DECLARATION

I hereby declare that this submission is my own work towards the degree of Master of Philosophy (Economics) and that, to the best of my knowledge, it contains no material previously published by another person, or materials which has been accepted for the award of any other degree of the University, except where acknowledgement has been made in the text.

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DEDICATION

I dedicate this thesis to GOD ALMIGHTY and to my lovely parents. I also dedicate this thesis to Dr. E. F. Oteng-Abayie for his brotherly love, Rev. Dr. Lazarus Akaburi, Mr. Akolgo Ayine, Mr. Solomon Aboagye, Mr. John Asaana, mama Comfort Akambonbire and Napoleon Dillon. I appreciate you for all you sacrificed for me.

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ABSTRACT

This study examines the determinants of crude oil demand in Ghana. Applying the vector error correction (VECM), the study isolates the long-run determinants of crude oil demand from the short-run using annual frequency data from 1980 to 2013. The results showed that real gross domestic product per capita, crude oil price, real effective exchange rate and time trend were the long-run drivers of oil demand in Ghana. There is the evidence of exogenous technical progress in the long-run. The study, based on the variance decomposition function (VDFs) and impulse response functions (IRFs) via the VAR estimates also found that positive shocks from real effective exchange rate had positive impacts on crude oil demand in Ghana. It is recommended that GNPC, NPA and TOR adopt a strategic oil demand security by establishing and sustaining a planned crude oil reserve system, shopping for alternative sources of energy. Bank of Ghana must also implement policies that strengthen the cedi against major currencies

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CHAPTER ONE INTRODUCTION

1.1 Background to the Study

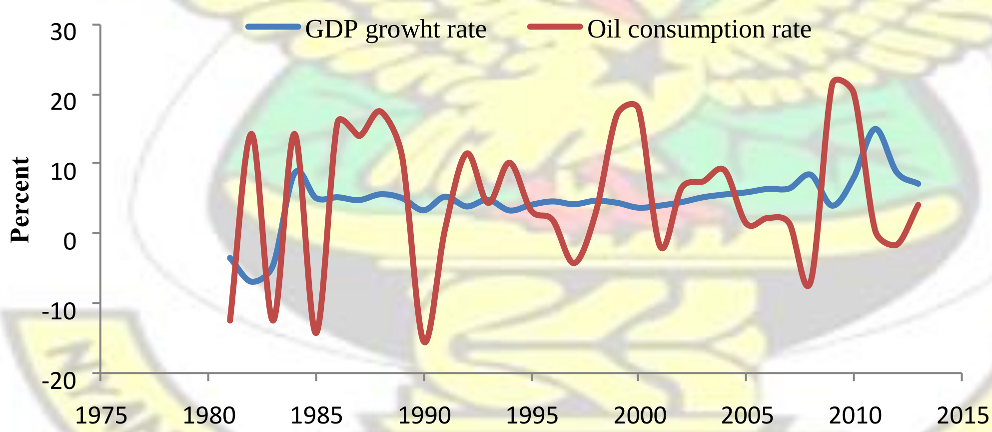
Global production of oil for the year 2014 was at 4,220.6 million tonnes, an equivalent of 88,673 barrels per stream day. This value represents a 2.3 percent increment in oil production from the previous year. Non-OECD countries share of total production was an estimated value of 75.4 percent, non-OPEC countries share of total production was also estimated at 43 percent, OPEC countries share of total production was estimated at 41 percent while the share of total production of European Union and the Former Soviet Union was estimated at 1.6 percent and 16 percent respectively. However, global consumption of oil for the year 2014 was estimated at 92,086 barrels per stream day, which represents a 0.8 percent increment from the previous year (BP, 2015). Crude oil is used for electricity generation and is the main fuel that is used to facilitate transportation and it is demanded in industries (Yazdan and Sadr Seyed, 2012). Energy and its related sources are the main force that drives the wheels of economic activity in both developed and developing economies.

There has been an increasing demand for crude oil in Ghana before and after independence. Crude oil consumption in Ghana in the 1980s averaged 21,000 barrels per day. Between 1990 and 2009, crude oil demand in Ghana averaged 53,870 barrels per stream day. Ghana's demand for crude oil increased significantly to 64,730, 65,000, 63,950 and 66,570 barrel per day in 2010, 2011, 2012 and 2013 respectively. In the 1980s
Ghana recorded no production in crude oil except in 1986 when it recorded an average of 300 barrels per stream day in production. From 1992 to 1994 crude oil production averaged 1,300 barrel per day. Crude oil production in Ghana peaked in 2010 when Ghana

discovered oil in commercial quantities. In 2010 Ghana produced about 7,190 barrels per day. Crude oil production in Ghana increased significantly to 76,510, 78,360 and 97,910 barrels per day in 2011, 2012 and 2013 respectively (U.S EIA, 2014). It follows from the above that domestic consumption of crude oil has always outweighed production.

Oil supports many sectors of an economy because it is a multi-purpose energy source which is highly consumed in most countries (Stambuli, 2014). Basically, the major sectors (transportation, power generation and industry) consume much oil resources relative to that which is consumed by the minor sectors (households and government) (Bedi-uz-Zaman et al, 2011). Oil is an important input for production in industry, manufacturing, agricultural and electricity generation in Ghana.

Figure 1.1: Growth rate in oil consumption and GDP in Ghana from 1980-2010 (percentages)



Source: United States Energy Information Administration, WDI

Figure 1.1 above describes the behavior of the growth rate in GDP and the growth rate in oil consumption in Ghana. Ghana recorded negative growth rates in GDP from 1981 to 1983. Thereafter, our growth rate has been positive at an average of 5% from 1984 to

2013. The highest growth rate in Ghana's GDP was recorded in 2011. On the hand, the economy recorded three events of negative growth in oil consumption in the 1980s, two events of negative growth in oil consumption in the 1990s and three events of negative growth in oil consumption in the 2000s. Ghana growth pattern has consistently been stable with a few upwards and downwards swings. However, the growth in oil consumption has not followed a consistent pattern.

