AN ANALYSIS OF ECONOMIC GROWTH, ENERGY CONSUMPTION AND CARBON EMISSIONS: THE CASE OF ZAMBIA

By

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DECLARATION

I PATRICK BWALYA MULENGA declare that this dissertation is my own work and other material there in has been properly cited and that it has not been submitted for the degree at this or any other university.

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APPROVAL

This dissertation of PATRICK BWALYA MULENGA is approved as partial fulfilment of the requirements for the award of the Master of Arts Degree in Economics by the University of Zambia.

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ABSTRACT

This study focuses on examining the long run relationship and granger causality between economic growth, carbon emissions, energy consumption, in Zambia from 1980 to 2017. The study employs Johansen cointegration technique, Vector error correction model (VECM), error correction-based granger causality and variance decomposition (VDC) to determine cointegration and direction of causality among the three variables. The overall results show that energy consumption is vital in driving Zambia's economy and that pursuance of energy conservation policies, such as rationing energy consumption will result in a slowdown in economic growth. On the other hand, environmental conservation policies aimed at controlling carbon dioxide emissions are likely to adversely affect the real GDP growth of Zambia in the short run. The long run results lean towards a negative relationship between economic growth and carbon emissions meaning increased carbon emissions work to reduce economic growth. Furthermore, Variance Decomposition Analysis (VDC) results reveal that capital and labour remain key in accounting for variations in economic growth relative to energy consumption and carbon emissions. Therefore, Zambian policy makers should ensure establishing policies that supports expansion of energy generation capacity as well as develop a diversified energy base. Particular focus should be on developing clean/renewable energies so as to ensure sustainable economic growth with minimal adverse effects on the environment.

Key words: Economic growth, Energy consumption, Granger Causality, Variance decomposition, Carbon emissions

DEDICATION

This dissertation is dedicated to my beloved family particularly my mother Faustina Mwape Mulenga for her unwavering support towards my academic journey. She has been there for me and encouraged me when no one else believed in me. I thank her for being patient with me throughout my academic life and I wouldn't have managed to pursue this work without her support and prayers, may the almighty God bless you abundantly mum.

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LIST OF ABBREVIATIONS

7NDP	Seventh National Development Plan
ADF	Augmented Dickey Fuller
AFDB	African Development Bank
AIC	Alkaike Information Criterion
ARDL	Auto Regressive Distributed Lag
CUSUM	Cumulative Sum
ECT	Error Correction Term
EKC	Environmental Kuznets Curve
ERB	Energy Regulation Board
EPR	Energy Policy Review
FPE	Final Prediction Error
GDP	Gross Domestic Product
GNP	Gross National Product
HQ	Hannan-Quinn Information Criterion
IPPs	Independent Power Producers
IES	International Energy Statistics
JB	Jacque Bera

LF	Labor Force
LM	Lagrange Multiplier
MW	Mega Watts
NEP	National Energy Policy
OLS	Ordinary Least Squares
PCO2	per Capita Carbon Emissions
PCEC	per Capita Energy Consumption
PCGDP	per Capita Real Gross Domestic Product
PP	Philip Peroni
SIC	Schwarz Information Criterion
TY	Toda Yamamoto
VAR	Vector Auto regression
ECM	Error Correction Model
ZESCO	Zambia Electricity Supply Corporation
ZDA	Zambia Development Agency

INTRODUCTION

1.0 Background

Energy plays a pivotal role in the running of various economic activities. Energy, particularly commercial energy is vital in driving the economy propelling most of the production activities especially in the agriculture, manufacturing and mining sectors. Khalisani (2004) arrived at a similar conclusion by noting that there exists a strong connection between per Capita gross National Product (GNP) and energy consumption. Higher per capita GNP countries consume more energy per head. Therefore, the relationship between energy consumption and economic progress is of great concern to the energy economists seeing that it is not possible to realize high growth in one, without keeping speed with another. Even though energy is vital in promoting accelerated economic growth, its use also comes with inevitable problems such as increased carbon dioxide emissions.

With a shift to sustainable development goals, many economies are increasingly considering effects of accelerated economic growth and energy use in their development planning so as not to degrade the environment. Zambia has not been spared by the effects of climate change. According to the seventh National Development Plan (7NDP, 2018 - 2021), the impact of climate change (whose main cause is carbon emissions) will cost Zambia approximately 0.4 percent of annual economic growth. Furthermore, it is estimated that without action, rainfall variability alone could lead to losses of 0.9 percent of GDP growth over the next decade, thereby keeping a significant section of Zambia's population below the poverty line (ibid).

In order to get a full understanding of the role of energy in economic growth, there is need to establish the inter-linkage of energy, economic growth, and carbon dioxide emissions. This will help policy makers to formulate comprehensive and prudent economic, energy, and environmental policies that are both progressive and sustainable both in the short and long run. The role of energy in economic growth is so vital that past experiences of shocks of components of energy such as petroleum had adversely affected most countries that imported oil in the early 70s. A good example is the oil supply shock of the 1970s which made most developing countries, Zambia inclusive, to suffer serious balance of payment problems coupled with sharp economic declines in output. It was during this period that a number of studies on the relationship between energy consumption and economic growth were done, among the early researchers on the subject was (Kraft and Kraft 1978) who pioneered the work on the causal relationship between energy consumption and economic growth. Since then several other studies (Ozturk and Acaravci, 2010), (Asafu-Adjaye, 2000), (Ang, 2008) have been done often with mixed results depending on the structure of the economy of a given country, choice of variables and methodology.

It is therefore clear from this background that a comprehensive policy framework is needed if balanced growth is to be achieved and it is for this reason that the study of the inter-linkage of economic growth, energy consumption and carbon emissions is very important in formulating suitable policies that address the various facets of development. In most studies done thus far i.e. (Asafu-Adjaye, 2000) and (Odhiambo, 2009), focus has been on either the energy consumption – economic growth link which only addresses the association between economic growth and energy consumption or the energy consumption – environmental pollutants nexus which addresses the linkage between economic growth and carbon emissions. There are few studies that have focused on the inter-linkage of these three variables by analyzing the two nexuses in one framework; among the few studies that have combined the two nexus is that of (Ozturk and Acaravci, 2010).

There seems to be various hypotheses concerning the direction of causality among the three variables, one hypothesis is based on the branch of research that focuses on the link between environmental pollutants and economic growth. This is what is famously known as the environmental Kuznets curve hypothesis (EKC) which says that environmental degradation rises as per capita income rises in the early stages of economic growth but eventually declines after reaching some threshold (Ozturk and Acaravci, 2010).

Other studies such as those of (Shyamal and Bhattacharya, 2004) as well as (Apergis and Payne, 2009) focus on the association between energy consumption and economic growth or output growth. The idea behind such studies is that higher economic growth and economic development in general requires higher amount of energy consumption. In this strand, the direction of causality may run from energy consumption to economic growth, economic growth to energy consumption or both ways (bidirectional). Despite having received a fair share of attention, the inter linkage of economic growth, energy consumption, and carbon emissions has yielded mixed results. This is partly due to a number of factors that include but not limited to different sample sizes (time period) methodological approaches, and different economic structures and choice of variables.

To get an idea of how the three variables have been behaving, below is Figure 1 showing how energy use has increased over time in close association with GDP and CO_2 emissions both globally and in individual countries.

Source: International Energy Statistics (IES)

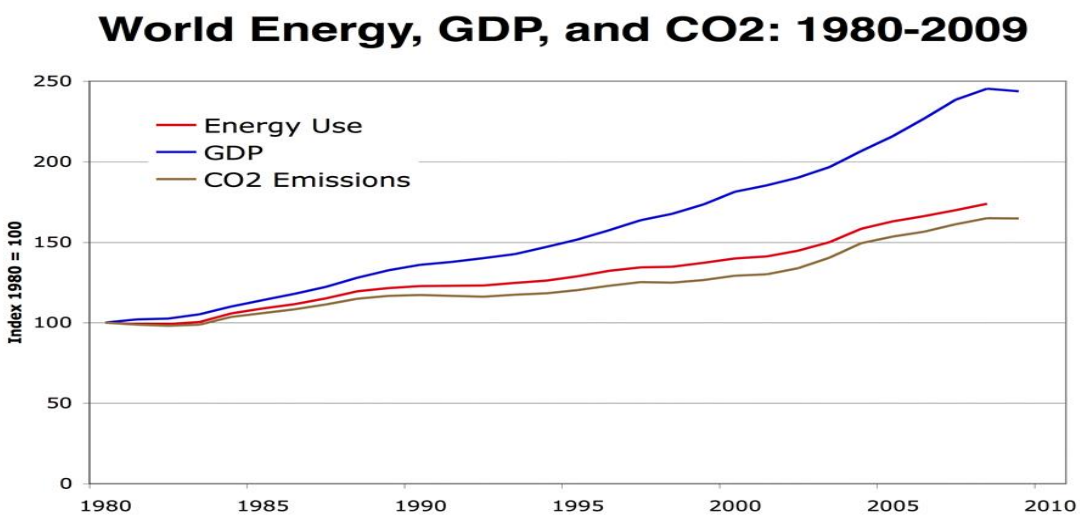


Figure 1: World energy, GDP and CO2 trend (1980 – 2009)

Figure 1 shows that the three variables have been showing an upward trend from 1980 to around 2009. It should however be noted that energy consumption and carbon emission have grown much slower than GDP at global scale. We note that the direction of causality in the energy consumption – output growth nexus has serious implications, if the direction is running from output growth to energy consumption, then it is possible to pursue energy conservation policies with little adverse effects on output growth. On the other hand, if the direction of causality is running from energy consumption to output growth, any pursuance of energy conservation policies will definitely reduce output. Lastly, as noted by (Asafu-Adjaye, 2000), if there is no causality in both directions then energy conservation policies have absolutely no impact on output growth implying that there is no relationship between energy consumption and economic growth.

1.1 An overview of Zambia's Energy Profile

Zambia's energy sources include; electricity, petroleum, coal, biomass, and renewable energy. The country's economy has been growing at an average of 5% per annum over the past 10 years and demand for energy has also been rising but more than the supply (ZDA, 2014). The demand for the most important energy source in the country - electricity has been growing at an average of about 3% per annum mainly due to the increased economic activity in the country especially in the agriculture, manufacturing and mining sectors, as well as increased activity in the region where Zambia exports some of its electric energy (ibid).

Furthermore, the country's growing economy has also led to an increase in the demand for other forms of energy such as petroleum and coal, as these are vital in the production and operations in most sectors of the economy such as manufacturing and transport sectors. The demand for renewable energies has also seen significant growth in the recent years as the market explores alternative sources of energy, with renewable energies proving to be a viable alternative (ZDA, 2014). While Zambia is self-sufficient in other forms of energy, Petroleum is an exception. The country imports all its petroleum requirements; these are categorized into crude and refined respectively. Indeni Oil Limited accounts for about 60% of the refined petroleum demand and the other 40% is met via importation of refined petroleum.

According to the Energy Policy Review for Zambia (EPR, 2018), diversification of the country's energy mix through use of renewable energy has been the main focus in the past few years. The policy has emphasized creating conditions that ensure availability of adequate supply of energy from various sources which are dependable at lowest economic, financial, social and environmental costs consistent with national development goals (MMEWD, 2015). Despite these sound policy guidelines, it's practically hard to keep up with the higher energy needs due to expansion in economic activities on one hand. On the other hand, there is need to address the environmental impact energy consumption may bring hence there is need for well-balanced policy framework that addresses all the issues. With an emphasis on alternative sources of energy other than electricity, Zambia's energy consumption in other forms is likely to increase. This is due to the unreliable nature of rainfall patterns that have an effect on hydro electric energy generation. The unreliable nature of rainfall was what led to serious power shortages the country experienced between 2014 and 2016.

Zambia is faced a deficit of about 568 megawatts in 2015 in its energy supply particularly electric energy because of unusually low water levels in the Kariba Dam, the world's biggest man-made reservoir (EPR, 2018). Furthermore, from the total installed Electricity Generation Capacity of Zambia of 2,347 megawatts (MW), hydropower is the most important energy source in the country with 2,259 MW (96%), followed by diesel contributing about 4% to the national energy supply. The recent energy crisis has prompted the economy to move to other sources of energy like solar, diesel and hence the increase in the use of generators in most small – medium businesses and a call to bring Independent Power producers (IPPs) on board to augment the Zambia Electricity Supply Corporation (ZESCO). It is envisaged that other sources of energy such as geothermal, wind, solar and coal would grow to about 15 percent by 2030. To increase supply, there is need for additional investment in hydro, geothermal, wind and solar energy generation (7NDP, 2017). Under the petroleum sub-sector, Zambia imported its petroleum products to support socio-economic activities seeing that petroleum is one of the energy resources the country does not naturally possess. With regard to petrol and diesel, 60% of the demand was refined at the INDENI oil Refinery and about 40% was imported in the year 2017. Below is a pie chart showing the national energy demand by source.

Source: Own computation from 2017 ERB reports

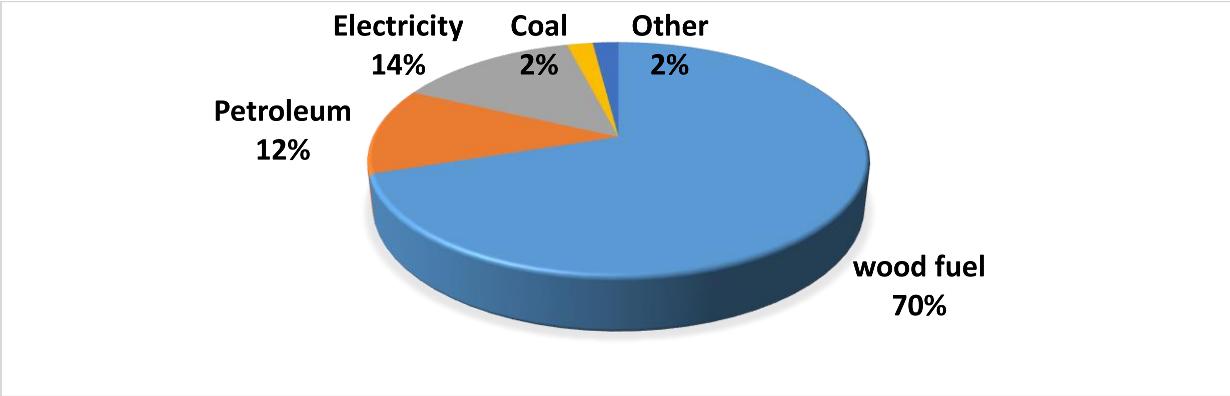


Figure 2: Zambia's National Energy Demand by Source

As seen above wood fuel accounts for the largest percentage of energy demand at national level, and this is not surprising given wide spread use of wood fuel especially in rural parts of Zambia. Electricity and petroleum come in at second and third position respectively in terms of national energy demand, coal and other sources of energy take up the lowest energy demand at 2%.

