Difference

Null Hypothesis: D(LPCEC) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on AIC, maxlag=1)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.540101	0.0041
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

PP Test Results

i.) LPCGDP at Level

Null Hypothesis: LPCGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on AIC, maxlag=1)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		1.236102	0.9999
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

ii.) LPCGDP at First Difference

Null Hypothesis: D(LPCGDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on AIC, maxlag=1)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.893757	0.0000
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

a.) Zivot and Andrews Unit root test

i.) Unit root test for LPCEC

zandrewslpcec
Zivot-Andrews unit root test for lpcec
Allowing for break in intercept
Lag selection via TTest: lags of D.lpcec included = 1
Minimum t-statistic -3.693 at 1989 (obs 19)
Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

ii.) Unit root test for LPCGDP

zandrewslpcgdp
Zivot-Andrews unit root test for lpcgdp
Allowing for break in intercept
Lag selection via TTest: lags of D.lpcgdp included = 0
Minimum t-statistic -0.792 at 2003 (obs 33)
Critical values: 1%: -5.34 5%: -4.80 10%: -4.58

.

Appendix A 3

Structural Break Test Result

Quandt-Andrews Structural Test

Quandt-Andrews unknown breakpoint test
Null Hypothesis: No breakpoints within 15% trimmed data
Equation Sample: 1973 2013
Test Sample: 1980 2007
Number of breaks compared: 28

Statistic	Value	Prob.
Maximum LR F-statistic (1995)	3.948333	0.0586
Maximum Wald F-statistic (1995)	15.79333	0.0586
Exp LR F-statistic	0.958470	0.1575
Exp Wald F-statistic	5.453715	0.0378
Ave LR F-statistic	1.630453	0.0965
Ave Wald F-statistic	6.521814	0.0965

Note: probabilities calculated using Hansen's (1997) method

Appendix A 4

Johansen Co-integration Table of Results

Date: 06/02/16   Time: 15:43
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
Trend assumption: Linear deterministic trend
Series: LPCEC LPCGDP
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.435843	25.97258	15.49471	0.0009
At most 1	0.059229	2.503278	3.841466	0.1136

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

Appendix A 6:

In Sample Causality Analysis Tables

Estimated ModelVEC Model 1 (Equation 7)

Vector Error Correction Estimates
Date: 06/02/16 Time: 15:48
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
Standard errors in ( ) & t-statistics in [ ]

CointegratingEq:	CointEq1	
LPCEC(-1)	1.000000	
LPCGDP(-1)	-0.687816	
	(0.17197)	
	[-3.99954]	
C	-2.143930	
Error Correction:	**D(LPCEC)**	**D(LPCGDP)**
CointEq1	-0.152161	-0.159269
	(0.04715)	(0.03460)
	[-3.22719]	[-4.60327]
D(LPCEC(-1))	0.411280	0.051579
	(0.14675)	(0.10769)
	[2.80260]	[0.47898]
D(LPCGDP(-1))	-0.509889	-0.240767
	(0.23376)	(0.17154)
	[-2.18125]	[-1.40360]
C	-0.005441	0.000596
	(0.00762)	(0.00560)
	[-0.71357]	[0.10656]
R-squared	0.307696	0.401442
Adj. R-squared	0.251563	0.352910
Sum sq. resids	0.085623	0.046106
S.E. equation	0.048105	0.035300

F-statistic	5.481578	8.271750
Log likelihood	68.33671	81.02619
Akaike AIC	-3.138376	-3.757375
Schwarz SC	-2.971198	-3.590197
Mean dependent	-0.009211	3.54E-05
S.D. dependent	0.055605	0.043883

Determinant resid covariance (dof adj.)	2.85E-06
Determinant resid covariance	2.32E-06
Log likelihood	149.6320
Akaike information criterion	-6.811318
Schwarz criterion	-6.393374

VEC Model 1 (Equations 7): Long run and Short run variables coefficients with their associated p-values

Dependent Variable: D(LPCEC)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 07/01/16 Time: 13:15
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
D(LPCEC) = C(1)*(LPCEC(-1) - 0.687816342692*LPCGDP(-1) -
2.14393037209) + C(2)*D(LPCEC(-1)) + C(3)*D(LPCGDP(-1)) + C(4)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.152161	0.047150	-3.227190	0.0026
C(2)	0.411280	0.146749	2.802597	0.0080
C(3)	-0.509889	0.233760	-2.181252	0.0356
C(4)	-0.005441	0.007625	-0.713572	0.4800

R-squared	0.307696	Mean dependent var	-0.009211
Adjusted R-squared	0.251563	S.D. dependent var	0.055605
S.E. of regression	0.048105	Akaike info criterion	-3.138376
Sum squared resid	0.085623	Schwarz criterion	-2.971198
Log likelihood	68.33671	Hannan-Quinn criter.	-3.077499
F-statistic	5.481578	Durbin-Watson stat	2.112265
Prob(F-statistic)	0.003217		

VEC Model 1 (Equation 7): Wald Test for Joint (Long/short run) causality

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	5.235584	(2, 37)	0.0099
Chi-square	10.47117	2	0.0053

Null Hypothesis: C(1)=C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	-0.152161	0.047150
C(3)	-0.509889	0.233760

Restrictions are linear in coefficients.