Studies on the determinants of crude oil demand have revealed the significance of macroeconomic variables in influencing crude oil demand. Some macroeconomic variables identified in most studies to be key drivers of crude oil demand include; the price of crude oil quoted in the international market, real gross domestic product, and exchange rate (Royfaizal, 2011; Askari and Krichene, 2010; Zhao and Wu, 2007;

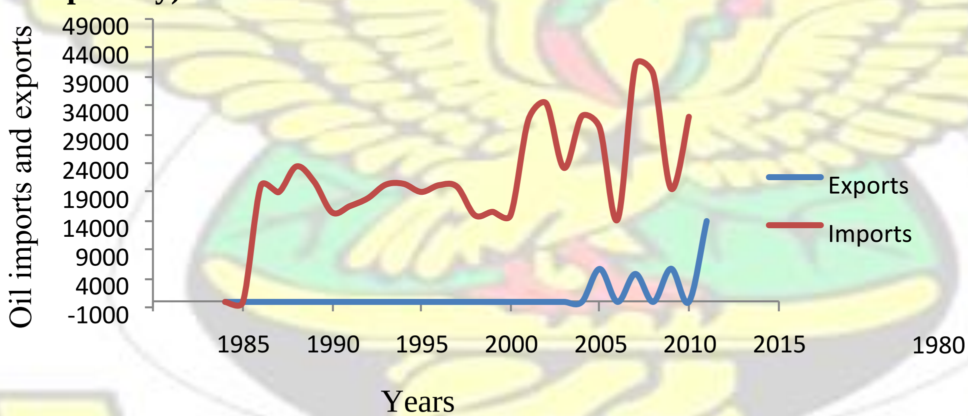
Tsirimokos, 2011; and De Schryder and Peersman, 2013). Huntington (2010), Kumar and Managi (2009), and Grubb and Kohler (2000) showed how exogenous technical progress significantly affected crude oil demand. These studies used a time trend variable to capture the effect of exogenous technical progress. According to Huntington (2010), exogenous technical progress is considered policy driven measures which basically comes from government investment in research and development. Kumar and Managi (2009) however argued that there is little evidence of price induced technical progress with regards crude oil demand.

It follows from the above discussion that it is important for policy makers to understand the determinants of crude oil demand in Ghana. The study on the determinants of crude oil demand will guide policy makers on measures that can be used to manage external shocks that are likely to emanate from disruptions in the crude oil market. This study therefore provides a background to the determinants of crude oil demand in Ghana and as well explains the effects of shocks that emanate from these macroeconomic variables.

1.2 Problem Statement

Economic and non-economic factors that affect the activities in the oil market directly or indirectly affect macroeconomic variables such as budget deficit, balance of payment problems, inflation, output (GDP) and unemployment. For instance crude oil importation has been associated with imported inflation, budget deficits and trade deficits (stambuli, 2014). Ghana imports most of its oil resources for use in the various sectors of the economy.

Figure 1.2: Trend of crude oil imports and exports in Ghana from 1984-2010 (thousand barrels per day)



Source: United States Energy Information Administration

The above figure is a pictorial representation of the trend of crude oil imports and exports in Ghana. It is depicted from the figure above that the period the value of crude oil import far outweighs exports. It is evident from the diagram that the economy is experiencing an increasing trend in the importation of crude oil with just a few intermittent declines. The amount of oil that is imported and consumed annually in Ghana has important economic implications when making decisions and forecasting about current and future oil needs since it has the potential of weakening her trade position and most macroeconomic variables.

Crude oil importation accounted for approximately 80 percent of trade deficit in 2001 and the cost of crude oil importation rose from US$280m in 2000 to over US$500 by 2004 (Ghana Energy Commission, 2006). The economy is left vulnerable if the transmissions channels through which oil demand affect economic activity in Ghana are not given the necessary attention despite its sensitivity and enormity. The importation of oil and other crude products into Ghana require crude oil demand policies that are in synchronization with Ghana's growth and development. To this end, it is important for policy makers to appreciate and understand the macroeconomic determinants of crude oil demand in Ghana. It is apparent from the dearth of literature that the determinants Ghana has not been examined. For instance, (Marbuah, 2014) investigated the behavior of crude oil import demand in Ghana. A study which focused on how crude oil import responds to price and income changes in Ghana. Etornam (2015) and Etornam and Dogah (2015) also studied oil price shocks and the macro-economy of Ghana and oil price fluctuation and macro-economic performance in Ghana respectively. This makes this study timely and purposeful. Therefore, there is a research and knowledge gap that this study proposes to fill.

1.3 Objectives of the Study

Generally, the study estimates the determinants of crude oil demand in Ghana.

Specifically, the objectives of this study include the following;

1. To estimate the drivers of crude oil demand in Ghana;
2. To examine the effect exogenous technical progress on oil demand in Ghana
3. To examine how shock (innovations) in real gross domestic product per capita, crude oil price, real effective exchange rate and technical progress affects crude oil demand in Ghana

1.4 Research Hypotheses

The following research hypotheses were formulated;

1.

H_0: Real gross domestic product per capita, oil price, real effective exchange rate and exogenous technical progress are not determinants of oil demand in Ghana.

H_1: Real gross domestic product per capita, oil price, real effective exchange rate and exogenous technical progress are the determinants of oil demand in Ghana.

2.

H_0: Exogenous technical progress has no significant impact on crude oil demand in Ghana

H_1: Exogenous technical progress has a significant impact on crude oil demand in Ghana.

3.

H_0: Shocks (innovations) in real gross domestic product per capita, crude oil price, real effective exchange rate and exogenous technical progress have no significant effect on crude oil demand in Ghana.

H_1: Shocks (innovations) in real gross domestic product per capita, crude oil price, real effective exchange rate and exogenous technical progress have a significant effect on crude oil demand in Ghana.

1.5 Significance of the Study

The research work will be justified and significant in three ways; the study will be expected to influence policy direction, bridge knowledge gaps and to contribute to literature for further researches. The efforts of government to enhance growth in Ghana can on be achieved if the economy becomes efficient in the use of crude oil resource. It must be stated that the government has so much stake in national development. Academicians, opinion leaders and other interested observers like, the international community and organizations have expressed much concern about the fact that external oil shocks can impact greatly on Ghana's growth and development.