Figure 3 below shows how per capita GDP has been moving from 1980 to 2017 in the Zambian case. We immediately note that from the 1980s around 1995 GDP per capita had been falling reaching a record around 1999, there after there has been an upward trend from 2000 to 2017.

Source: Own computation using AFDB Data Portal Statistics

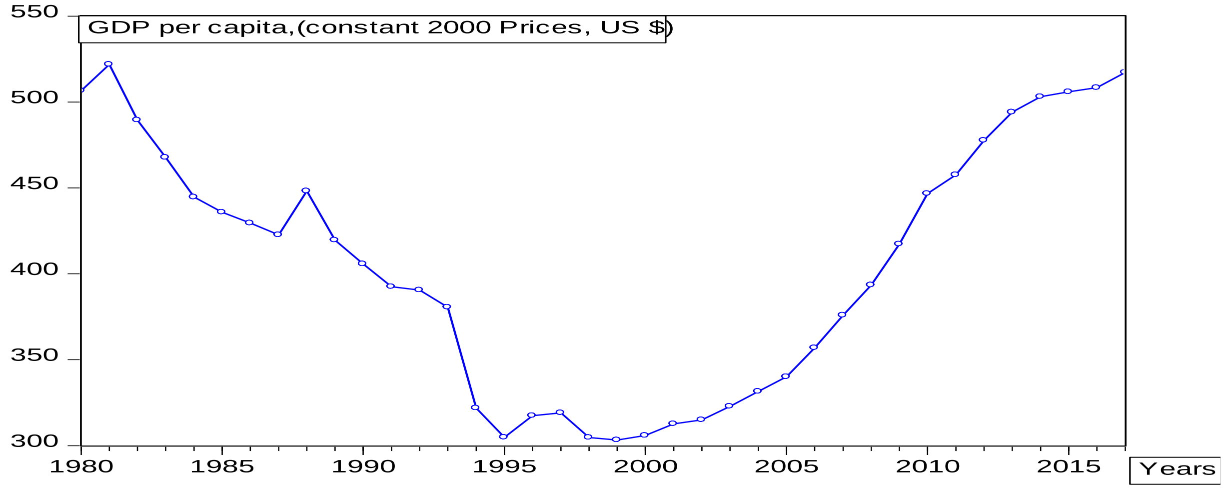


Figure 3: Trends in per capita GDP Zambia

Figure 4 below denotes the trend in per capita energy consumption in Zambia from 1980 to 2017. There is a general downward trend over the entire period with few episodes of fluctuations for instance between 1986 and 1988, 1995 and 1999.

Source: Own computation using AFDB Data Portal Statistics

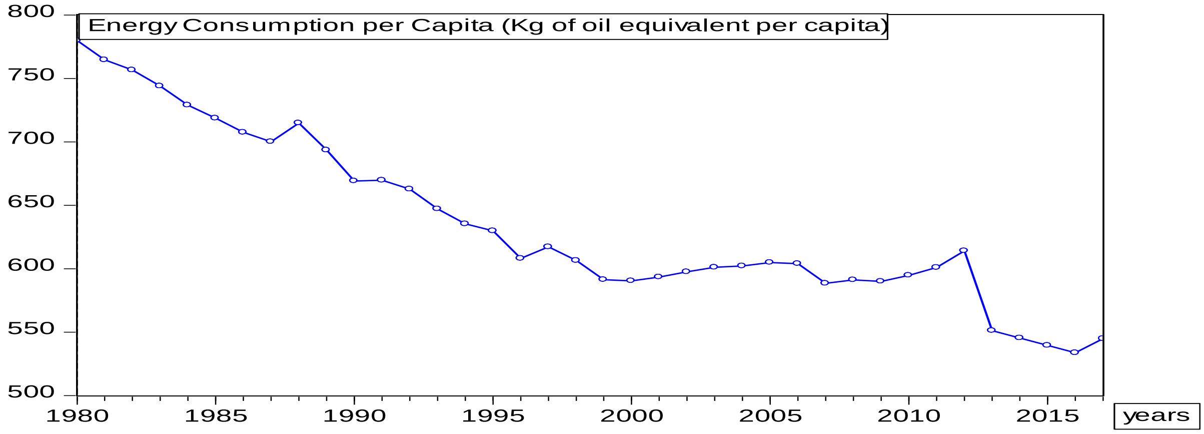


Figure 4: Trends in per capita energy consumption Zambia

Figure 5 below is a graph showing per capita carbon emissions for Zambia between 1980 and 2017. As seen, there has been a downward trend from 1980 to 2017 similar to per capita energy consumption, but the trend has shown an upward movement beginning 2009 to 2012 and thereafter declined until 2017.

Source: Own computation using AFDB Data Portal Statistics

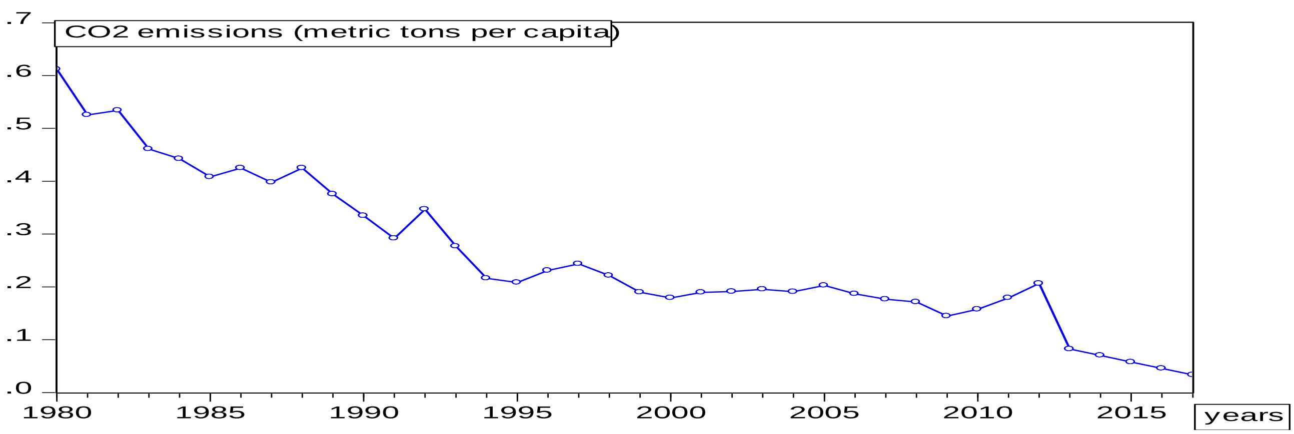


Figure 5: Trends in per capita Carbon dioxide Emissions in Zambia

Having looked at the energy profile for Zambia and how various sources of energy are distributed in terms of use and demand the section that follows formally states the problem regarding the relationship between Energy consumption, Economic growth and carbon emission

1.2 Statement of the Problem

Being a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Zambia's targets are to reduce greenhouse gases (GHG) by 25% and 47% with limited and substantial international support respectively (WRI CAIT, 2015). Further, it is vital to note that after independence, Zambia has had a number of national development plans, the general aim of which has been to quicken its economic growth and eliminate problems of poverty and unemployment. This view is amplified by the (7NDP, 2017) which envisions a prosperous middle-income economy that offers decent employment opportunities for all Zambians of different skills and background.

To achieve this Zambia needs a stable source of energy to power the various economic sectors. In recent years, one of the obstacles to achieving the above objectives has been the widespread energy shortages in the economy. The ramifications of the country's energy shortages came to light in 2015 when the electric energy deficit resulted in unprecedented levels of electric energy supply rationing to all consumers and subsequent reductions in output in most energy intensive sectors. This was worsened by effects of low rainfall that reduced the power generation capacity of the two major power stations; Kariba North and Kafue gorge. Further, according to (ERB report, 2017) the country's main refinery Indeni is only able to satisfy about 50% of national demand for refined petroleum, the other 50% being satisfied via importation which poses a risk of a supply shock.

Given this scenario the following questions arise; is the country able to pursue energy conservation policies without affecting national output? Is the country able to increase national output and energy consumption without degrading the environment? Answers to these questions have serious implications for energy, economic and environmental policies respectively. Therefore this study attempted to establish the inter-linkages among economic growth, energy consumption and carbon emissions. The only country specific study done on this topic was that of (Chitumbo, 2016) who investigated the causal relationship between electricity consumption and economic growth. However, his study only considered electric energy and growth without consideration of variables such as capital, labour and carbon dioxide emissions. Against this background, it is imperative to establish how the above variables interact with Economic growth so as to design future energy policies that are prudent and specific to Zambia.

1.3 Objectives

1.3.1: General Objective

- To determine the impact of energy consumption and environmental degradation on economic growth in Zambia.

1.3.2: Specific Objectives

- To assess the short- and long-run impact of energy consumption on economic growth in Zambia.
- To assess the short and long-run impact of carbon emissions on economic growth in Zambia.

1.4 Statement of Hypotheses

Below are the statements of hypothesis stated in terms of the null hypothesis H_0 and the alternative hypothesis H_1 respectively.

H_0: There is unidirectional causality from energy consumption per capita to economic growth.

H_1: There is no unidirectional causality from Energy consumption per capita to economic growth

H_0: There is unidirectional causality from economic growth to energy consumption per capita.

H_1: There is no unidirectional causality from economic growth to energy consumption per capita.

H_0: There is bi-directional causality between economic growth and per capita energy consumption.

H_1: There is no bidirectional causality between economic growth and per capita energy consumption

H_0: There is a unidirectional causality running from economic growth to carbon dioxide emissions per capita.

H_1: There is no unidirectional causality running from economic growth to carbon dioxide emissions per capita

1.5 Significance of the study

A number of studies have been conducted on the energy-output nexus across countries by using diverse methodologies most of them yielding mixed outcomes. We did not come across any country specific study that incorporates the effects of carbon emissions on economic growth for Zambia on this topic to the best of our knowledge. This is probably one of a few studies that attempts to analyze both energy-output nexus and the environment-growth nexus in one framework. The closest country specific study was done by (Chitumbo, 2016) and was a bivariate causality analysis that focused on electric energy consumption and output. Furthermore, a large volume of literature has been predominantly conducted in developed countries with developing countries recording only few studies.

(Wolde-Rufael, 2009) did a panel study of 19 African countries Zambia inclusive, but this study did not include any environmental variables such as carbon emissions. However, as earlier stated, it is vital to conduct a country specific study as results vary depending on time period, structure of economy, methodology used and variables Therefore, this study is of policy relevance especially in contributing to the understanding of the relationship among economic growth, energy consumption and carbon emissions and their relative importance compared to capital and labour force. The findings will give insight to policy makers on the best course of action depending on how the three variables are related especially after the power crisis experienced between 2014 and 2015. With sustainable development being promoted in the implementation of national development plans, findings of this study will give more clarity to policy makers on how to sustainably carry out the economic growth agenda.

It should also be noted that this will be a country specific study hence its findings will be unique to the country and that makes it more representative and reliable in terms of policy relevance. The study will also go a long way in providing a basis upon which future research can be built and improved on to ensure sound economic, environmental and energy policies are put in place for sustainable economic growth.

1.6 Organisation of the Dissertation

This proposal proceeds as follows; the next section (chapter 2) will look at the literature review which is segmented into two parts, beginning with the review of theoretical literature which focuses on existing theories that link economic growth, energy consumption, and carbon emissions. Thereafter, review of empirical literature will follow to review research work done on the subject outside Africa, within Africa and in Zambia. Chapter 3 focuses on the methodology and data sources while chapter 4 and 5 will look at presentation of findings and discussion respectively. Lastly chapter 6 will focus on conclusion and policy implications.

LITERATURE REVIEW

2.0 Introduction

This section will focus on reviewing relevant theories and models as well as empirical studies done on the link between economic growth and energy consumption and carbon emissions. Special emphasis will be on the role energy plays in the process of economic growth as explained in the ecological and biophysical models of energy economics.

2.1 Review of Theoretical Literature

2.1.1 The Conventional Theory of Growth (Neo-Classical models)

As far as the neoclassical growth theory is concerned, energy is not an important input in the production function but rather acts as an intermediate input, emphasis is placed on capital and labour. They argue that the only source of continued growth is technological progress (Stern & Cleveland, 2004). The original models did not explain how improvements in technology come about. They are just assumed to happen exogenously, so that these models are said to have exogenous technological change (Romer, 2010). Hence energy in this regard plays no role in driving economic growth.

2.1.2 Energy in Production: Physical Theory and Economic Models

The physical theory is predominantly based on the concept of reproducibility of factors. Factors such as capital and labor and other natural resources can be reproduced. On the other hand, energy in itself cannot be reproduced but energy fuels are reproducible (Stern, 1999). Thus, most scientists and some ecological economists have placed a very heavy stress on the role of energy and its availability in the economic production and growth processes (Hall et al., 2001, 2003). The second law of thermal dynamics is often used to show that a minimum quantity of energy is required to carry out the transformation of matter. All production involves the transformation or movement of matter in some way. Therefore, there must be limits to the substitution of other factors of production for energy (Stern, 1997a). All economic processes must, therefore, require energy, so that energy is always an essential factor of production.

2.1.3 Biophysical Models of the Economy

In some biophysical economic models e.g. (Gever *et al*., 1986) geological constraints fix the rate of energy extraction. Therefore, 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 and other forms of energy can have adverse effect on the economic prospects of a country (Mallick, 2007). Hence these models presume some kind of positive relationship between energy consumption and economic growth that is a disruption in the energy supply in a given economy will lead to loss of output.

That is $\boldsymbol{Y} = \boldsymbol{F}(\boldsymbol{EC})$

Where Y is output and EC is energy consumption.

2.1.4 Ecological model of economic growth

Ecological economists often tend to focus on the substantial 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 extreme environmental impacts may restrict economic growth (Cleveland, 1999).To this end, energy use should be considered as a significant factor in sustaining and achieving higher economic growth.

2.2 Review of Empirical Literature

In this section we review a number of studies done by looking at methodologies employed, choice of variables and results obtained as well as strengths and weaknesses. Most of the studies done on this topic center on five standard hypotheses namely; the environmental Kuznets curve (EKC) which suggests that environmental degradation rises with increased economic growth up to a point and thereafter falls, the growth hypothesis which suggests a unidirectional causality running from energy consumption to economic growth, this implies that any energy conservation measures undertaken are likely to adversely affect economic growth. Secondly, the conservation hypothesis proposes a unidirectional causality running from economic growth to energy consumption which entails that energy supply shocks or pursuance of energy conservation policies will have little or no effect on economic growth.