VEC Model 1 and Model 2 (Equation 7 & 8): VEC Wald Test for short run causality

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 07/11/16 Time: 18:25
Sample: 1971 2013
Included observations: 41

Dependent variable: D(LPCEC)

Excluded	Chi-sq	Df	Prob.
D(LPCGDP)	4.757861	1	0.0292
All	4.757861	1	0.0292

Dependent variable: D(LPCGDP)

Excluded	Chi-sq	Df	Prob.
D(LPCEC)	0.229417	1	0.6320
All	0.229417	1	0.6320

VEC Model 2 (Equation 8)

Vector Error Correction Estimates
Date: 06/02/16 Time: 15:52
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
Standard errors in ( ) & t-statistics in [ ]

CointegratingEq:	CointEq1
LPCGDP(-1)	1.000000
LPCEC(-1)	-1.453876 (0.20837) [-6.97746]
C	3.117010

Error Correction:	D(LPCGDP)	D(LPCEC)
CointEq1	0.109548	0.104659
	(0.02380)	(0.03243)
	[4.60327]	[3.22719]
D(LPCGDP(-1))	-0.240767	-0.509889
	(0.17154)	(0.23376)
	[-1.40360]	[-2.18125]
D(LPCEC(-1))	0.051579	0.411280
	(0.10769)	(0.14675)
	[0.47898]	[2.80260]
C	0.000596	-0.005441
	(0.00560)	(0.00762)
	[0.10656]	[-0.71357]
R-squared	0.401442	0.307696
Adj. R-squared	0.352910	0.251563
Sum sq. resids	0.046106	0.085623
S.E. equation	0.035300	0.048105
F-statistic	8.271750	5.481578
Log likelihood	81.02619	68.33671
Akaike AIC	-3.757375	-3.138376
Schwarz SC	-3.590197	-2.971198
Mean dependent	3.54E-05	-0.009211
S.D. dependent	0.043883	0.055605
Determinant resid covariance (dof adj.)		2.85E-06
Determinant resid covariance		2.32E-06
Log likelihood		149.6320
Akaike information criterion		-6.811318
Schwarz criterion		-6.393374

VEC Model 2 (Equations 8): Long run and Short run variables coefficients with concerned p-values

Dependent Variable: D(LPCGDP)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 07/01/16 Time: 13:28
Sample (adjusted): 1973 2013
Included observations: 41 after adjustments
D(LPCGDP) = C(1)*(LPCGDP(-1) - 1.45387647535*LPCEC(-1) + 3.11700993277) + C(2)*D(LPCGDP(-1)) + C(3)*D(LPCEC(-1)) + C(4)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.109548	0.023798	4.603269	0.0000
C(2)	-0.240767	0.171536	-1.403595	0.1688
C(3)	0.051579	0.107687	0.478975	0.6348
C(4)	0.000596	0.005595	0.106562	0.9157

R-squared	0.401442	Mean dependent var	3.54E-05
Adjusted R-squared	0.352910	S.D. dependent var	0.043883
S.E. of regression	0.035300	Akaike info criterion	-3.757375

Sum squared resid	0.046106	Schwarz criterion	-3.590197
Log likelihood	81.02619	Hannan-Quinn criter.	-3.696498
F-statistic	8.271750	Durbin-Watson stat	1.871296
Prob(F-statistic)	0.000245		

VEC Model 2 (Equation 8): Wald Test for Joint (Long/short run) causality

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	10.61123	(2, 37)	0.0002
Chi-square	21.22245	2	0.0000

Null Hypothesis: C(1)=C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	0.109548	0.023798
C(3)	0.051579	0.107687

Restrictions are linear in coefficients.

Appendix A 7: Out of Sample Causality Analysis Tables

Variance Decomposition Table

Variance Decomposition of LPCEC: Period	S.E.	LPCEC	LPCGDP
1	0.048105	100.0000	0.000000
2	0.077393	96.62820	3.371800
3	0.097003	96.23052	3.769477
4	0.109795	96.39342	3.606578
5	0.117877	96.74152	3.258479
6	0.122806	96.99531	3.004692
7	0.125717	96.94767	3.052331
8	0.127474	96.41304	3.586956
9	0.128771	95.22952	4.770483
10	0.130174	93.28588	6.714124

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Decomposition of LPCGDP: Period	S.E.	LPCEC	LPCGDP
1	0.035300	1.304228	98.69577
2	0.046661	0.875802	99.12420
3	0.059934	2.946544	97.05346
4	0.074774	7.491535	92.50847
5	0.091589	13.06210	86.93790
6	0.110141	18.60163	81.39837
7	0.130167	23.61795	76.38205
8	0.151405	27.97767	72.02233
9	0.173633	31.70523	68.29477
10	0.196665	34.87927	65.12073