The study on estimating the determinants of crude oil demand in Ghana would influence policy in the following ways; Firstly, the study as part of its objectives seeks to examine the determinants of crude oil demand in Ghana. The results from this study will inform policy makers on how to manage shocks emanating from instabilities in world crude oil prices and how to regulate upstream and downstream activities in Ghana. Also, results from the investigation of the determinants of oil demand in Ghana will inform policy makers on measures that can be adopted to improve oil consumption efficiency in Ghana.

In the academic front, this study is significant terms of timing and purpose. The understanding the determinants of crude oil demand has important implications at the hypothetical, practical and the micro level. Recent studies on the subject matter are biased in terms of purpose. They focus on energy consumption and economic growth (Mallick, 2009); oil vulnerability index (Gupta, 2008); oil demand and supply with monetary policy (Noureddine, 2010); crude oil shocks and stock markets (Zhu et al, 2011); oil prices and exchange rates (Benhmad, 2012); sectorial oil consumption and economic growth (Bedi-uz-Zaman et al, 2011). However, other related studies are also centered on countries that are considered major players in the oil market or considered emerging economies (Hamilton, 1996; Ahmed and Wadud, 2011; Stambuli, 2014; Akin and Babajide, 2011). The study therefore is expected to bridge knowledge gaps and contribute to literature on the subject matter in Ghana

1.6 Scope of the Study

Contextually, the study estimated the determinants of crude oil demand in Ghana. Answering the question whether oil prices, real gross domestic product per capita, real effective exchange rate and technical progress impact greatly on Ghana's demand for crude oil is critically examined. The study designed to cover a period of 1980 to 2013. The study period is chosen to enable the researcher have access to relevant data for the selected time period. This period was chosen due to the availability of relevant data and also considered reasonably long enough to provide adequate information on oil consumption in Ghana.

1.7 Organization of the Study

The study is organized into five main chapters with each chapter further divided into sections and subsections. The second chapter reviews both theoretical and empirical works on oil demand, oil price and growth. Chapter three will present the methodology of the study; this consists of the model specification and estimation techniques. Chapter four analyses and discusses the findings of the study. Finally, chapter five concludes the study by summarizing the findings, and enumerating the policy implications and recommendations.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

This chapter reviewed theoretical and empirical literature on the subject matter that is studied. The study makes a critical review of both theoretical and empirical literature on the determinants of crude oil demand, crude oil demand income relationships, the effects of oil price shocks on macroeconomic variables and the effects of exogenous technical progress on oil demand.

2.2 Theoretical Review

Some of the few theories and models that explain the behavior and dynamic of oil price and how it affects demand and consumption are most rooted in the theory of nonrenewable natural resources, the cartel model, the dominant firm model, the target revenue model and the limit price theory.

2.2.1 The Theory of Non-Renewable Natural Resources

The brain work of Hotelling (1931) is the main source of literature that explains the changes in oil price. The theory is made plausible by first assuming that oil as an exhaustible natural resource exhibits the following features. Given that any quantity of oil is available at time (t), as time approaches infinity with the continual extraction of oil resources, the amount of oil that will be available will also approach zero. The second assumption is that, the demand for oil at any time largely outweighs supply. In relative terms there is some asymmetry between the supply and demand for oil. Oil is therefore treated as a non-renewable resource in the context of the features stated above. Therefore the consumption and production of oil at time (t) inevitably affect the consumption and production of oil at any time in the future. The competitive market condition of marginal revenue equating marginal cost does not apply in the non-renewable natural resource market due to the "scarcity effect". Hence price must always be greater than marginal cost as a markup for scarcity. The literature refer to this positive markup as a premium known as scarcity rent. This is compensation in the form of a reward to the owner of the resource.

To make the theory more plausible, Hotelling made the following prepositions; given that there are no cost to the extraction of resource, at a given market price and real risk free interest rate *r*, the optimum path of resource extraction in a competitive market, would require that the increase in a unit price of resource must be greater that the rate of interest (r). Intuitively, the owner of the resource is faced with two options, either to extract the resource today or in the future. If the owner decides to extract the resource today he will invest the money received from the sale of the resource at the current interest rate. The owner of the resource can hold on to the extraction of the resource in an event where he expects the price of resource to rise faster than the rate of interest. If other producers should behave in a like manner then there will be a drastic decline in the quantity that is put in the market (supply) which will definitely drive up the price. This theory is very influential in the work of earlier writer who sought to explain the behavior of oil prices

(see Pindyck, 1999; Lynch, 2002; Krautkraemer, 1998 and Berck, 1995)

2.2.2 The Cartel Model

Bhattacharyya (2011) defined and explained the cartel model. This is price fixing strategy adopted by an organization of firms who enter into agreement seeking to regulate the market by restricting supply through quotas. The cartel works as either a monopoly producer or as a market shared agreements with the aim of controlling competition to gain higher profit returns. In the absence of any production treaties individual firms are mandated to produce and sell at the market clearing price and quantity. The individual can only make higher profits by charging a higher price if they agree to restrict the quantity of output below the market clearing quantity to maintain the higher price. The individual firms will be happy to join the collusive moment because controlling competition allows them to reap higher returns and benefits in terms of profits. Firms enjoying higher returns will have the tendency to increase output “cheating” to increase self-profit. Overproduction will result hence breaking monopoly power and the existing internal cohesion. Cheating by members for selfish gains undermine the position of the cartel. Data on the nature of supply and demand curves for respective countries, their level of actual and final production and together with their demand elasticity of members will enable them break this difficulty.