The third hypothesis is referred to as neutrality hypothesis says that there is no relationship running from energy consumption to economic growth and vice versa hence energy conservation policies have no effect on economic growth. Fourth, and last, the feedback hypothesis suggests bidirectional causality between energy consumption and economic growth, that is; both energy consumption and economic growth affect each other.

2.3 Energy-Economic Growth Nexus

2.3.1 Cross Country Studies (outside Africa)

A number of studies have been done on the energy-growth nexus with varying methodologies and different sets of control variables. Below we begin with reviewing cross country studies done outside Africa,

With regards to multi country studies done outside Africa, a panel study of 5 countries was done on the energy-economic growth nexus by (Fuinhas and Marques, 2011) covering a period from 1965 to 2009. They used the autoregressive distributed lag (ARDL) bounds test and granger causality, and their results show the existence of a bi-directional causality from energy consumption to economic growth and vice versa suggesting the existence of the so-called feedback hypothesis. The ARDL bounds test is preferred because it employs a single reduced form equation specifying the dependent and independent variables and includes lagged values of the dependent and independent variables which work to take care of residual correlation in the model. The model can also be used for variables that are integrated of different order. However, this procedure is less useful if there are multiple long run relationships among variables. It should also be noted that the granger causality procedure takes care of the direction of causality in their study.

In another study by (Soytas and Sari, 2007) a panel of six developing countries with varying economic structures and energy statistics were analyzed by making use of the production function framework including both capital and labor spanning a period from 1971 to 2002. They specifically employed the generalized variance decomposition and generalized impulse response techniques in an attempt to establish whether growth of income and energy consumption have sufficient information to forecast each other. In all the countries energy appears to be a significant driver of income (economic growth) and results show a unidirectional causality running from energy consumption to economic growth signifying that the growth hypothesis holds. This is contrary to (Fuinhas and Marques, 2011) that found a feedback effect implying the two variables granger cause each other. The defense in the findings of the two studies could be due to different economic structures of respective countries and the fact that the latter included production function variables in their model. Next we consider studies outside Africa that are country specific in order to compare with multi country panels in terms of methodology employed and findings.

2.3.2 Country Specific Studies (outside Africa)

Unlike multi country panel studies where sometimes it is not easy to isolate country specific characteristics upon which policy can be formed, country specific studies focus on particular countries to establish the energy-growth nexus. In this section we look at some country specific studies done outside Africa.

(Fatai et al., 2002) investigated the energy consumption – growth nexus for New Zealand over a period from 1960-1999 using a combination of estimation procedures such as Granger causality, ARDL, Toda and Yamamoto test. Results from all 3 procedures point out the existence of the neutrality hypothesis that is there is no causal relationship between economic growth and energy consumption. Care must be taken however when generalizing findings because this should be strictly for larger sample sizes and may not hold for small sample sizes which is one of the weaknesses of the TY granger causality procedure.

(Ozturk and Acaravci, 2010) also examined the long run and causal relationship between economic growth, carbon emissions, energy consumption and also included employment ratio as a proxy for labour in Turkey. By making use of autoregressive distributed lag (ARDL) bounds testing approach of cointegration empirical results for Turkey over the period 1968-2005 suggest an evidence of a long-run relationship between the variables at 5% significance level in Turkey. Furthermore, there was no causality in either direction between energy consumption and real GDP per capita however employment ratio was found to cause real GDP per capita in the short run.

2.3.3 Cross Country Studies (Africa)

The preceding two sections have looked at studies done out of Africa most of them in developed countries, but as earlier noted structure of economy is a key aspect that explains some differences in findings hence in this section we focus on multi country studies within Africa where most countries are categorized as least developed countries and have some similarities in size of economies.

Among the multi country studies done in Africa that include Zambia was a panel study by Wolde-Rufael (2005). The study looked at a panel of 19 African countries covering a period from 1971 to 2001 and used the Toda Yamamoto granger causality technique. Results showed evidence of causality running from GDP to energy consumption for 7 countries implying existence of the conservation hypothesis. Further, 3 countries showed evidence of causality running from energy consumption to GDP pointing to the presence of the growth hypotheses , lastly 2 countries (Zambia and Gabon) were found to have a bi-direction causal relationship between energy consumption and GDP and for the rest of the countries there was no causal relationship between these two variables. The Toda Yamamoto was used because unlike the standard granger causality it avoids the bias associated with unit roots and cointegration tests as it does not require pre-testing of cointegrating properties of a system. Despite these attractive properties TY procedure possess some weaknesses, i.e. it is inefficient and undergoes some loss of power since the VAR model is intentionally over-fitted (Toda and Yamamoto, 1995). Further, the asymptotic distribution may be a poor approximation to the distribution of the test statistic for small sample sizes.

Due to the weaknesses of the methodology of the earlier study and choice of variables, (Wolde-Rufael, 2009) re-examined the causal relationship between energy consumption and economic growth 4 years later for 17 as opposed to 19 African countries Zambia inclusive in a multivariate framework by including labor and capital as additional variables for 1971–2004 period. They applied the variance decomposition analysis in addition to the multivariate modified Toda Yamamoto technique to evaluate how important is the causal impact of energy consumption on economic growth relative to labor and capital. The results of multivariate modified Granger causality analysis due to Toda and Yamamoto lean towards rejecting the neutrality hypothesis for the energy–income relationship in 15 out of the 17 countries. In contrast, results of variance decomposition analyses show that in 11 out of the 17 countries, energy isn't that vital in contributing to output growth and more so when compared with capital and labor. Labor and capital are the most important factors in output growth and fluctuations in 15 out of 17 countries.

2.3.4 Country specific Studies (Africa)

(Belloumi, 2009) investigated energy-growth nexus and for Tunisia over the period 1971–2004 using Granger causality, VECM. The results from this study indicate the presence of bi-direction causality between energy consumption and GDP in the long run. However, short run results were somewhat different, the results showed a unidirectional causal relationship running from energy consumption to GDP making the growth hypothesis to hold in the short run. Granger causality helps determine the direction of causality among variables and in his study; Belloumi employed the VECM which requires that variables be cointegrated. However, as earlier noted there are a number of limitations which include but not limited to the requirement that the generative system be linear, stationary and time invariant. But many time series data sets do not always meet these requirements and hence the need for improved versions of establishing causality.

(Chitumbo, 2016) investigated the energy growth nexus for Zambia but specifically focused on electric energy over a period of 1971 – 2013, He made use of error correction model (ECM) and the findings of his study concluded that there is a long run positive relationship between electric energy consumption and economic growth in Zambia. Furthermore, variance decomposition analysis (VDC) indicates that electricity consumption contributes more to economic growth than economic growth does to electricity consumption a result consistent with the growth hypothesis. Despite the interesting insight revealed by this study about the importance of electric energy in impacting growth, this study was bivariate in nature and did not address issues of omitted variable bias and sustainability as it did not include any production function variables and environmental pollutants variables.

2.4 Environment-Growth Nexus

2.4.1 Cross country studies

For the multi-country surveys, (De Bruyn et al, 1997) studied the linkage among income and pollutant emissions using dynamic time series models for a sample of four countries namely the Netherlands, West Germany, the UK, and the US, respectively and they used three different proxies for environmental degradation carbon dioxide, Sulphur dioxide and nitrogen oxide . They found that income has a positive significant impact on the environment proving the EKC hypothesis holds for the respective countries. Similarly, (Onafowora and Owoye, 2014) examine this linkage for eight countries using the ARDL bounds test. The empirical results show that the inverted U-shaped EKC hypothesis holds in Japan and South Korea implying that the environmental degradation rise with increase in income up to some threshold and then declines afterwards.

However as noted earlier the ARDL bounds test despite its attractiveness given that one can use variables that are of different orders of integration i.e. I(0) and I(1) and one is able to determine whether there is a long run relationship among variables in a single reduced form equation specifying the dependent and independent variables, the procedure cannot tell us the direction of causality among variables, hence the need for granger causality test or error-based granger causality. Furthermore, if the computed F-statistic is not above or below the critical values but in between, then it is impossible to make an irrefutable inference without knowing the order of integration of the given regressors.

2.4.2 Country Specific Studies

In this framework, He and Richard (2009) investigated the nexus among CO2 emissions and income in the Canadian context over the period 1948–2004. They employed the co-integration technique and their results show little evidence in favor of the EKC hypothesis. This implied there was no significant relationship between economic growth and environmental pollutants such as carbon dioxide. Similarly, (Fodha and Zaghdoud, 2010) investigated this linkage for Tunisia over the period from 1961 to 2004. They found that CO2 is co-integrated with per capita output, but their results for CO2 indicated a monotonically increasing relationship relative to economic growth rather than the U-shaped EKC. A more recent study by (Lau et al, 2014) examined this relationship including FDI and trade, in the case of Malaysia during the period from 1970 to 2008 by applying the Bounds tests and Granger causality methodology. Their results show the existence of inverted-U shaped nexus among economic growth and environment in both the short-and long-run for Malaysia validating the environmental Kuznets hypothesis.

2.5 Conclusion

Having reviewed the above studies covering both energy-growth nexus and growth-carbon emissions nexus we note that there is some convergence in results as well as differences. The mixed results mainly stem from different methodologies, choice of variables, economic structures and sample sizes. Most importantly, most of these studies tend to neglect the inter-linkages in economic growth, energy consumption and carbon emissions and often investigate the two nexus in isolation; furthermore, most studies suffer omitted variable bias by failing to incorporate production function variables such as labour and capital.

No studies have been done in Zambia by taking into account of the two nexuses in one framework as well as comparing the importance of energy in economic growth relative to production function variables. Therefore, this study endeavored to fill this gap with a view of informing economic, energy and environmental policy formulation. We see therefore, that this study is vital in the formulation of a well-balanced policy framework that addresses both economic growth and environmental sustainability issues. Lastly, this study also makes use of a dynamic testing framework (VDC) in addition to the VECM to give more credibility to the overall results.

RESEARCH METHODOLOGY

3.0 Research Design

This paper will investigate the relationship between economic growth, energy consumption and carbon emissions in Zambia from 1980 to 2017 and will specifically make use of the Johansen cointegration technique, Vector error correction model (VECM), error correction-based granger causality techniques and Variance Decomposition Analysis (VDC).

3.1 Theoretical Framework

This study will make use of the theoretical framework based on the production function model which will be augmented by energy consumption per capita and per capita carbon dioxide; equation 1 below shows the general form of the augmented production function.

$$\boldsymbol{Y = F(K, L, E, C)} \text{ .... } \textbf{(1)}$$

Where Y is national output, K is capital, L is Labour force and E and C are energy consumption and carbon dioxide emissions respectively, capital and labour are included to avoid omitted variable bias and based on the theory of growth that these two are key inputs in growth. The specific model adopted is one used by (Hong, Wijeweera and Charles, 2011) and (Lorde, 2010), however unlike the bivariate models employed by (Jamil, 2010), (Bildirici, 2013), the model will be augmented by both labour force and capital formation as explanatory variables in addition to energy consumption and carbon emissions, below is the representation;

$$\boldsymbol{Y = AE^{\theta}C^{\pi}L^{\gamma}K^{\delta}} \text{ .... } \textbf{(2)}$$

Where **E** is representing energy consumption, **C** is carbon emissions, **L** is labour force and **K** is capital. Taking the logs on both sides of the equation (2) transforms the model into a log-log model with $\boldsymbol{\theta, \pi, \gamma}$ *and* $\boldsymbol{\delta}$ acting as elasticities as shown below:

$$\boldsymbol{Log(pcgdp) = \beta_1 + \theta Log(pcec) + \pi Log(pco2) + \gamma Log(lf) + \delta Log(gcf) + \varepsilon} \text{ ...... } \textbf{\textit{(3)}}$$

Where, $\boldsymbol{pcgdp}$ is per capita real gross domestic product, $\boldsymbol{pco2}$ is per capita carbon emissions $\boldsymbol{pcec}$ is per capita energy consumption, $\boldsymbol{lf}$ is labour force, $\boldsymbol{gcf}$ is gross capital formation and ε

is the error term. All variables are specified in logarithms form to obtain coefficients as elasticities.

It is well known that most economic time series data is rarely stationary, for this reason it is imperative to test the data for stationarity. A time series is said to be stationary if its mean and variance are time invariant i.e. do not change with time. If a series becomes stationary after being differenced d times, then it is said to be integrated of order$I(d)$. There are a number of methods for testing stationarity, but for purposes of our analysis we shall employ the Augmented Dickey-Fuller test (ADF) as well the Philips Peron (PP) test. The later will be used because it takes into account structural breaks that the ADF may not capture. These tests are particularly useful because non-stationary data if not remedied leads to spurious regression results and standard statistical tests such as t-test and F-test are rendered useless due to lack of long run relationships.

This study made use of two techniques namely Johansen cointegration technique developed by Johansen (1988) to establish presence of long run relationships among the variables and number of cointegrating equations. Thereafter, the vector error correction model (VECM) was done to establish both short and long run relationships among the variables. In order to determine the direction of granger causality among the variables we used the two-steps procedure from the Engle and Granger (1987) model to examine the relationship between carbon emissions per capita, per capital energy consumption, gross capital formation, labour force and per capita GDP.

Below is the error correction (ECM) representation

$$\Delta \ln pcgdp_t = \beta_0 + \sum_{i=0}^{\alpha 1} \theta_{1i} \Delta \ln pcec_{t-i} + \sum_{j=0}^{\alpha 2} \pi_{1j} \Delta \ln pco2_{t-j} + \sum_{k=0}^{\alpha 3} \gamma_{1k} \Delta \ln lf_{t-k} + \sum_{p=0}^{\alpha 4} \delta_{1p} \Delta \ln gcf_{t-p} + \Psi ECT_{t-1} + \varepsilon_{1t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where;

$\mathbf{\Delta ln}\, \boldsymbol{pcgdp_t}$ is the log of per capita GDP

$\mathbf{\Delta ln}\boldsymbol{pcec_{t-i}}$ is the log of per capita energy consumption

$\mathbf{\Delta ln}\, \boldsymbol{pco2_{t-j}}$ is the log per capita carbon dioxide emissions

$\mathbf{\Delta ln}\, \boldsymbol{lf_{t-k}}$ is the log of labour force

$\mathbf{\Delta ln}\boldsymbol{gcf_{t-p}}$ is the log of gross capital formation

$\boldsymbol{ECT_{t-1}}$ denotes an error correction term, represents a cointegrating vector

$\boldsymbol{\Psi}$ represents an adjustment coefficients showing how much disequilibrium is corrected .