Cholesky Ordering: LPCEC LPCGDP

Impulse Response Function Table

Response of LPCEC: Period	LPCEC	LPCGDP
1	0.048105	0.000000
2	0.058937	-0.014211
3	0.057159	-0.012358
4	0.050650	-0.008949
5	0.042686	-0.004242
6	0.034436	0.000616
7	0.026345	0.005410
8	0.018564	0.010023
9	0.011140	0.014428
10	0.004077	0.018620

Response of LPCGDP: Period	LPCEC	LPCGDP
1	0.004031	0.035069
2	-0.001678	0.030468
3	-0.009315	0.036444
4	-0.017692	0.041061
5	-0.026016	0.046049
6	-0.034072	0.050811
7	-0.041775	0.055383
8	-0.049110	0.059735
9	-0.056082	0.063872

10	-0.062704	0.067803
Cholesky Ordering: LPCEC LPCGDP		

Appendix A 8:

Diagnostic Results Tables

VEC Model 1 (Eq. 4)

Normality Test

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 06/02/16 Time: 16:13
Sample: 1971 2013
Included observations: 41

Component	Skewness	Chi-sq	df	Prob.
1	-0.483464	1.597209	1	0.2063
2	-0.966058	6.377336	1	0.0116
Joint		7.974545	2	0.0186

Component	Kurtosis	Chi-sq	df	Prob.
1	3.303604	0.157466	1	0.6915
2	4.876901	6.018046	1	0.0142
Joint		6.175512	2	0.0456

Component	Jarque-Bera	df	Prob.
1	1.754675	2	0.4159
2	12.39538	2	0.0020
Joint	14.15006	4	0.0068

Heteroscedasticity Test

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 06/02/16 Time: 16:14
Sample: 1971 2013
Included observations: 41

Joint test:

Chi-sq	df	Prob.
17.64685	18	0.4791

Individual components:

Dependent	R-squared	F(6,34)	Prob.	Chi-sq(6)	Prob.
res1*res1	0.121216	0.781639	0.5902	4.969865	0.5477
res2*res2	0.128384	0.834669	0.5517	5.263752	0.5105
res2*res1	0.159837	1.078057	0.3949	6.553320	0.3641

VEC Residual Heteroskedasticity Tests: Includes Cross Terms
Date: 06/02/16 Time: 16:15
Sample: 1971 2013
Included observations: 41

Joint test:

Chi-sq	Df	Prob.
23.48903	27	0.6585

Individual components:

Dependent	R-squared	F(9,31)	Prob.	Chi-sq(9)	Prob.
res1*res1	0.162398	0.667825	0.7311	6.658327	0.6726
res2*res2	0.191610	0.816427	0.6053	7.856021	0.5487
res2*res1	0.198068	0.850739	0.5769	8.120793	0.5220

LM Serial Correlation test

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 06/02/16 Time: 16:16
Sample: 1971 2013
Included observations: 41

Lags	LM-Stat	Prob
1	5.039063	0.2833
2	1.889544	0.7561

Probs from chi-square with 4 df.

VEC Model 2 (Eq. 5)

Normality Test

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 06/02/16 Time: 16:06
Sample: 1971 2013
Included observations: 41

Component	Skewness	Chi-sq	df	Prob.
1	-0.902784	5.569300	1	0.0183
2	-0.595535	2.423521	1	0.1195
Joint		7.992821	2	0.0184

Component	Kurtosis	Chi-sq	df	Prob.
1	4.839816	5.782576	1	0.0162
2	3.374109	0.239095	1	0.6249
Joint		6.021671	2	0.0493

Component	Jarque-Bera	df	Prob.
1	11.35188	2	0.0034
2	2.662616	2	0.2641
Joint	14.01449	4	0.0072

Heteroscedasticity Test

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 06/02/16 Time: 16:04
Sample: 1971 2013
Included observations: 41

Joint test:

Chi-sq	df	Prob.
17.64685	18	0.4791

Individual components:

Dependent	R-squared	F(6,34)	Prob.	Chi-sq(6)	Prob.
res1*res1	0.128384	0.834669	0.5517	5.263752	0.5105
res2*res2	0.121216	0.781639	0.5902	4.969865	0.5477
res2*res1	0.159837	1.078057	0.3949	6.553320	0.3641

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 06/02/16 Time: 16:07
Sample: 1971 2013
Included observations: 41

Joint test:

Chi-sq	df	Prob.
17.64685	18	0.4791

Individual components:

Dependent	R-squared	F(6,34)	Prob.	Chi-sq(6)	Prob.
res1*res1	0.128384	0.834669	0.5517	5.263752	0.5105
res2*res2	0.121216	0.781639	0.5902	4.969865	0.5477
res2*res1	0.159837	1.078057	0.3949	6.553320	0.3641

LM Serial Correlation Test

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 06/02/16 Time: 16:03
Sample: 1971 2013
Included observations: 41

Lags	LM-Stat	Prob
1	5.039063	0.2833
2	1.889544	0.7561

Probs from chi-square with 4 df.