2.2.3 The Dominant Firm Model

According to Bhattacharyya (2011), the cartel can only maximize revenue if it is able control the market power in presence of "cheating" (increasing output above the restricted quantity to increase returns) among members. The dominant firm model is also known as the cartel with a leader. The dominant firm's (the leader's) behavior has an influence on the internal cohesion of the group and can influence the group to accept its suggestions, thereby staying with the leader's interest. The dominant firm must be very responsive to changes in energy market, adapt to changes in capacity utilization, have a higher market share and the leader must have low financing requirements. In this model, the dominant firm is the leader and the other firms in the cartel are followers. There is a leader's advantage in this model since the firm that takes up the leadership firm is the price maker and the other firms (followers) are price takers.

2.2.4 The Target Revenue Model

Ezzati (1976) developed the target revenue model from his studies on future OPEC price and production strategies. According to Ezzati (1976), OPEC pricing and investment decisions must align with the budget targets of a countries national budget. Ramcharran (2001), studied OPEC behavior in the 1970's and the results showed the targeted revenue hypothesis. The budgetary need of OPEC countries is explained by its ability to contain productive investment. A productive Investment projects that has a rate of return ranked above the market rate of return must implemented in other to meet the revenue targets. Revenue schedules can are drawn for different levels of oil and quantities of oil producing export revenue equal to investment requirements. If the share allotted to the country is not enough to meet the investment demand, the country would cheat seek an increase in share. If share is more than that required to meet investment demand, the country may voluntarily reduce output. Only members who are marginal in oil resources would have tendency to cheat. Rich members may not prefer to leave oil to ground as the return may not be remunerative. Small producers may like to defer production.

2.2.5 The Limit Price Theory

According to Bhattacharyya (2011), the limit pricing model sets a price that allows the cartel to be faced with a specific demand curve and above which there will be no production. Activities of non-cartel members and as well as other fuel can potentially result into competition. Non-cartel members can affect the demand and supply decisions of the cartel. The limit pricing model is often examined in two dimensions. Two strategies that are generally considered are the offensive strategies and defensive strategies. With the offensive strategy, the cartel initiates a price war while with the defensive strategy members of the cartel are mandated to conserve resources giving noncartel producers freedom and space to produce. The defensive strategy is adopted whenever the cartel is threatened with the entry of a substitute. There is certain price that makes the substitute viable and in such instance the cartel set a price below a threshold level where the cartel may not necessarily be making profit but prevents the entry of new substitutes.

2.3 The Determinants of Crude Oil Demand

According to Jiping and Ping (2008) oil demand is synonymous to oil consumption due to absence of statistical information for oil demand. Oil demand is the quantity of oil people are willing and able to buy in specific time period. Most studies model oil consumption either as an aggregate demand function or a disaggregated oil demand function taking into consideration the consumption of oil by all sectors, that is, oil consumption by; industrial, household, aviation, transport, agricultural and commercial sector (see Bedi-uz-Zaman and Ullah, 2011; Stambuli, 2014; Suleiman and Muhammad, 2012; and Marbuah 2014). Suleiman (2013) writes, most researchers find it difficult with what variable to use as dependent variable when specifying an oil demand function due to absence of an appropriate economic theory to guide them. According to him, most studies use oil consumption as the dependent variable either in per capita term or physical units. In such studies technology, real income (GDP), capital efficiency, climatic variations and real prices (real end user price) are used as independent variables. Bhattacharyya and Blake (2009) in study that investigates the determinants of four petroleum product demand in the Middle East and North African countries used real price of petroleum products and per capita real gross domestic product as the main determinants of real per capital consumption of petroleum products.

Fattouh (2007) outlined economic activity, price effects, financial flimsiness, regulatory lapses, balance between energy security and climatic change, technology and energy efficiency as the key determinants of oil demand for both developed and developing countries. Economic activities of both OECD countries and NON-OECD have non-linear effects on oil demand. Dynamics such as oil price swings, price volatility and relative price in energy mix explain crude oil demand. Financial fragility, technology and climate changes are often considered the non-oil market determinants of crude oil demand. Askari and Krichene (2010) incorporated monetary policy variables such real interest and the U.S dollar exchange rate in a model to estimate the determinants of oil supply and demand in the United States. The results showed very low elasticity coefficient for oil demand with respect to price. This feature makes oil price very volatile with wider fluctuation compared with other commodities. They suggest that stimulating oil demand in the US will require aggressive monetary policy.

Royfaizal (2011) applied the ARDL bounds testing technique to estimate to estimate an oil demand function in Japan using price and income as the independent variables and crude oil import demand as the dependent variables. The results showed that the coefficient of elasticity for crude oil demand for income and price were 1.35 and -0.08 respectively. The results indicate that crude oil in demand Japan is inelastic and elastic for price and income respectively. The implication of an elastic income coefficient is that, as the incomes in and economy improves, crude oil demand also increases. However, a developed country like Japan will demand the same quantity of crude oil regardless of the price changes.

Real GDP per capita, real oil prices, oil consumption with one period lag and time as a trend variable to denote technological advancement were used as explanatory variable to model the demand for crude oil in ten IEA member-countries. These variables were estimated in a multiple regression equation following the Nerlove's partial adjustment model. An estimate of the elasticities with respect to price and income showed that the coefficient of elasticity for both price and income were inelastic in the short run for all ten countries. However, oil consumption is inelastic with respect to price and elastic with respect to income in the short and long-run. This means that countries are more likely to be responsive to income changes in oil consumption in the long run than in the short run (Tsirimokos, 2011).

2.3.1 Determinants of Crude Oil Demand in Ghana

Crude is demanded in Ghana to meet the refinery needs of Tema Oil Refinery (TOR) and for electricity generation. The quantity of crude oil that is demanded by TOR is refined and distributed to meet industrial demand, the demand for households, for aviation purposes, for transportation, agricultural and commercial purposes. The demand for crude oil at TOR is considered derived demand since the crude is refined to various petroleum products for final distribution and sale to the public. The increase in the demand for crude oil by TOR is explained by the increasing demand by the various sectors except the power sector. The drastic deep in the demand for crude oil by TOR in 2008 and after

2011 is the result of the indebtedness and other technical challenges of TOR. US EIA (2013), report that Ghana's oil consumption between 1980 and 2013 averaged 4.9 percent. Ghana's population growth rate for the same time period also averaged 2.87 percent (IMF, 2015). In 2010, total crude oil import demand for Ghana was estimated at 1661.6 kilotonnes, 961.1 kilotonnes out of the total amount represented TOR's demand while 700.5 kilotonnes was for electricity generation. In 2003, total import demand increased to 1302.4 kilotonnes and TOR's demand declined to 373.4 kilotonnes while the demand for power generation increased to 927.8 kilotonnes (Energy Commission, 2006). In 2010, the population of Ghana was an estimate of 23.69 million while in 2013 the population was estimated at 25.56 million. This is an indication that Ghana's total crude oil import demand increases whenever the population increases.