θ_{1i}, π_{1j} γ_{1k} and δ_{1p} are income elasticities of the respective variables

$\boldsymbol{\varepsilon_{1t}}$ (for i=1, 2) are serially uncorrelated random error terms

3.2 Error Correction Granger Causality Estimation

As opposed to the conventional pairwise Granger causality method, the error correction-based causality test permits for the inclusion of the lagged error-correction term derived from the cointegration equation (long run). This procedure allows us to capture both short and long run granger causality relationships among the variables.

To determine long and short run granger causality we make use of the error correction based granger causality technique. Below is the VEC granger equation in matrix form employed by Ozturk and (Acaravci, 2010) and also (Jaupllari and Zoto, 2013).

$$\begin{bmatrix} \Delta pcgdp_t \\ \Delta pcec_t \\ \Delta pco2_t \\ \Delta gcf_t \\ \Delta lf_t \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \\ \tau_5 \end{bmatrix} + \begin{bmatrix} \sigma_{11,1} & \sigma_{12,1} & \sigma_{13,1} & \sigma_{14,1} & \sigma_{15,1} \\ \sigma_{21,1} & \sigma_{22,1} & \sigma_{23,1} & \sigma_{24,1} & \sigma_{25,1} \\ \sigma_{31,1} & \sigma_{32,1} & \sigma_{33,1} & \sigma_{34,1} & \sigma_{35,1} \\ \sigma_{41,1} & \sigma_{42,1} & \sigma_{43,1} & \sigma_{44,1} & \sigma_{45,1} \\ \sigma_{51.1} & \sigma_{52,1} & \sigma_{53,1} & \sigma_{54,1} & \sigma_{55,1} \end{bmatrix} \begin{bmatrix} \Delta pcgdp_{t-1} \\ \Delta pcec_{t-1} \\ \Delta pco2_{t-1} \\ \Delta gcf_{t-1} \\ \Delta lf_{t-1} \end{bmatrix} + \ldots \ldots +$$

$$\begin{bmatrix} \sigma_{11,k} & \sigma_{12,k} & \sigma_{13,k} & \sigma_{14,k} & \sigma_{15,k} \\ \sigma_{21,k} & \sigma_{22,k} & \sigma_{23,k} & \sigma_{24,k} & \sigma_{25,k} \\ \sigma_{31,k} & \sigma_{32,k} & \sigma_{33,k} & \sigma_{34,k} & \sigma_{35,k} \\ \sigma_{41,k} & \sigma_{42,k} & \sigma_{43,k} & \sigma_{44,k} & \sigma_{45,k} \\ \sigma_{51,k} & \sigma_{52,k} & \sigma_{53,k} & \sigma_{54,k} & \sigma_{55,k} \end{bmatrix} \begin{bmatrix} \Delta pcgdp_{t-k} \\ \Delta pcec_{t-k} \\ \Delta pco2_{t-k} \\ \Delta gcf_{t-k} \\ \Delta lf_{t-k} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \\ \varphi_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \epsilon_{4t} \\ \epsilon_{5t} \\ \epsilon_{6t} \\ \epsilon_{7t} \\ \epsilon_{8t} \end{bmatrix}$$

Note that the residual terms ϵ_{4t}, ϵ_{5t}, ϵ_{6t}, ϵ_{7t} and ϵ_{8t} are assumed to be independently and normally distributed with zero expected value and constant variance. A suitable lag selection is based on a criterion such as AIC and SBC. Now the above representation granger causality relationships can be observed in two ways:

Firstly, Short-run or weak Granger causalities are detected through the F-statistics or Wald test for the significance of the relevant $\boldsymbol{\sigma}$ coefficients on the first differenced series. Secondly, causality can also be observed via the ECT in equations; the long-run causalities are examined through the t-test or Wald test for the significance of the relevant φ coefficients on the lagged error‑correction term.

3.3 Diagnostic test and robust checks

After fitting the data to the model and estimating the slope coefficients, various diagnostic tests were conducted to test such things as Heteroscedasticity, autocorrelation, stationarity, model specification and parameter stability.

Below are the various tests that were be conducted to ensure the results of the regression are robust.

1. The LM Serial correlation test was used to detect for autocorrelation.
2. The Jarque-Bera (JB) test was carried out so as to determine whether the residuals are normally distributed or not.
3. White's Heteroscedasticity test was employed to determine whether variance is equal or unequal.
4. To determine parameter stability, CUSUM and CUSUM squares test were conducted.

3.4 Data Sources

The study made use of secondary data on per capita energy consumption, per capita GDP, per capita carbon emissions, labour force and gross capital formation from World Development Indicators data base as well as the African Development Bank data portal. The study covered a period from 1980 – 2017.

3.5 Variable Definition

GDP per capita: It 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 divided by the population.

Energy Consumption per capita: Measured as energy consumption per capita (Kg of oil equivalent per capita)

Gross Capital Formation: Consists of gross domestic fixed capital formation plus net changes in the level of inventories, at constant 2000 prices and exchange rates (Constant 2000 US$).

Labour Force: This refers to the number of all employed and unemployed persons (including those seeking work for the first time). It covers employers; self-employed workers; salaried employees; wage earners; unpaid workers assisting in a family, farm or business operators.

Carbon Emissions per capita: Data are calculated by dividing the data on total carbon dioxide emissions from the consumption and flaring of fossil fuels in million metric tons of carbon dioxide units for each country and divided by the gross domestic product using market exchange rates in billions of 2000 U.S. dollars.

3.6 Limitation of the Study

This study focused on analyzing the relationship among per capita GDP, per capita energy consumption, carbon emissions per capita, gross capital formation and labour force. Further, this study focused on overall per capita energy consumption to assess its impact on economic growth due to lack of sufficient data on sector specific energy consumption. However, this does not account for impact that energy consumption in specific sectors has on per capita GDP. The study was also limited in the quality of production function variables such as economic growth, capital and labour and hence relied on proxies like per capita GDP, gross capital formation and labour force. We recommend better proxies for future studies. In future studies, we recommend use of specific forms of energy by source or by sector so as to determine for instance in which sector does energy consumption matter most or which type of energy consumption matters i.e. industrial energy must be separated from domestic energy consumption or alternatively energy could be grouped in types i.e. petroleum, hydroelectric, coal etc. (clean and non-clean energy). We also recommend use of other methodologies that improve on the methods used in this paper probably three methodologies so as to see if there is convergence in results.

PRESENTATION OF RESULTS

4.0 Introduction

This section presents findings of the study and begins by first presenting descriptive data for the dependent and independent variables. Thereafter is a graphical representation in log form of the variables. Finally unit root test results, vector error correction estimates, granger causality, and variance decomposition results are presented.

4.1 Descriptive Statistics

The Table 4.1 below indicates summary of descriptive statistics of the original data that was used to run the models.

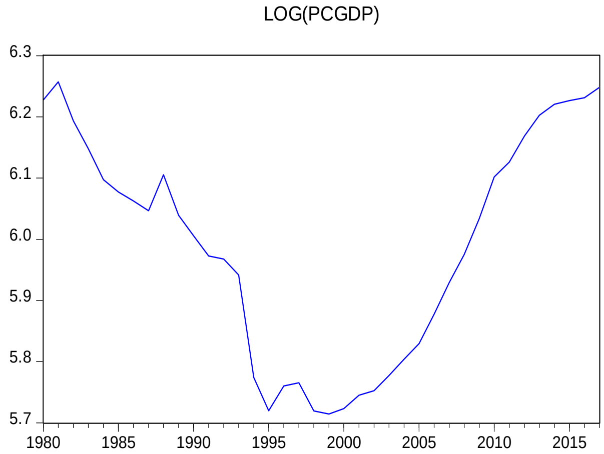
Table 4.1 Descriptive Statistics of the original data

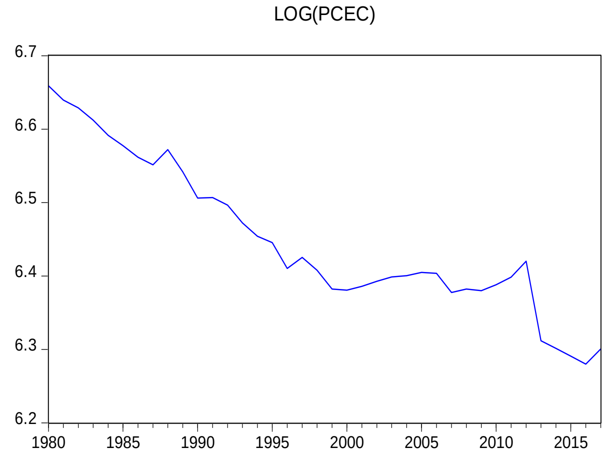
	PCGDP	PCEC	PCO2	LF	GCF
Mean	405.5012	635.0650	0.258628	791740.0	2.71E+09
Median	411.5285	607.3032	0.207304	4878.626	6.70E+08
Maximum	521.8165	779.7958	0.612200	3236006.	9.53E+09
Minimum	303.2140	533.7530	0.033560	2825.306	2.88E+08
Std. Dev.	73.70191	67.35100	0.143894	1261550.	3.36E+09
Skewness	0.025064	0.568461	0.625427	0.988101	1.130040
Kurtosis	1.637056	2.310122	2.657500	2.061782	2.584162
Jarque-Bera	2.945202	2.800163	2.663078	7.577249	8.361404
Probability	0.229328	0.246577	0.264071	0.022627	0.015288
Sum	15409.04	24132.47	9.827878	30086121	1.03E+11
Sum Sq. Dev.	200983.0	167837.8	0.766100	5.89E+13	4.18E+20
Observations	38	38	38	38	38

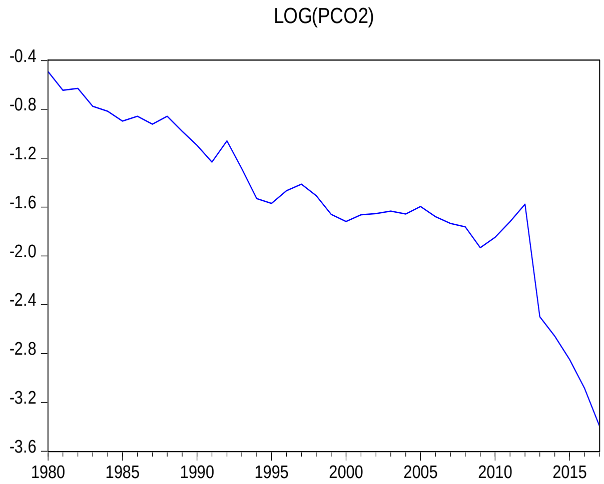
Notes: PCGDP is real Gross Domestic Product per capita, PCEC is per capita Energy Consumption, PCO2 is per capita Carbon dioxide emissions, and GCF is gross capita formation and LF is Labour Force

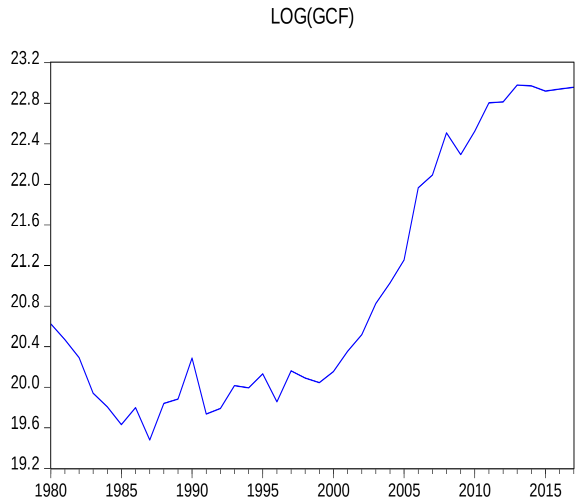
From the descriptive statistics above we note that three variables exhibited normality. This includes per capital GDP, per capita energy consumption and per capita carbon dioxide emissions, the Jacque Bera statistics of the three variables are small with high p-values. The variables labour force and gross capital formation have however exhibited non normality of residuals therefore; we can conclude that the variables are jointly normal at 1% significance level. The sample period is from 1980 to 2017 culminating in a sample size of 38 observations.

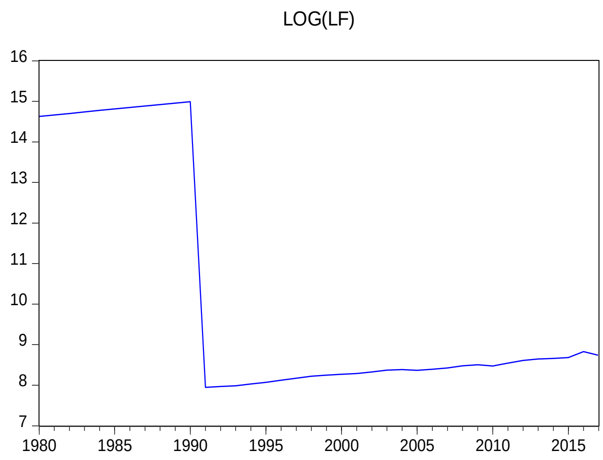
4.2 Trend Characteristics of the Variables











As seen above, all variables seem to have a constant and trend hence in running unit root tests, we included scenarios where there is only a contant and another scenario with both constant and trend. We employed both the augmented Dickey Fuller test as well as the Philip Perron tests to ensure convergence. The latter test also takes structural breaks into account hence was included in the tests in addition to the ADF test.

Table 4.2 Unit root test results in level form

Unit root test results in level form (Intercept only)					
Variable	**ADF Statistic**	**Lags**	**p-values**	**PP Statistic**	**p-values**
PCGDP	-1.7356	5	0.4044	-1.1051	0.7036
PCEC	-1.8801	0	0.3377	-2.0125	0.2804
PCO2	-2.1225	0	0.2374	-2.2311	0.1992
GCF	1.0624	0	0.9964	0.9189	0.9947
LF	-1.4843	0	0.5303	-1.484	0.5305

Unit root test results in level form (Trend and intercept)					
Variable	**ADF Statistic**	**Lags**	**p-values**	**PP Statistic**	**p-values**
PCGDP	-0.569	0	0.9751	-0.569	0.9751
PCEC	-2.2238	0	0.4631	-2.2238	0.4631
PCO2	-3.3423	0	0.0753	-3.3305	0.0771
GCF	-1.2965	0	0.8733	-1.294	0.8739
LF	-1.8604	0	0.6545	-1.9118	0.6283

Notes; a) McKinnon Critical values for both ADF and PP are ***-4.2732****,* ***-3.5577*** *and* ***-3.2123*** *at 1%, 5% and 10% respectively.*

From Table 4.2, we note that all the variables are not stationary in level form whether with inclusion of intercept only or both intercept and trend at all the three levels of significance. This is confirmed by both ADF and PP test statistics which are below the critical values. Furthermore, high p-values also suggest the presence of a unit root in the variables in level form. Hence, we fail to reject the null hypothesis that the variables have a unit root. We repeat the procedure in Table 4.3 by specifying the variables in their respective first difference forms as shown below.