Marbuah (2014) identified variables such as real GDP, crude oil price, real effective exchange rates, domestic crude oil production, and population growth as the determinants of oil import demand in Ghana. He concluded that real GDP which measured as real economic activity as the strong determinant of crude oil demand in Ghana. Applying the ARDL estimation techniques, Marbuah (2014) revealed that crude oil had inelastic demand with respect to changes in prices both in long and short-run. However, the coefficient of real GDP was found to give combined estimates of elastic and inelastic in both the short and long run and is the strongest determinant of crude oil demand. Changes in crude oil prices does not change domestic demand crude oil given that some factors that take part in the level of economic activity remain fixed. Given that all the variables that contribute to economic activity in Ghana can be varied, changes in real GDP can either cause a change in domestic demand for oil or domestic demand for oil can remain unchanged with changes in real GDP.

Table 2.1: Summary of some empirical findings (determinants of oil demand)

Study/Country	Country Status	Determinants	Elasticities	Methodology/ Sample period
Marbuah (2014) Ghana	Net oil importer, Net oil exporter after 2010	GDP in constant prices in US$, oil price (Brent, D.F., WTI)	Price inelastic (0.660) in S.R and (0.277) in L.R, income inelastic (0.524) S.R and elastic (1.638) in L.R	ARDL 1980-2012
Royfaizal (2011) Japan	Net oil importer	Real GDP and crude oil price	Price inelastic (0.08) and income elastic (1.35)	ARDL bounds testing approach of cointegration 1992:Q1 to 2006:Q2
Askari and Krichene (2010) U.S.A	Net oil importer	Real GDP, crude oil nominal price, interest rates and effective US dollar exchange rates	S.R price elastiticies (-0.002, -0.018), L.R price elasticities (-0.028, -0.013, -0.01), S.R income elasticities (0.02, 0.38, 0.327), L.R income elasticities (0.28, 0.62, 0.41, 0.46)	SEM 1970:Q1 to 2008:Q4
Zhao and Wu (2007) China	Net oil importer	Relative oil price, industrial output, energy production domestically, volume of traffic	Price coefficient insignificant, industrial output elasticity (2.76, 7.28)	Cointegration and VECM 1995:Q1 to 2006:Q1

Tsirimokos (2011) Ten IEAmember countries	Net oil importers	Real oil price, real GDP per capita, lagged oil consumption, time trend	S.R Price (-0.03 to 0.104). L.R price (-0.066 to -0.221). S.R income (0.3 to 0.7). L.R income (0.865 to 3.245)	Nerlove's partial adjustment model 1980 to 2009
De Schryder and Peersman (2013) Oil importing countries	Net oil importers and exporter	GDP, Oil price, real effective exchange rate and time trend	S.R I_E 0.56 for OECD & (0.63) for non- OECD. L.R I_E 0.67 for OECD, 0.88 for non-OECD. E_E 0.20, P_E 0.05 for OECD and 0.02 for non-OECD	Panel ECM 65 oil importing countries

2.4 Crude Oil Demand and Income Relationships

According to Solow (1974; 1986) model with scarce natural resources, exhaustible resource such as oil and gas are essential for aggregate production. Exhaustible resources are depleted with continuous use in production and pose a dampening effect on growth when more is used in aggregate production to drive growth. Oil used in this model represents a general name for exhaustible resources. The aggregate of oil resource present at the initial stage of production will not remain the same as it is used continuously as an input in production. An increase in the units of effective labor together with an increase in the units of effective capital will depress the available oil resource. This creates a negative growth in income per worker through diminishing returns. As time approaches infinity, the severity of diminishing return to effective labor and capital becomes intensified as oil resources gradually disappears. Driving growth through the extraction oil resources will result in a faster depletion rate, implying a faster negative effect on the other factors. An empirical estimate of the using a sample of 64 countries using data from the World Bank's estimates for the value of subsoil assets per capita and GDP per worker revealed a positive impact of the amount of exhaustible resources on the level of GDP per capita. Higher amounts of exhaustible resources lead to higher income per capita in the long-run. The model however concludes that the abundance of natural resource is good and cross country empirics are consistent with the prediction of the Solow model with oil.

The neutrality hypothesis takes the position that energy and its related sources have a negligible impact on economic growth because the cost of energy forms a small share of GDP. Hossein (2012) provides an empirical insight into the causality between oil consumption and economic growth using annual data for a period of 1980-2010 from Iran applying an ARDL testing technique. The results show that in that in the short-run, Causality run from economic growth to energy consumption but such results did not occur in the long run. Likewise if a unidirectional causality runs from energy consumption to economic growth means that reducing energy consumption will reduce economic growth. Stambuli (2014) also showed another highlight which aligns with the conservative hypothesis from the results of his studies on oil consumption and economic growth nexus using both co integration and causality analysis. He concluded that there was unidirectional causal relationship running from per capita real GDP to per capita oil consumption. This depicts that there would be no adverse effects on the growth of an economy if it decides to reduce the amount of oil it imports. Aqeel and Butt (2001) employed the Hsiao version of the Granger Causality and co-integration to test the relationship between energy consumption and economic growth in Tanzania. They conclude that economic growth drives growth in petroleum consumption but same was not for gas. The reason been that increasing economic activity results in growth in energy consumption and since petroleum products are largely imported, this transmit its effect on GDP growth. Using an ARDL model, (Royfaizal, 2011) tested the causality between oil consumption and economic growth. The results showed the presence of a long-run causality running from economic growth to crude oil import. This also supports the hypothesis that reducing crude oil demand will not affect economic growth in the future.

2.5. Crude Oil Demand and the Macro Economy

The demand for oil has both microeconomic and macroeconomic implications for oil importing and exporting countries and even net exporting countries. Oil demand and supply shocks are most like to affect trade position, the GDP (measured by the volume of economic activity), inflation, real balances, the foreign exchange earnings and the wealth of a country. Oil impacts greatly on most macroeconomic variables because it has no substitutes and countries considered to be oil dependent are significantly affected whenever shocks occur. This study examines three transmission mechanisms through which oil affects the macro economy. These are demand side effects, the real balance effect and the trade effect.

2.5.1 Oil and Exchange Rate

The U.S dollar is the standard currency for pricing crude oil in the international market. This has serious implications for oil importing and exporting countries. Oil importing countries whose currency is not the dollar are mandated to buy the dollar to undertake oil related transactions. A change in the value of the dollar will inevitably change the price they pay for oil in their domestic currency. Oil exporters will also respond to changes in the value of the dollar exchange rates. Fluctuation in the value of the dollar exchange rates will also affect the volume of foreign exchange earnings for oil exporting countries (Trehan and General, 1986).

Exchange rate changes directly or indirectly affects the demand for oil and the pricing of oil. There is growing literature on the relationship between oil price and exchange rates and exchange rate and oil demand movement. Novotný (2012) studied the relationship between a particular type of crude oil and the dollar exchange rate. Using Brent crude oil, he observed a negative relationship between the price of Brent crude oil and the dollar exchange rate. A falling value of the dollar exchange rate is associated with rising price of crude oil. A falling value of the U.S dollar is the cause of loose monetary policy and therefore countries whose international transactions are quoted in the dollar are most likely to experience a similar loose in monetary policy. The immediate effect of a loose monetary policy is an increase in demand for crude oil which will drive up the price of crude oil. Likewise in a floating exchange rate regime, a weak U.S dollar against other currencies implies an appreciation in the local currencies and the price of will fall in the respective local currencies. The demand for oil in these countries will increase locally thereby causing global demand for oil to increase hence driving up the price of oil. In this case oil price is demand driven through an exchange rate effect.

Breitenfellner and Cuaresma (2008) stated hypothetically that the inverse relationship between crude oil price and exchange rates could take place through the following mechanisms; domestic prices in non-U.S. dollar regions, the supply side, the monetary policy regime in oil-exporting countries, the purchasing power of oil export revenues and on the demand side, currency market efficiency and investments in crude oil-related asset markets. These transmissions basically explain how the relative currency appreciation or depreciation affect oil demand and oil price both domestically and internationally. De

Schryder and Peersman (2013) also demonstrated how exchange rate dynamics affect the demand for oil in countries whose currencies are not denominated in the U.S. dollar. A fall in the value of the U.S. dollar implies a fall in the price of oil in non-U.S. dollar countries thereby increasing their demand for oil. The increase in demand in demand for oil in these countries will directly affect the global demand and the price of oil quoted in the U.S. dollar.

There are diverse empirical evidence results regarding oil price, oil demand and exchange rates in the literature. Novotný (2012) studied the causality between the price of Brent crude oil and exchange rates. The results showed that the direction of causality has been from the dollar exchange rates to the price of Brent crude price and the degree of response of crude price to a (one) 1 percent fall in the dollar exchange rate was reported to be 2.1 percent. The coefficient of elasticity using monthly data for January 1982 to September 2010 is said to be elastic. Ali et al. (2015) found that exchange rates and oil price had a long-run relationship since both variables were cointegrated for a sample period of 54 years using Engel-Granger. However exchange rates did not have any significant effect on crude oil price and both variable did not show any order of integration from the results of the Momentum Threshold Autoregressive (MTAR) and the Threshold Autoregressive (TAR) model. Benhmad (2012) examined the nonlinear and linear causality between the real effective U.S. dollar exchange rate and the real price of oil employing the wavelet technique. The results revealed strong bidirectional causality between the two variables (U.S dollar exchange rate and the real price of oil) for the United States.

2.5.2 Demand Side Effects

The demand side effect is a depiction of how oil demand affects major macro-economic variables. The demand side effect of oil is often best understood in a demand-supply framework of analysis. For instance, Trehan and General (1986) explained how OPEC behavior that cause an increase in the price of oil force firms in oil importing countries to reduce their demand for oil which significantly causes a decline in industrial output. Cashin et al., (2014) revealed how oil-demand shocks caused a long-run inflationary pressures and a short- run increase in real output. The inflationary pressures may be caused by the failure of oil producers to meet demand. The will push up oil prices and hence result to inflation. However oil price spikes can be endogenous due to movements in global economic activity. The short-run rise in output may be the result of the country experiencing a boom or the country is enjoying some gains from trade openness.

The demand side effect of oil can also be understood through oil price shocks. Iwayemi and Fowowe (2011) explained how positive and negative oil shocks affected some selected macro-economic variables such as government expenditure, real exchange rates, output and inflation in Nigeria. According to them, positive oil shocks did not significant cause any of the selected macro-economic variables but negative oil shocks did significantly cause exchange rates and output in Nigeria. González and Nabiyev (2009) also showed how oil price changes affect output and employment through production cost and investment decisions. Rising oil prices represents an increase in the cost of production for most firms. Output will fall and firms will cut down employment. Firms are also likely to postpone their business investment decisions due to uncertainties associated with oil price increase. This will result to a fall in aggregate output and a sharp decline in employment and rise in unemployment. Huson Joher and Mokhtarul (2012) provided an empirical foundation to understanding how macroeconomic activity responds to oil price shocks. Huson Joher and Mokhtarul (2012) applied an SVAR technique to study how oil price shocks impacts on macroeconomic activities. The results from the impulse response function showed a stifling effect of oil price shocks on Malaysian industrial production. Oil price dynamics can sometimes reduce output due to the fact they cause a delay in business investment by causing uncertainties.