Table 4.3 Unit root test results in first difference

Unit root test results in first difference (Intercept only)

Variable	ADF Statistic	Lags	p-values	PP Statistic	p-values
ΔPCGDP	-3.6665	0	0.009	-3.6907	0.0085
ΔPCEC	-6.3342	0	0.000	-6.3538	0.000
ΔPCO2	-7.4062	0	0.000	-10.3842	0.000
ΔGCF	-6.1015	0	0.000	-6.2048	0.000
ΔLF	-6.0741	0	0.000	-6.0766	0.000

Unit root test results in first difference (Trend and intercept)

Variable	ADF Statistic	Lags	p-values	PP Statistic	p-values
ΔPCGDP	-5.4715	0	0.0004	-5.4715	0.0004
ΔPCEC	-6.4444	0	0.000	-6.5084	0.000
ΔPCO2	-7.3687	0	0.000	-13.1782	0.000
ΔGCF	-7.0057	0	0.000	-6.9315	0.000
ΔLF	-6.0197	0	0.0001	-6.0293	0.0001

Note; *McKinnon Critical values for both ADF and PP are* ***-4.2845**, **-3.5628** and **-3.2152** at 1%, 5% and 10% respectively.*

All the variables are stationary at first difference as evidenced by their respective ADF and PP statistics which are greater than the McKinnon critical values at 1% level of significance. Since most of the variables exhibit trends we adopt the results which include both an intercept and a trend, however results of the unit root test are similar whether only an intercept is included or both trend and intercept. We also not that the respective p-values are extremely small hence we reject the null hypothesis of presence of a unit root in the variables in differenced form and conclude that all variables are now stationary at first difference implying they are integrated of order 1 i.e. I (1). Having established stationarity, we now proceed to the cointegration analysis using the Johansen cointegration test so as to determine the number of cointegrating equations.

4.3 Johansen Cointegration Test

We now carry out the Johansen cointegration test developed by Johansen (1988), below are results of the maximum eigen value test and trace test.

Table 4.4 Johansen Cointegration Test Summary

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.701887	81.99590	60.06141	0.0003
At most 1	0.482412	38.42572	40.17493	0.0742
At most 2	0.170240	14.71702	24.27596	0.4781
At most 3	0.137411	7.998747	12.32090	0.2368
At most 4	0.071672	2.677345	4.129906	0.1203

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

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.701887	43.57017	30.43961	0.0007
At most 1	0.482412	23.70870	24.15921	0.0574
At most 2	0.170240	6.718275	17.79730	0.8374
At most 3	0.137411	5.321402	11.22480	0.4333
At most 4	0.071672	2.677345	4.129906	0.1203

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

The above results show that there is one cointegrating relationship based on both the trace test statistic and the maximum Eigen value statistic. Therefore, we reject the null hypothesis that there is no cointegrating relationship since the Eigen value statistic and the trace statistic are greater than their respective critical values at 5%. Since there is only one cointegrating relationship, we run both the long run model as well as the short run error correction model (ECM).

Before we conduct the ECM we first conduct the VAR lag order selection criteria as follows:

Table 4.5 VAR lag order selection criterion

VAR Lag Order Selection Criteria
Endogenous variables: LOG(PCGDP) LOG(PCEC) LOG(PCO2) LOG(LF) LOG(GCF)
Exogenous variables:
Date: 05/07/19 Time: 18:23
Sample: 1980 2017
Included observations: 35

Lag	LogL	LR	FPE	AIC	SC	HQ
1	141.1642	NA	9.10e-10	-6.637952	-5.526989*	-6.254448*
2	163.9872	32.60430	1.11e-09	-6.513553	-4.291627	-5.746544
3	202.4255	43.92950*	6.36e-10*	-7.281456*	-3.948568	-6.130944

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

In the table above (*) indicates optimal lag length chosen by criterion

After conducting a VAR lag order selection criterion Table 4.5 shows the various optimal lag lengths of each criterion. With a maximum lag length of 3, HQ and SC criteria chose 1 as optimal lag length whereas the rest of the criteria such as AIC, FPE chose an optimal lag length of 3. We adopt 1 as optimal lag length based on Schwarz Information Criteria because (Swanson, Saviano and Zha, 2010) have shown that when AIC and SC choose different models, SC will choose a more parsimonious model than AIC and other criteria more so in small samples which is the case for this study.

Table 4.6 Long Run Elasticities

Long Run Vector Error Correction Elasticities				
Variable	**Elasticities**	**Standard Error**	**t-statistic**	**P-value**
log(PCEC)	0.31	0.0529	-5.823	0.0001***
log(PCO2)	-0.11	0.0482	2.181	0.0364**
log(GCF)	0.16	0.0185	-8.6711	0.0001***
log(LF)	0.05	0.0062	-7.8667	0.0001***

****, **,and * denote statistical significance at 1%, 5% and 10% respectively*

As seen in the long run model above, elasticities of all variables are statistically significant at 1% level with energy consumption, gross capital formation and labour force exhibiting a positive significant impact on economic growth.

Table 4.7 Error Correction Model (Short run estimates)

Error Correction Model (Short run estimates)				
Variable	**Elasticities**	**Standard Error**	**t-statistic**	**P-value**
ECT(-1)	**-0.364**	**0.052**	**-7.0042**	**0.0001*****
log(ΔPCEC)(-1)	-0.4515	0.3624	-1.2458	0.2216
log(ΔPCO2)(-1)	0.1047	0.0468	2.2332	0.0324**
log(ΔGCF)(-1)	0.0727	0.0224	-3.2441	0.0027***
log(ΔLF)(-1)	-0.0115	0.0046	-2.4702	0.020**
R^2 = 0.6996				
Adj R^2 = 0.6495				

****, **,and * denote statistical significance at 1%, 5% and 10% respectively*

The coefficient of determination is high and entails that 69.96% of the variation in the dependent variable is explained by the regressors in the model. Lastly, the error correction coefficient ECT **-0.364** has a negative sign and is statistically significant at all 3 levels of significance implying that when there is disequilibrium in the model in the short run, such disequilibrium is corrected to long run equilibrium at a speed of 36.4% and this will roughly take about 2.7 years for equilibrium to be restored given that we used annual data.

Results of the short run estimates of the error correction model based on the t-test indicate that per capital energy consumption is the only variable that is not significant whereas gross capital formation, per capita carbon dioxide emissions and labour force are significant at 1% and 5% level of significance respectively.

4.4 Model residual and stability Diagnostic Tests

Below we present various diagnostic tests of the underlying Vector Error Correction model (VECM) before any formal interpretations and policy implications can be made. This is done so as to ensure the model is not mis-specified, and that parameters are stable, unbiased and consistent.

4.5 Residual & Stability Diagnostic Tests

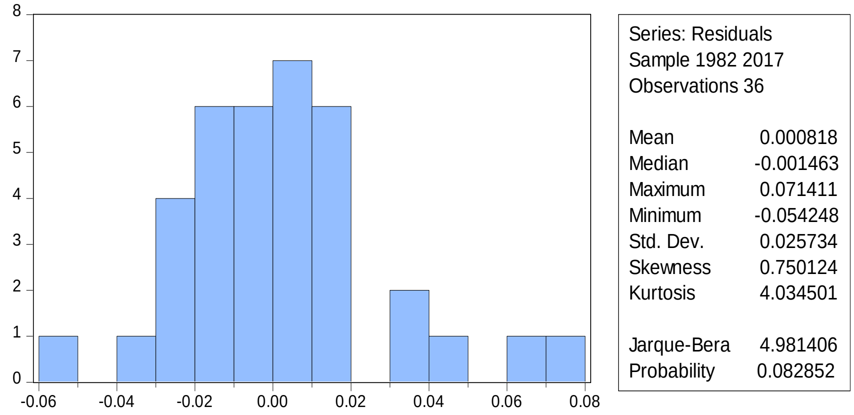


Figure 6 Normality

As seen in the diagram above, the p-value of the Jarque-Bera statistic is high hence we fail to reject the null hypothesis of normally distributed residuals at 5% level of significance and conclude that residuals are normally distributed.

Table 4.8 (Model Diagnostic test results)

Type of Test	Observed Chi-square	Probability
BG Serial Correlation LM Test	0.728356	0.6948
White Heteroscedasticity Test	4.376194	0.7356

The LM serial correlation test indicates a chi-square value of 0.728356 and a p-value of 0.6948 hence we fail to reject the null hypothesis of no serial correlation in residuals at all levels of significance and conclude that there is no serial correlation in the residuals of the model.

Lastly, we conduct the white Heteroscedasticity test and testing the null hypothesis that residuals of the model are homoscedastic, given a chi-square value of 4.376194 with a p-value of 0.7356 we fail to reject the null hypothesis of homoscedastic residuals and conclude that there is no Heteroscedasticity in the model.

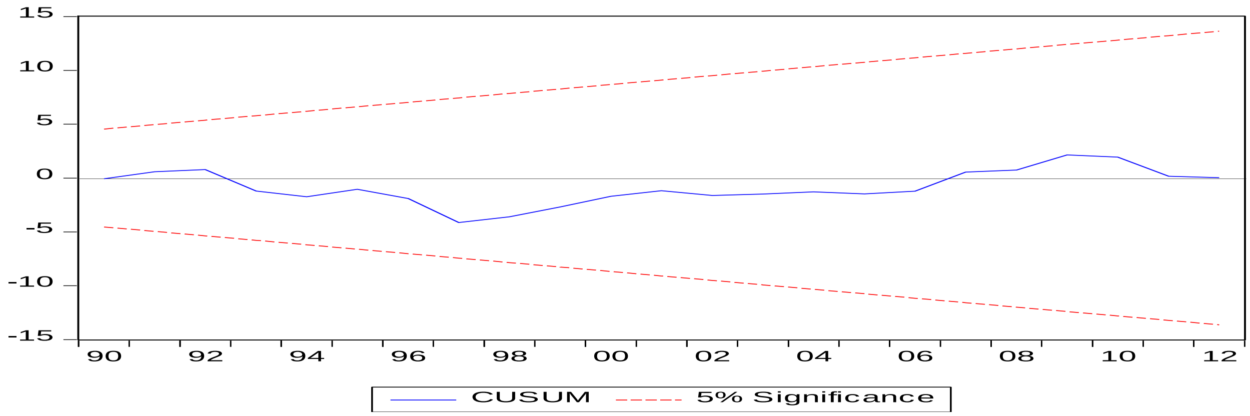


Figure 7 CUSUM

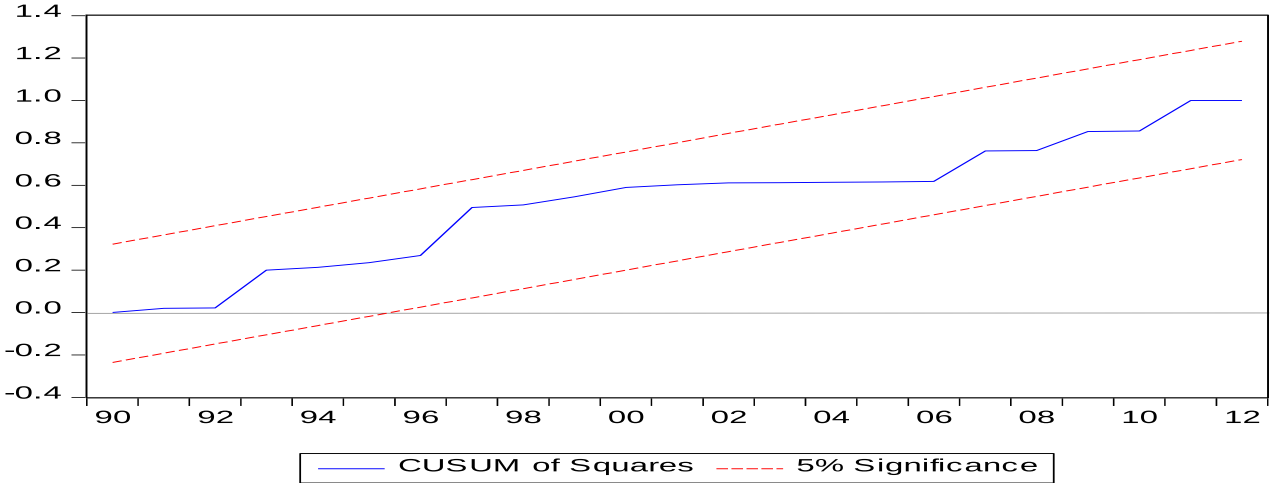


Figure 8 CUSUM of square

As shown above in Figure 7 and 8, both the CUSUM and CUSUM of Squares tests show that the model parameters are stable in the long run as the parameters lie within the 5% bounds. We now proceed with causality test results based on error correction granger causality (VEC Granger) and interpretation of the models.

4.6 Error Correction Based Granger Causality Analysis

Table 4.9 VEC Granger Results

	Error Correction Based Granger Causality Results					
	REGRESSORS					
REGRESSANDS	∑ΔLOG(PCGDP)	∑ΔLOG(PCEC)	∑ΔLOG(PCO2)	∑ΔLOG(GCF)	∑ΔLOG(LF)	ECT(-1)
ΔLOG(PCGDP)	----	-0.4515	**0.1047**	**-0.0727**	**-0.0115**	**-0.364**
ΔLOG(PCEC)	0.0483	----	0.0166	-0.0305	0.0008	-0.0567
ΔLOG(PCO2)	-0.1760	-0.1700	----	-0.1594	-0.0274	-0.2224
ΔLOG(GCF)	1.3803	-1.8829	0.2624	----	-0.0271	-0.4491
∑ΔLOG(LF)	6.0528	3.0835	-3.0505	-1.4721	-----	1.9503

Short Run	**Type of Direction**	**Long Run**	**Type of Direction**
PCEC ---- PCGDP	No granger causality	PCEC→ PCGDP	Unidirectional
PCO2 →PCGDP	Unidirectional	PCO2→ PCGDP	Unidirectional
PCEC ---- PCO2	No granger causality	PCEC ---- PCO2	No granger causality

-------- indicates no granger causality, → indicates unidirectional granger causality; ↔ denotes bi-directional granger causality.

Table 4.9 shows both short run and long run granger causality. The short run granger causality is determined by the t-test on the coefficient of the variables while the long run granger causalities are determined via the coefficients of the error correction term lagged one period. We immediately note that when log of PCGDP is the dependent variable, all variables jointly granger cause real GDP per capita in the long run at 1% significance level as indicated by the coefficient of ECT. In the short run however, only per capita energy consumption does not individually granger cause per capita GDP at, the rest of the variables granger cause per capital GDP.