2.5.3 The Real Balance Effect

According to the monetarist perspective, a rise in oil price is often accompanied with an increase in the demand for money to meet the volume of transactions in the oil market. If monetary authorities are unable to meet the increase in the demand for money by increasing money supply, a rise in interest rates is inevitable. This poses a dampening effect on output and employment. Bernarke (1997) demonstrated how oil price shocks were associated with endogenous tight monetary policy. Contracting money supply to meet increasing money demand as a result of an increase in oil price are the main causes of oil price shocks. Bernanke et al., (1997) explained that tightening of monetary policy in the U.S was often accompanied with a rise in the price of imported crude oil. To them, the refusal of the Fed to increase money supply to meet demand most of the time resulted in an increase in the price of imported crude oil. A decision by the central bank to increase money demand will inevitably induce the demand for oil and the absence of enough supply to meet demand will cause instability in the oil market and interfere with economic growth. Stimulating growth and ensuring oil market stability can only be achieved by restraining monetary policy for a long period coupled with a rise in interest rates (Askari and Krichene, 2010).

Ahmed and Wadud (2011) applied the SVAR approach to investigate oil price shocks and monetary policy response in Malaysia. The results revealed that the central bank of Malaysia often pursue an expansionary monetary policy in response to an unlikely event of oil price uncertainties.

2.5.4 Trade Effect

They further explained how oil demand is a form of wealth transfer within firms and across countries. In periods of rising oil prices, profits are transferred from firm consuming oil to firms consuming oil. Wealth in the form of profit is also transferred from oil consuming countries to oil producing countries (mork, 1994). Oil net importing and oil importing countries will experience weakening terms of trade. As demand fall in these countries will lead to some form of wealth been transferred to oil exporting countries from oil importing countries (Iwayemi and Fowowe, 2011)

2.6 Technical Progress and Oil Demand

Huntington (2010) distinguished between price-induced technical progress and exogenous technical progress and how they affect oil demand. According to him, energy demand and technical progress relationships can either be exogenous over time or endogenously through a mixture of sharp changes in oil prices. This the second instance, an economy adopt more cost-reductions schemes or follow the learning by doing technique. Technical progress in the form of technological advancement is very instrumental in reducing the consumption of energy and its related sources (Kumar and Managi, 2009). According to them, on world average, there is little evidence of energy induced technical progress. This means that most technical changes are often associated with exogenous technical progress. They further posit that in interpreting parameters that involve technical progress, a positive parameter represents technical regress while a negative parameter represents technical progress.

Grubb and Kohler (2000) attribute exogenous technical change to government investment in research and development (R&D) while considering induced technical change to a response to market conditions which depends on investments by corporate organizations and learning by doing. When economic models contain elements of induced technical change, they become endogenous. According to Grubb and Kohler (2000), models in economics capture technical change as an exogenous variable. It occurs in an autonomous process such that it is not contingent on economic variables. Löschel (2002) writes, the appropriate parameter that is used in most economic model that involves climate change is the autonomous energy efficiency parameter (AEEI). This parameter is non-price induced technological improvement index which is affected most by energy intensity.

Using an ARDL estimation approach, Huntington (2010) found out that technological improvement operating as exogenous trend reduced oil demand by 0.16% annually in the short-run. However, 0.16% reduction in oil demand was dependent on the growth rate in income. He was emphatic to state clearly that exogenous technical progress was potent enough to bring about an increase in oil demand at a slow rate over time. Incorporating the trend effect, an economy experiencing a growth rate of 2.2% is expected to have its oil demand grow at a rate of 2.6% for OECD countries.

CHAPTER THREE METHODOLOGY

3.1 Introduction

The chapter presents the procedure that is used to implement the research objectives. It discusses the main source of data and the type of data, an empirical specification of the model and a detailed discussion and description of selected variables and the prior theoretical expectations and the variable estimation procedure. To avoid spurious results, a model diagnosis test is provided to test the time series properties of the selected variables. However, the unit root test and the cointegration test procedure follow the

Augmented Dickey Fuller test (ADF) and Phillip-Perron (PP) unit root test and the Johansen test of cointegration. An alternative unit root test procedure proposed by Perron and Vogelsang (1992) and Perron (1997) which test for structural breaks is applied to test for evidence for structural breaks in the data. The Vector Error Correction Model

(VECM) estimation procedure is applied to obtain parametric estimates of the variables. ARDL is applied as a robust check. Finally, impulse response function and variance decomposition is also carried out to capture the effects of shocks in the independent variables and their affect the dependent variable.

3.2 Data type and sources

This study employed the use of secondary data. Annual time series data from 1980 to 2013 was employed in this study. The variables employed in this study include; world crude oil prices of Brent quoted in United States dollars, real GDP per capita at constant US$, real effective US$ exchange rates, annual crude oil consumption and population growth rate. Oil consumption and Brent crude oil prices quoted in United States Dollars is sourced from British Petroleum and the United States Energy Information Administration, real GDP per capita income estimates and population growth are sourced from the World Bank (World Development Index) and the real effective US$ exchange rate is sourced from World Bank (World Development Index).

3.3 Model specification

The study adopts it theoretical background from the theory of demand which states that demand consist of two factors: the desire and the ability to buy. The desire to buy is determined by taste which drives the willingness to pay a specific price. The ability to pay is determined by the size of income (Whelan et al., 2001). From the above, it follows that the demand function for good or service is specified as;

$$D_t = f(Taste_t, Price_t, income_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Following Askari and Krichene (2010); De Schryder and Peersman (2013); Huntington (2010); Royfaizal (2011); and Zhao and Wu (2007), the study makes an extension of Equation 3.1 to formulate the demand for crude oil as a function of real GDP, Oil prices, real effective exchange rate, population and time trend. Population variable was chosen by the research to examine how population growth dynamics will affect oil consumption while the time variable is measured as a trend variable that is expected to account for how technical changes will affect the consumption of oil in Ghana. An extension of the model is specified as follows;

$$OilD_t = f(rGDP_t, OilP_t, REEX_t, Pop_t, T) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where OilD represents oil demand, rGDP represents real GDP, OilP represents oil price, REEX represents effective exchange rates, Pop is the growth rate in population variable and T is the time variable. However, there is evidence of multicollinearity in the functional form specified above with the inclusion of rGDP and Pop. The functional form in the above is re-specified as;

$$OilC_t = f(rGDPPC_t, OilP_t, REEX_t, T) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.3$$

The functional form in 3.2 incorporates real gross domestic products per capita, which is a ratio of rGDP to Pop. The re-specification of the functional form is to be able to correct for multicollinearity.