4.7 Dynamic Causality Models

4.7.1 Variance Decomposition Analysis

In addition to Vector Error Correction Model (VECM) and Granger causality, Variance Decomposition Analysis (VDC) based on the VECM results was conducted and the figures below shows percentage variation in each variable due to shocks of other variables over time. In the long run, a shock to per capita energy consumption accounts for more than 6% of variation in per capita GDP a result consistent with the long run estimates of the VECM. In the short run however, a shock in per capita energy consumption only accounts for about 2% variation in per capita GDP again consistent with short run results of VECM that per capita energy consumption is not so significant in explaining per capita GDP fluctuations. Shocks to per capita GDP only account for about 3% of the variation in per capita energy consumption hence confirming results of VEC granger causality results that energy consumption explains more variation in per capita GDP than GDP per capita explains variation in per capita energy consumption in the long run.

A shock or impulse in per capita carbon emissions only account for less than 10% of the variation in per capita GDP both in the short and long run consistent with results of the VECM model. On the contrary shocks to per capita GDP do not appear to account for any variation in per capita carbon emissions. This result is in agreement with short run granger causality but not in the long run. Overall results of variance decomposition are in support of a unidirectional relationship running from per capita carbon emissions to per capita GDP and not the other way round.

An impulse in per capita carbon emissions does not appear to account for any variation in per capita energy consumption in both short run and long run, however innovations in per capita energy consumption accounts for over 50% variation in per capita carbon emissions and this result is consistent with granger causality results in the long run but not short run. Overall results of variance decomposition just like granger causality lean towards a unidirectional relationship running from per capita energy consumption to per capita carbon dioxide emissions in the short run.

Therefore, variance decomposition (VDC) results appear to support a long run unidirectional relationship running from per capita energy consumption to per capita GDP. This is because the percentage variation of per capita GDP due to energy consumption per capita is higher than the percentage variation of per capita energy consumption due to per capita GDP.

Interestingly, a shock to per capita GDP accounts for about 74% of variation in per capital GDP itself in in the short run and about 52% variation in per capita GDP in the long run. Shocks to Gross capital formation and labour force account for 21% and 14 % variation in per capita GDP in the long run respectively see Variance Decomposition table in **Appendix 3** under per capita GDP equation.

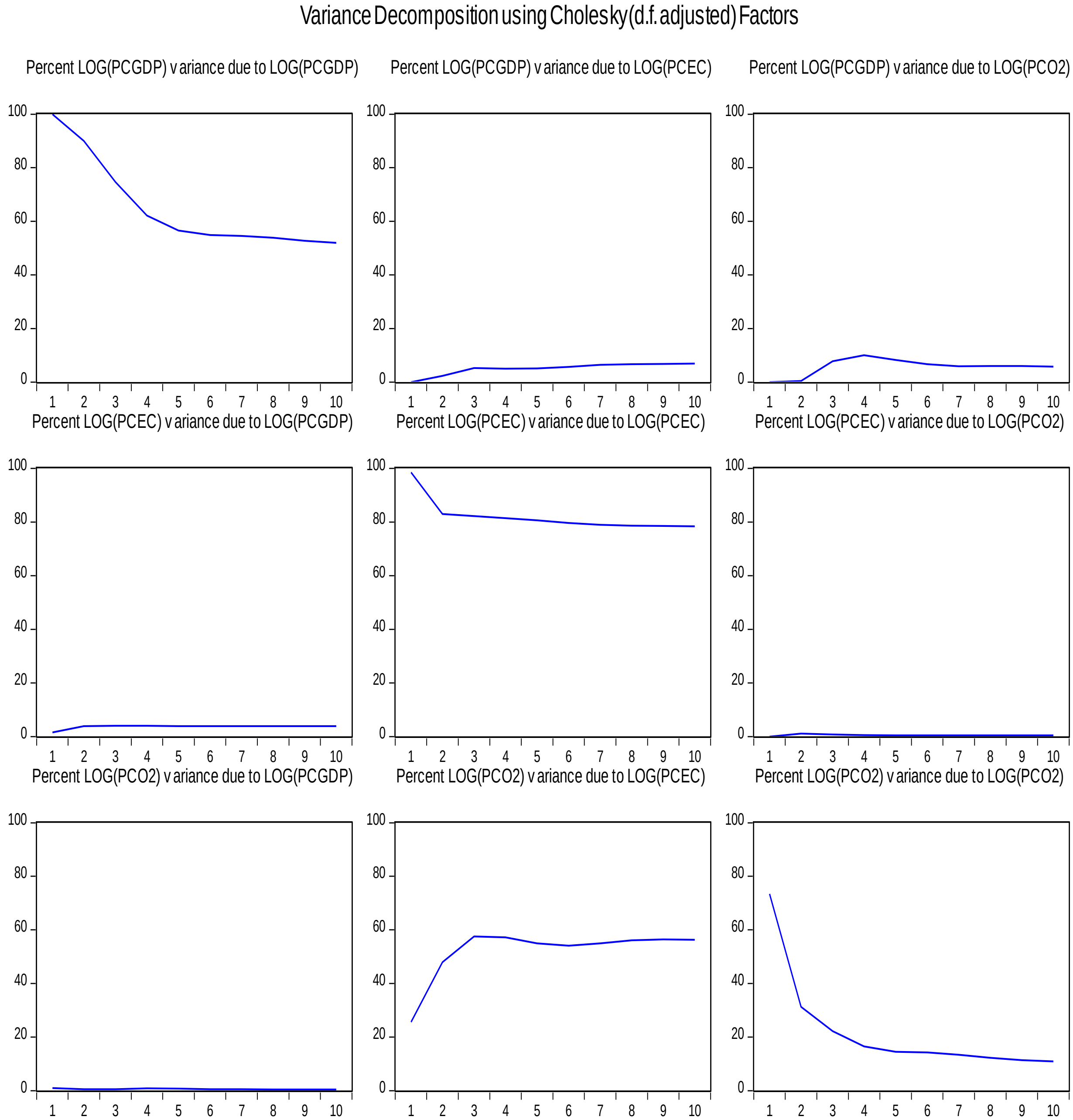


Figure 9 Variance Decomposition graphical representations

DISCUSSION OF RESULTS

5.0 Introduction

To begin with the model independent variables, explain about 69.96. % of the variation in the log of per capital GDP as shown by the R^2 under **table 4.7** On the other hand, the coefficient of the error correction term is -0.364 and is statistically significant at 1% level implying existence of a long run relationship among the variables. This implies that short run deviations from equilibrium are corrected to long run equilibrium at a rate 36.4% which is a period of about 2.7 years.

5.1 VEC Long run and Short Run results

Long Run: Results of Johansen cointegration rank revealed existence of one cointegrating relationship for the chosen model hence, an error correction model was conducted and below are the results of respective coefficients.

Per Capta Energy Consumption: We note that log of per capita energy consumption has a statistically significant positive impact on log of per capita GDP at 1% significance level, the estimated income elasticity of total energy consumption is 0.31, implying that ceteris paribus a 1% increase in total energy consumption increases per capita GDP by 0.31%. This result supports the growth hypothesis that energy consumption drives economic growth and is valid in the Zambian case in the long run. This result is also synonymous with findings of (Belloumi, 2009), (Tiwari, 2011) as well as indications from the physical and biophysical models that propose a positive relationship from energy consumption to economic growth. Hence this presents evidence that pursuance of energy conservation policies will reduce economic growth in the long run.

Carbon Dioxide Emissions: Carbon emissions per capita have a negative significant impact on per capita GDP at 5% level of significance. The elasticity of carbon emissions is -0.11, this suggests that ceteris paribus a 1% increase in carbon emissions reduces economic growth by 0.11% in the long run. This outcome is similar to findings of (Tiwari, 2011) and (Ang, 2008). This outcome could be because a persistent decline in environmental quality over a long period of time may generate negative externalities for the economy through reducing health human capital and productivity which ultimately further trickle down to economic growth. This observed negative relationship cannot be attributed to climate change related relationships as suggested in the Seventh National Development Plan because most developing countries such as Zambia have negligible carbon emissions.

Labour Force: Labour force was found to have a positive statistically significant impact on economic growth in the long run. The income elasticity of labour force was 0.05 implying a 1% rise in the labour force raise per capita GDP by 0.05%. This result is also affirmed by results of variance decomposition analysis and in tandem with classical growth theory that emphasize its role in economic growth.

Gross Capita Formation: As expected of gross capital formation had a positive statistically significant impact. The estimated income elasticity of gross capital formation stood at 0.16 which entails a 1% rise in the stock of capital raises per capita GDP by 0.16%. This results is in line with economic growth theory that emphasize capital accumulations as vital for growth.

Short Run: In the short run, results indicate that per capita energy consumption was insignificant at whereas per capita carbon emissions, gross capital formation and labour force were found to be statistically significant at 5%, 1% and 5% respectively. Contrary to the long run result, carbon emissions are positively related to economic growth in the short run implying that carbon emission reduction measures would result in reduced economic growth. An explanation for this result could be due to the positive correlation due to increased economic activities especially in the manufacturing and mining sectors which is typical in most growing economies.

Labour force was also found to have a negative significant impact on per capita GDP in the short run. This result could be due to the fact that in the short run part of the labour force especially in a developing country like Zambia is unskilled and therefore low productivity works against economic growth, but over time (in the long run) as skills are acquired the impact on per capita GDP tends to be significant. This result is in line with findings of (Shahid, 2014) who found that labour force participation in Pakistan had a negative relationship in the short run and he recommended policies such as training that build skills of existing labour force to increase productivity.

5.2 Error Correction based Granger Causality Results

Results for the existence of direction of granger causality indicate that all the independent variables granger-cause per capita GDP in the long run as evidenced by the statistically significant error correction term in Table 4.9. Furthermore, all variables granger cause per capita GDP in the short run except per capita energy consumption. These results are contrary to what (Zhang, Xing-Ping, and Xiao-Mei Cheng 2009) and (Soytas, Ugur, and Ramazan Sari, 2009) found, where economic growth was not affected by carbon emissions. Therefore, we fail to reject the growth hypothesis at granger causality framework just like in the long run VEC model, that is energy consumption drives economic growth in the long run but not in the short run. However, we reject the conservation hypothesis which suggests that economic growth is the one that drives energy as Table 4.9 show that per capita GDP does not granger cause energy consumption both in the short and long run.

The feedback and neutrality hypotheses are also not valid at granger causality framework as the relationship between energy consumption is unidirectional from energy to per capita GDP. These results are contrary to results obtained by Ozturk & Acaravci (2010) where none of the independent variables granger caused per capita GDP in the case of Turkey.

We also note that there exists a unidirectional granger causality from carbon emissions to per capita GDP both in the short and long run Table 4.9 Finally, whereas both per capita energy consumption and per capita carbon dioxide emissions granger cause per capita GDP in the long run, energy is insignificant in the short run suggesting the two variables energy and carbon emissions are not related at in the short run.

5.3 Variance Decomposition Analysis Results

Overall results indicate that production function variables capital and labour account for much of the variation in per capita GDP relative to per capita carbon emissions and per capita energy consumption. This result is similar to findings of Wolde-Rufael (2009) who applied the variance decomposition analysis to evaluate how important the causal impact of energy consumption is on economic growth relative to labor and capital. His conclusion was that energy isn’t that vital in contributing to output growth in 15 out of 17 African countries analyzed and more so when compared with capital and labor. However, in this analysis despite capital and labour accounting for a significant amount of variation, variance decomposition results show that per capita energy consumption is also key particularly in the long run where a shock in per capita energy consumption accounts for slightly over 6% of the variation in per capita GDP affirming the VECM results.

CONCLUSION AND POLICY IMPLICATIONS

6.0 Conclusion

This study looked at the existence of long run relationships among per capita GDP, per capita carbon emissions, per capita energy consumption, gross capital formation and labour force. Results from cointegration analysis using VECM indicate presence of long run relationship among the variables at all conventional levels of significance and results further reveal that contrary to conventional growth theory and some studies done, energy consumption is key in driving economic growth especially in the long run, further, carbon emissions are also key as their impact is significant both in short and long run. Results based on granger causality show evidence of a granger causality running from carbon emissions to per capita GDP in the short suggesting that environmental conservation policies aimed at reducing carbon emissions will result in sacrificing economic growth. In the long run however, the relationship is inverse implying that increased carbon emissions reduce economic growth. This implies the Zambian economy cannot pursue energy conservation policies and carbon emission reduction policies in the long run as this would slow down economic growth. This calls for policy makers to consolidate the policy framework to ensure the economy is grown sustainably

6.1 Policy Recommendations

This study focused on establishing existence of long run relationships among per capita GDP, per capita energy consumption, per capita carbon emissions, gross capital formation and labour force in the Zambian case as well as to determine the direction of granger causality among the variables. The overall results of the VECM, error correction-based granger causality and variance decomposition analysis (VDC) show that energy consumption is key in driving economic growth in the long run. Further, production function variables still remain key in explaining fluctuations in economic growth while carbon emissions are also significant both in the short and long run.

Granger causality results reveal evidence of a long run unidirectional causality running from per capita energy consumption to per capita GDP, hence pursuance of energy conservation policies or energy rationing as evidenced in 2015 has an effect of reducing per capita GDP in the long run. Therefore, it is vital for policy makers to make investments in expanding energy generation capacity of the main power off taker ZESCO. Secondly, Independent Power Producers (IPPs) must be taken on board and promoted so as to ensure that in the long term the country has sufficient amounts of energy to drive the economy. Thirdly, there is need to expand to more reliable and renewable energy sources, as hydroelectric energy is dependent on rainfall which in some cases is erratic and to prevent environmental degradation. Lastly consideration must be made on possible construction of hydro power plants in the Northern Circuit of Zambia which is closer to the equator and receives a good amount of rainfall. This will prevent the Zambian economy from facing a situation of power rationing in the long term which according to our findings will negatively impact economic growth.

The VECM results together with long run estimates indicate that carbon emissions per capita have a negative significant impact in the long run and a positive significant impact in the short run. Therefore, an increase in carbon emissions works to reduce per capita GDP in the long run. Granger causality results however show that there is a positive unidirectional relationship running from carbon emissions to per capita GDP both in the short run. The implications of this are that pursuance of environmental conservation policies will mean sacrificing some of the economic growth. Hence this presents a tradeoff that policy makers must not ignore even as they try to sustainably grow the economy and particular attention must be given to the extent to which carbon emission reduction policies are implemented in the short run. In the long run however, the relationship is negative hence pursuance of carbon emission policies is desirable and will work to improve economic growth. We also recommend that there be a shift from using carbon producing energy sources to renewable alternatives such as solar, biofuels and wind that do not generate carbon emissions in major production activities.

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REFERENCES

Ang, J.B. (2008). “Economic Development, Pollutant Emissions and Energy Consumption in Malaysia”. Journal of Policy Modelling, 30: 271-278.

Arrow, K. J. (1962). “The economic implications of learning-by-doing.” Review of Economic Studies 29: 155-173.

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics 22, 615– 625.

Belloumi, M. (2009). Energy Consumption and GDP in Tunisia: Cointegration and Causality Analysis. Elsevier, Energy Economics (37), p. 2745–2753.

Bildirici, M. E., 2013. The Analysis of the Relationship between Economic Growth and Electricity Consumption in Africa by ARDL Method; Energy Economics Letters, 1(1), pp. 1-14.

Chitumbo, B. S. (2016). Causality Analysis between Electricity Consumption, and Economic Growth: Evidence from Zambia.

Cleveland, C. J. and D. I. Stern (1999). “Indicators of natural resource scarcity: a review and synthesis.” In: J. C. J. M. van den Bergh (ed.), Handbook of Environmental and Resource Economics. Cheltenham: Edward Elgar.

De Bruyn, S.M. and J. B. Opschoor (1997). “Developments in the throughput-income Relationship: theoretical and empirical observations.” Ecological Economics 20: 255-268.

Engle, R. E. and C. W. J. Granger (1987). “Cointegration and error-correction: representation, Estimation, and testing.” Econometrica 55: 251-276.

EPR, 2018. Independent Power Producers and Power Sector Reform: Some Lessons from Comparative Experience in Sub-Saharan Africa.

Fatai, K. Oxley, L. Scrimgeour, F. (2002). Energy Consumption and empoyement in New Zealand: Searching for Causality. Paper presented at NZAE conference.

Fodha, M. Zaghdoud, O. (2010). Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve.

Fuinhas and Maques (2011). Energy consumption and economic growth nexus in Portugal, Italy, Greece, Spain and Turkey: An ARDL bounds test approach (1965–2009).

Gever J., R. K. Kaufmann, D. Skole, and C. Vörösmarty (1986). Beyond Oil: The Threat to Food and Fuel in the Coming Decades. Cambridge, MA: Ballinger.

Hall, C. A. S., D. Lindenberger, R. Kümmel, T. Kroeger, and W. Eichhorn (2001). "The need to reintegrate the natural sciences and economics." Bioscience 51: 663-673.

Hall, C. A. S., P. Tharakan, J. Hallock, C. Cleveland, and M. Jefferson (2003). "Hydrocarbons and the evolution of human culture." Nature 426: 318-322.

He, J. Richard, P. (2009). Environmental Kuznets Curve for CO2 in Canada, a Working paper.

Hicks, J. R. (1932). The Theory of Wages. London: Macmillan.

Hong, T. Wijeweera, A. Charles, M, B, (2011). Energy and Economic Growth – The case of Australia. Business School, Southern Cross University.

Jamil, F. N. & Eatzaz, A., 2010. The relationship between electricity consumption, electricity prices, and GDP in Pakistan. Elsevier, Energy Policy(38), p. 6016–6025.

Jaupllari, S. Zoto, O. (2013). Understanding Industrial Innovation and Upgrade from Modularization's Perspective, Journal of Knowledge Management, Economics and Information Technology.

Johansen S, Juselius K, 1990. Maximum likelihood estimation and inference on cointegration ‑ with applications to the demand for money. Oxford Bulletin of Economics and Statistics; p52:169‑210.

Johansen S. 1988. Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control; p12:231‑54.

Kraft J, Kraft A. On the relationship between energy and GNP. Journal of energy and development 1978.

Lau LS, Choong CK, Eng YK, 2014. Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter?. Energy Policy.

Lorde, T., Waithe, K. & Francis, B., 2010. The importance of electrical energy for economic growth in Barbados. Eselvier, Volume 32, pp. 1411-1420.

Mallick, H., 2007. Does Energy Consumption Fuel Economic Growth in India. [Online] Available at: http://www.cdc.edu [Accessed 7th January, 2018].

MEWD, 2015. Opportunities in the energy sector in Zambia. Government of the republic of Zambia.

MMEWD, 2015. Energy Policy in Zambia, Ministry of Mines, Energy and Water Development, Zambia.

Narayan P.K. 2005. The saving and investment nexus for China: evidence from Cointegration tests. Applied Economics. p37:1979‑90.

Onafowora OA, Owoye O, 2014. Bounds testing approach to analysis of the environment Kuznets curve hypothesis. Energy Econ.

Ozturk, I. and Acaravci, A. 2010. CO2 emissions, energy consumption and economic growth in Turkey; Renewable and Sustainable Energy Reviews 14 (2010) 3220‑3225.

Pesaran HM, Shin Y, 1999. Autoregressive distributed lag modelling approach to Cointegration analysis. In: Storm S, editor. Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium.

Pesaran, H.M., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of long-run relationships. Journal of Applied Econometrics 16, 289–326.

Romer, D. (2010). Advanced Macroeconomics. 4 ed. California: McGraw-Hill.

Shahid, M. (2014). Impact of Labour Force Participation on Economic Growth in Pakistan; National University of Modern Language Press, Islamabad.

Shyamal and Bhattacharya (2004). Causality between energy consumption and economic growth in India: a note on conflicting results.

Soana, J.T. and Olta, Z. (2013). An Assessment of Demand for Imports through the VECM Model. Faculty of Economics, European University of Tirana, Albania

Soytas, U., Sari, R., Ewing, B.T., 2007. Energy consumption, income, and carbon emissions in the United States. Ecological Economics 62, 482–489.

Stern, D.I. Cleveland, C.J. (2004). Energy and Economic Growth. Rensselaer Working Paper in Economics.

Stern D.I. 2004. The rise and fall of the environmental Kuznets curve. World Development

Stern, D. I. (1997a). “Limits to substitution and irreversibility in production and consumption: a neoclassical interpretation of ecological economics.” Ecological Economics, 21: 197-215.

Stern, D. I. (1999). “Is energy cost an accurate indicator of natural resource quality?” Ecological Economics 31: 381-394.

Swanson, E. Saviano, C. Li, Z. (2015). Schwarz Information criterion versus Alkaike Information Criterion.

Tiwari, A.K. (2011). Energy Consumption, Co2 Emissions and Economic Growth: A Revisit of The Evidence From India.

Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregressions with Possibly integrated processes. Journal of Econometrics 66, 225–250.

Toman, M. A. and B. Jemelkova (2003). "Energy and economic development: an assessment of the state of knowledge." Energy Journal 24(4): 93-112.

Wolde-Rufael, 2005. Energy Demand and economic growth: The African Experience. Journal of Policy Modelling, Issue 27, pp. 891-903.

Wolde-Rufael, Y., 2009. Energy Consumption and Economic Growth: Experience of African Countries revisited. Energy Economics, Issue 31, pp. 217-224.

WRI CAIT, (2015). World Resources Institute Climate Analysis Indicators Tool; Working paper 2.0.

ZDA, 2014. Energy sector Profile; Zambia Development Agency. Government printers.

APPENDIX 1

ADF UNIT ROOT RESULTS IN LEVELS (INTERCEPT ONLY)

Null Hypothesis: PCGDP has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.735576	0.4044
Test critical values:	1% level	-3.653730	
	5% level	-2.957110	
	10% level	-2.617434	

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

Null Hypothesis: PCEC has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.880129	0.3377
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

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

Null Hypothesis: PCO2 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.122478	0.2374
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

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

Null Hypothesis: LF has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.484279	0.5303
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

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

Null Hypothesis: GCF has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		1.062369	0.9964
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

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

UNIT ROOT RESULTS IN LEVELS (INTERCEPT AND TREND)

Null Hypothesis: PCGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.569040	0.9751
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

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

Null Hypothesis: PCEC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.223813	0.4631
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

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

Null Hypothesis: PCO2 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.342291	0.0753
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

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

Null Hypothesis: LF has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.860421	0.6545
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

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

Null Hypothesis: GCF has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.296532	0.8733
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

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

UNIT ROOT RESULTS IN 1ST DIFFERENCE (INTERCEPT ONLY)

Null Hypothesis: D(PCGDP) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.666554	0.0090
Test critical values:	1% level	-3.626784	
	5% level	-2.945842	
	10% level	-2.611531	

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

Null Hypothesis: D(PCEC) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.334253	0.0000
Test critical values:	1% level	-3.626784	
	5% level	-2.945842	
	10% level	-2.611531	

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

Null Hypothesis: D(PCO2) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.406176	0.0000
Test critical values:	1% level	-3.626784	
	5% level	-2.945842	
	10% level	-2.611531	

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

Null Hypothesis: D(LF) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.074118	0.0000
Test critical values:	1% level	-3.626784	
	5% level	-2.945842	
	10% level	-2.611531	

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

Null Hypothesis: D(GCF) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.101499	0.0000
Test critical values:	1% level	-3.626784	
	5% level	-2.945842	
	10% level	-2.611531	

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

UNIT ROOT RESULTS IN 1ST DIFFERENCE (INTERCEPT AND TREND)

Null Hypothesis: D(PCGDP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.471547	0.0004
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

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

Null Hypothesis: D(PCEC) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.444450	0.0000
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

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

Null Hypothesis: D(PCO2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.368709	0.0000
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

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

Null Hypothesis: D(LF) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.019655	0.0001
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

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

Null Hypothesis: D(GCF) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.005698	0.0000
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

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

APPENDIX 2
LAG SELECTION CRITERION

VAR Lag Order Selection Criteria
Endogenous variables: PCGDP PCEC PCO2 LF GCF
Exogenous variables: C
Date: 05/08/19 Time: 14:24
Sample: 1980 2017
Included observations: 35

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1576.319	NA	1.20e+33	90.36109	90.58328	90.43779
1	-1435.020	234.1527*	1.59e+30	83.71543	85.04859*	84.17564*
2	-1408.190	36.79525	1.57e+30*	83.61087	86.05498	84.45458
3	-1379.003	31.68882	1.60e+30	83.37160*	86.92669	84.59882

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

JOHANSEN COINTEGRATION TEST

Date: 05/08/19 Time: 14:26
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
Trend assumption: No deterministic trend
Series: PCGDP PCEC PCO2 LF GCF
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 *	0.701887	81.99590	60.06141	0.0003
At most 1	0.482412	38.42572	40.17493	0.0742
At most 2	0.170240	14.71702	24.27596	0.4781
At most 3	0.137411	7.998747	12.32090	0.2368
At most 4	0.071672	2.677345	4.129906	0.1203

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

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.701887	43.57017	30.43961	0.0007
At most 1	0.482412	23.70870	24.15921	0.0574
At most 2	0.170240	6.718275	17.79730	0.8374
At most 3	0.137411	5.321402	11.22480	0.4333
At most 4	0.071672	2.677345	4.129906	0.1203

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

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

VEC LONG RUN AND SHORT RUN ELASTICITIES

Vector Error Correction Estimates
Date: 05/07/19 Time: 18:53
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LOG(PCGDP(-1))	1.000000
LOG(PCEC(-1))	-0.307837 (0.05287) [-5.82304]
LOG(PCO2(-1))	0.105018 (0.04815) [2.18108]
LOG(LF(-1))	-0.049108 (0.00624) [-7.86677]
LOG(GCF(-1))	-0.160123 (0.01847) [-8.67111]

Error Correction:	D(LOG(PC...	D(LOG(PCEC))	D(LOG(PCO2))	D(LOG(LF))	D(LOG(GCF))
CointEq1	-0.364044 (0.05198) [-7.00420]	-0.056710 (0.04742) [-1.19600]	-0.222418 (0.39018) [-0.57004]	1.950311 (2.10422) [0.92686]	-0.449070 (0.49322) [-0.91049]
D(LOG(PCGDP(-1)))	0.191457 (0.11381) [1.68227]	0.048337 (0.10383) [0.46555]	-0.176029 (0.85437) [-0.20603]	6.052834 (4.60756) [1.31367]	1.380313 (1.07998) [1.27809]
D(LOG(PCEC(-1)))	-0.451479 (0.36239) [-1.24584]	-0.040636 (0.33061) [-0.12291]	-0.170039 (2.72048) [-0.06250]	30.08357 (14.6713) [2.05050]	-1.882956 (3.43886) [-0.54755]
D(LOG(PCO2(-1)))	0.104724 (0.04689) [2.23315]	0.016596 (0.04278) [0.38792]	0.224020 (0.35205) [0.63634]	-3.050450 (1.89855) [-1.60673]	0.262439 (0.44501) [0.58974]
D(LOG(LF(-1)))	-0.011525 (0.00467) [-2.47018]	0.000769 (0.00426) [0.18069]	-0.027402 (0.03502) [-0.78236]	0.228528 (0.18888) [1.20989]	-0.027080 (0.04427) [-0.61165]
D(LOG(GCF(-1)))	-0.072719 (0.02242) [-3.24407]	-0.030485 (0.02045) [-1.49068]	-0.159366 (0.16828) [-0.94703]	-1.472089 (0.90752) [-1.62211]	-0.134890 (0.21272) [-0.63413]
R-squared	0.699617	-0.058225	-0.068296	0.219313	0.041653
Adj. R-squared	0.649554	-0.234596	-0.246345	0.089199	-0.118072
Sum sq. resids	0.023202	0.019311	1.307577	38.02890	2.089324
S.E. equation	0.027810	0.025371	0.208772	1.125891	0.263902
F-statistic	13.97452	-0.330127	-0.383578	1.685540	0.260779
Log likelihood	81.16497	84.46931	8.594390	-52.06868	0.158424
Akaike AIC	-4.175832	-4.359406	-0.144133	3.226038	0.324532
Schwarz SC	-3.911912	-4.095486	0.119787	3.489958	0.588452
Mean dependent	-0.000245	-0.009414	-0.076406	-0.164598	0.069158
S.D. dependent	0.046977	0.022834	0.187005	1.179735	0.249579

Determinant resid covariance (dof adj.)	5.04E-10
Determinant resid covariance	2.02E-10
Log likelihood	146.3686
Akaike information criterion	-6.187146
Schwarz criterion	-4.647614
Number of coefficients	35

ERROR CORRECTION GRANGER CAUSALITY ESTIMATES
PER CAPITA GROSS DOMESTIC PRODUCT (PCGDP) EQUATION

Dependent Variable: D(LOG(PCGDP))
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/07/19 Time: 21:07
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
D(LOG(PCGDP)) = C(1)*(LOG(PCGDP(-1)) - 0.307837003021 *LOG(PCEC(-1)) + 0.105018120179*LOG(PCO2(-1)) - 0.0491080676277*LOG(LF(-1)) - 0.160123270187*LOG(GCF(-1))) + C(2)*D(LOG(PCGDP(-1))) + C(3)*D(LOG(PCEC(-1))) + C(4) *D(LOG(PCO2(-1))) + C(5)*D(LOG(LF(-1))) + C(6)*D(LOG(GCF(-1)))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.364044	0.051975	-7.004197	0.0000
C(2)	0.191457	0.113809	1.682272	0.1029
C(3)	-0.451479	0.362387	-1.245845	0.2225
C(4)	0.104724	0.046895	2.233152	0.0331
C(5)	-0.011525	0.004666	-2.470177	0.0194
C(6)	-0.072719	0.022416	-3.244069	0.0029

PER CAPITA ENERGY CONSUMPTION (PCEC) EQUATION

Dependent Variable: D(LOG(PCEC))
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/07/19 Time: 21:25
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
D(LOG(PCEC)) = C(7)*(LOG(PCGDP(-1)) - 0.307837003021*LOG(PCEC(-1)) + 0.105018120179*LOG(PCO2(-1)) - 0.0491080676277*LOG(LF(-1)) - 0.160123270187*LOG(GCF(-1))) + C(8)*D(LOG(PCGDP(-1))) + C(9)*D(LOG(PCEC(-1))) + C(10)*D(LOG(PCO2(-1))) + C(11) *D(LOG(LF(-1))) + C(12)*D(LOG(GCF(-1)))

	Coefficient	Std. Error	t-Statistic	Prob.
C(7)	-0.056710	0.047417	-1.195997	0.2411
C(8)	0.048337	0.103828	0.465548	0.6449
C(9)	-0.040636	0.330606	-0.122912	0.9030
C(10)	0.016596	0.042782	0.387918	0.7008
C(11)	0.000769	0.004256	0.180686	0.8578
C(12)	-0.030485	0.020450	-1.490681	0.1465

PER CAPITA CARBONDIOXIDE EMISSIONS (PCO2) EQUATION

Dependent Variable: D(LOG(PCO2))
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/07/19 Time: 21:29
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
D(LOG(PCO2)) = C(13)*(LOG(PCGDP(-1)) - 0.307837003021*LOG(PCEC(-1)) + 0.105018120179*LOG(PCO2(-1)) - 0.0491080676277*LOG(LF(-1)) - 0.160123270187*LOG(GCF(-1))) + C(14)*D(LOG(PCGDP(-1))) + C(15)*D(LOG(PCEC(-1))) + C(16)*D(LOG(PCO2(-1))) + C(17)*D(LOG(LF(-1))) + C(18)*D(LOG(GCF(-1)))

	Coefficient	Std. Error	t-Statistic	Prob.
C(13)	-0.222418	0.390182	-0.570036	0.5729
C(14)	-0.176029	0.854373	-0.206033	0.8382
C(15)	-0.170039	2.720480	-0.062503	0.9506
C(16)	0.224020	0.352045	0.636338	0.5294
C(17)	-0.027402	0.035025	-0.782360	0.4401
C(18)	-0.159366	0.168280	-0.947032	0.3512

LABOUR FORCE (LF) EQUATION

Dependent Variable: D(LOG(LF))
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/07/19 Time: 21:38
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
D(LOG(LF)) = C(19)*(LOG(PCGDP(-1)) - 0.307837003021*LOG(PCEC(-1)) + 0.105018120179*LOG(PCO2(-1)) - 0.0491080676277*LOG(LF(-1)) - 0.160123270187*LOG(GCF(-1))) + C(20)*D(LOG(PCGDP(-1))) + C(21)*D(LOG(PCEC(-1))) + C(22)*D(LOG(PCO2(-1))) + C(23)*D(LOG(LF(-1))) + C(24)*D(LOG(GCF(-1)))

	Coefficient	Std. Error	t-Statistic	Prob.
C(19)	1.950311	2.104217	0.926858	0.3614
C(20)	6.052834	4.607558	1.313675	0.1989
C(21)	30.08357	14.67130	2.050504	0.0491
C(22)	-3.050450	1.898548	-1.606728	0.1186
C(23)	0.228528	0.188884	1.209885	0.2358
C(24)	-1.472089	0.907517	-1.622106	0.1152

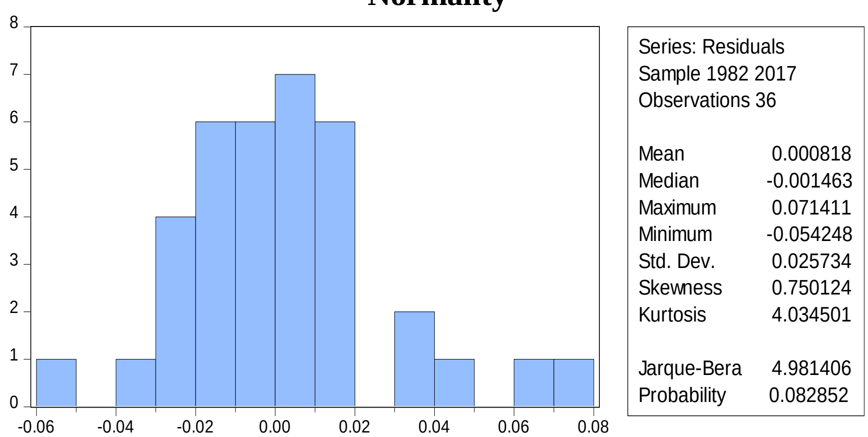
GROSS CAPITAL FORMATION (GCF) EQUATION

Dependent Variable: D(LOG(GCF))
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/07/19 Time: 21:44
Sample (adjusted): 1982 2017
Included observations: 36 after adjustments
D(LOG(GCF)) = C(25)*(LOG(PCGDP(-1)) - 0.307837003021*LOG(PCEC(
-1)) + 0.105018120179*LOG(PCO2(-1)) - 0.0491080676277*LOG(LF(
-1)) - 0.160123270187*LOG(GCF(-1))) + C(26)*D(LOG(PCGDP(-1))) +
C(27)*D(LOG(PCEC(-1))) + C(28)*D(LOG(PCO2(-1))) + C(29)
*D(LOG(LF(-1))) + C(30)*D(LOG(GCF(-1)))

	Coefficient	Std. Error	t-Statistic	Prob.
C(25)	-0.449070	0.493215	-0.910495	0.3698
C(26)	1.380313	1.079983	1.278088	0.2110
C(27)	-1.882956	3.438862	-0.547552	0.5881
C(28)	0.262439	0.445008	0.589740	0.5598
C(29)	-0.027080	0.044273	-0.611647	0.5454
C(30)	-0.134890	0.212716	-0.634133	0.5308

RESIDUAL DIAGNOSTIC TESTS

Normality



LM Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.252637	Prob. F(2,21)	0.7791
Obs*R-squared	0.728356	Prob. Chi-Square(2)	0.6948

White Heteroscedasticity Test

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	0.540078	Prob. F(7,23)	0.7952
Obs*R-squared	4.376194	Prob. Chi-Square(7)	0.7356
Scaled explained SS	4.424146	Prob. Chi-Square(7)	0.7298

APPENDIX 3
DATA SET

YEAR	PCEC	PCGDP	GCF	PCO2	LF
1980	779.80	506.58	904437446.98	0.61	2257790.17
1981	764.67	521.82	774279129.19	0.53	2333479.89
1982	756.61	489.52	649152051.68	0.53	2423779.14
1983	744.02	467.78	456711675.93	0.46	2518395.55
1984	728.89	444.72	399296267.90	0.44	2615239.31
1985	718.70	435.87	335388770.69	0.41	2712875.13
1986	707.52	429.49	396304776.43	0.43	2814072.42
1987	700.14	422.66	287999226.85	0.40	2915570.85
1988	714.85	448.23	412919382.24	0.42	3014968.09
1989	693.56	419.57	431723594.98	0.38	3124965.64
1990	669.19	405.77	646542857.99	0.33	3236006.40
1991	669.69	392.54	372003595.81	0.29	2825.31
1992	662.72	390.53	393295558.69	0.35	2883.18
1993	647.03	380.59	492418552.01	0.28	2945.18
1994	635.33	321.83	482009907.96	0.22	3071.36
1995	629.81	304.79	553375859.07	0.21	3199.30
1996	608.10	317.43	420099670.19	0.23	3379.47
1997	617.21	319.12	569815649.64	0.24	3544.29
1998	606.51	304.74	530655092.72	0.22	3722.05
1999	591.26	303.21	507204773.80	0.19	3813.78
2000	590.35	305.87	564722478.43	0.18	3910.19
2001	593.34	312.69	691097671.25	0.19	3969.17
2002	597.53	314.97	813823877.97	0.19	4137.64
2003	601.08	322.84	1106675349.95	0.20	4331.72
2004	602.14	331.59	1354807660.58	0.19	4374.12
2005	604.79	340.08	1699355412.60	0.20	4296.61
2006	604.01	356.94	3465950752.92	0.19	4417.57
2007	588.45	375.91	3931616216.40	0.18	4565.75

2008	591.17	393.52	5955965858.10	0.17	4821.12
2009	589.88	417.29	4805344057.46	0.14	4936.13
2010	594.71	446.72	6054883258.04	0.16	4796.40
2011	600.95	457.57	7998333992.53	0.18	5130.87
2012	614.00	477.58	8081500236.82	0.21	5493.74
2013	551.04	494.07	9530700940.92	0.08	5684.40
2014	545.28	503.09	9453592318.08	0.07	5766.72
2015	539.52	505.94	8984629530.77	0.06	5899.13
2016	533.75	508.37	9165299155.08	0.05	6831.80
2017	544.86	517.23	9335855935.80	0.03	6231.28

VARIANCE DECOMPOSITION ANALYSIS TABLE

Variance Decomposition of LOG(PCGDP):

Period	S.E.	LOG(PCGDP)	LOG(PCEC)	LOG(PCO2)	LOG(LF)	LOG(GCF)
1	0.030965	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.046959	90.00536	2.251098	0.438120	0.000505	7.304913
3	0.061181	74.63918	5.252708	7.826510	3.953499	8.328105
4	0.074866	62.09928	4.944343	10.01003	12.99208	9.954264
5	0.086805	56.57729	5.065711	8.186878	15.94152	14.22861
6	0.097348	54.89810	5.698867	6.606795	14.63060	18.16564
7	0.106266	54.52233	6.375895	5.891370	13.35828	19.85213
8	0.114199	53.84563	6.702141	5.959605	13.24493	20.24769
9	0.121834	52.79032	6.769406	6.014683	13.88425	20.54134
10	0.129177	51.99836	6.823683	5.749876	14.22612	21.20196

Variance Decomposition of LOG(PCEC):

Period	S.E.	LOG(PCGDP)	LOG(PCEC)	LOG(PCO2)	LOG(LF)	LOG(GCF)
1	0.013484	1.534376	98.46562	0.000000	0.000000	0.000000
2	0.020038	3.840498	82.97998	1.067796	0.246078	11.86565
3	0.025623	3.983127	82.14528	0.717048	0.264644	12.88990
4	0.029975	3.930719	81.38770	0.525329	0.222242	13.93401
5	0.033837	3.819077	80.63617	0.417741	0.291085	14.83592
6	0.037483	3.814790	79.62051	0.414228	0.268045	15.88243
7	0.040892	3.863177	78.91835	0.428798	0.225269	16.56441
8	0.043981	3.893015	78.61982	0.401664	0.194761	16.89074
9	0.046798	3.888261	78.48852	0.365679	0.179617	17.07792
10	0.049453	3.875359	78.32522	0.341571	0.175889	17.28197

Variance Decomposition of LOG(PCO2):

Period	S.E.	LOG(PCGDP)	LOG(PCEC)	LOG(PCO2)	LOG(LF)	LOG(GCF)
1	0.065967	0.976992	25.55730	73.46571	0.000000	0.000000
2	0.117708	0.466763	47.91524	31.27093	3.580319	16.76675
3	0.139960	0.508128	57.53653	22.17443	3.448401	16.33251
4	0.163138	0.806228	57.22829	16.52809	7.682902	17.75449
5	0.188600	0.704269	55.02462	14.53923	8.122981	21.60890
6	0.213408	0.550201	54.06539	14.22385	6.599827	24.56073
7	0.233148	0.461102	54.96000	13.33398	5.609186	25.63573
8	0.249023	0.426601	56.07272	12.23695	5.318696	25.94503
9	0.264216	0.421840	56.41978	11.38596	5.482875	26.28955
10	0.279768	0.398725	56.30703	10.95297	5.450505	26.89077

Variance Decomposition of LOG(LF):

Period	S.E.	LOG(PCGDP)	LOG(PCEC)	LOG(PCO2)	LOG(LF)	LOG(GCF)
1	1.177175	0.928452	21.70001	2.976324	74.39521	0.000000
2	1.736756	0.523047	10.08466	6.021530	67.69059	15.68017
3	2.210096	0.334812	6.230170	9.048244	59.08224	25.30453
4	2.576248	0.285105	4.610802	10.66853	53.84842	30.58713
5	2.878943	0.246419	3.714617	10.89412	51.88273	33.26211
6	3.162683	0.206964	3.084615	10.65994	51.52942	34.51906
7	3.438801	0.176972	2.612435	10.60178	51.15969	35.44913
8	3.696792	0.158896	2.266645	10.79379	50.37487	36.40580
9	3.930878	0.148822	2.013821	10.98700	49.60564	37.24472
10	4.146882	0.139539	1.817158	11.04566	49.16582	37.83182

Variance Decomposition of LOG(GCF):

Period	S.E.	LOG(PCGDP)	LOG(PCEC)	LOG(PCO2)	LOG(LF)	LOG(GCF)
1	0.250721	0.182666	0.669105	0.652195	13.65011	84.84593
2	0.291264	0.164935	0.600231	0.513382	17.35259	81.36886
3	0.331119	0.136004	0.557216	0.456109	19.42117	79.42950
4	0.367303	0.113012	0.468205	0.469630	22.02453	76.92462
5	0.400098	0.096152	0.416074	0.436995	24.22149	74.82929
6	0.428140	0.089438	0.388502	0.385917	25.66811	73.46803
7	0.453750	0.088269	0.378395	0.346555	26.51705	72.66973
8	0.478643	0.085409	0.368293	0.324352	27.16541	72.05654
9	0.503059	0.080424	0.354368	0.313854	27.81043	71.44093
10	0.526306	0.076027	0.341240	0.300464	28.41901	70.86326

Cholesky Ordering: LOG(PCGDP) LOG(PCEC) LOG(PCO2) LOG(LF) LOG(GCF)