In this study, the model that estimates the oil demand function is written as;

$$lnOilC_t = \beta_1 + \beta_2 lnrGDPPC_t + \beta_3 lnOilP_t + \beta_4 lnREEX_t + \beta_5 lnT_t + \varepsilon_t \ldots\ldots\ldots\ldots..3.4$$

Model 3.3 provides an empirical estimate of the determinants of oil demand in Ghana. It incorporates variables that are expected to explain crude oil demand in Ghana. The study expects β_2 to be positive. An increase in income which is the result of an increase in productivity will stimulate an increase in the demand for crude oil. As posited by the theory of demand, an increase in the price of crude will cause a decrease in the quantity of crude oil that is demanded. The study therefore expects β_3 to be negative. On the other hand, an appreciated currency makes crude oil products in the international market cheaper. An increase is the value of the domestic currency against major currencies is expected to cause an increase in the demand for crude oil. The coefficient of real effective exchange rate (β_4) is expected to be negative. The study expects the coefficient of the time trend variable to be either negative or positive. A negative coefficient implies technical progress while a positive coefficient implies technical regress (Huntington, 2010). The rational for transforming the series in equation 3.3 into logarithm is to change the series into the same unit of measurement. Transforming the data into logarithm also reduces heteroskedasticity problems in the oil demand function.

3.4 Description of Variables

All the variables selected as the dependent (explained) and the independent (explanatory) variables are described in detail in this section.

3.4.1 Dependent variable for the study

Crude oil demand *(OilD)*

Crude oil consumption is synonymous to oil demand. The quantity of crude of oil estimated in thousand barrels per stream day is used as measure of crude oil demand in Ghana. In similar studies by Royfaizal (2011) and Tsirimokos (2011) the term crude oil consumption is used to mean crude oil demand. Crude oil consumption is the total amount of crude that the economy of Ghana is willing to buy in a specific period time to meet the requirements of the refinery at Tema and the quantity needed for power generation.

3.4.2 Explanatory variables for the study

Oil Price *(OilP)*

Crude oil price is the world price of crude oil denominated in U.S dollars. The price of crude oil is quoted in nominal terms. The nominal prices adjusted to real price of oil using the consumer price index Ghana. Following the theory of demand, the prior expected relationship for the price variable is negative. Higher prices of crude oil in the world market will make it expensive for the economy to demand the same quantity of crude oil hence causing a fall in the demand for crude oil. We will expect a negative relationship between oil demand and oil prices.

Real Gross Domestic Products *(rGDPPC)*

The real gross domestic product variable is the value of gross domestic product of Ghana adjusted for the effects of price changes expressed as a ratio of population. It measures the volume of economic activity and incomes created. The inclusion of the real gross product in the model to measure the effect of income changes on crude oil demand in Ghana. Therefore the real gross domestic product per capita variable is a proxy for income changes. Economic theory posits a positive relationship between consumption and income such that an increase in income implies an increase in oil consumption.

Real Effective Exchange Rates *(REEX)*

The World Bank defines real effective exchange rate as the value of the domestic currency against weighted average of several foreign currencies divided by a price deflator. The study also investigates how exchange rate dynamics affects domestic oil consumption. The study seeks to understand Ghana's oil consumption behavior in relation the exchange rate swings. Oil prices in the international market are quoted in dollars. A depreciating local currency will exert a dampening effect on oil consumption in Ghana. The therefore expects a negative relationship between crude oil demand and real effective exchange rates. De Schryder and Peersman (2013) specified an oil demand model that incorporates effective U.S dollar exchange rates.

Time Trend *(T)*

The inclusion of time trend variable is to measure the effect of exogenous technical progress on the demand for oil in Ghana. The inclusion of time variable in the model was informed by specification of oil demand functions by Huntington (2010); Tsirimokos (2011) and De Schryder and Peersman (2013). The time variable is to capture the effect of policy driven measures on the demand for oil. It is a test variable for how improvement in technology that ensures oil consumption efficiency in the economy will affect the demand for oil. A negative coefficient for this variable implies technical progress while a positive coefficient implies technical regress.

Table 3.1: Summary description of variables and their expected signs

Variable	**Description**	**Expected sign**
Oil Consumption *(OilC)*	Total oil demand by all sectors of the economy at any point in time measured in thousand barrels per stream day.	None
Oil Price *(OilP)*	Measured the price of brent crude oil denominated in U.S dollars	Negative (-)

Real Gross Domestic Product per Capita *(rGDPPC)*	Measures the real volume of economic activity and incomes expressed as a ratio of population at constant USD	Positive (+)
Real Effective Exchange Rates *(REEX)*	Measures the value of the domestic currency against weighted average of several foreign currencies divided by a price deflator	negative (-)
Time Trend *(T)*	Captures the effect of exogenous technical progress	+/-

Researcher's own construct

3.5 Estimation Procedure

The study begins the VECM model estimation by first performing a model diagnosis test to achieve model viability and the stationarity properties of the variables. Checking the time series properties of the variables will ensures that the estimation and interpretation of spurious results is avoided completed. The study follows the Augmented Dickey Fuller (ADF) and the Phillip-Perron unit root test to check the stationarity properties of the variables that are studied. The Johansen cointegration test is applied to test if the variables in series follow a common trend. An alternative unit root test by Perron and Vogelsang (1992) and Perron (1997) which test for structural breaks is applied to test for evidence for structural breaks in the data.

3.5.1 Time Series Properties of Variables

3.5.1.1 Stationary and Unit Root Test Procedure

The Augmented Dickey Fuller (ADF), Phillip-Perron (PP) and Perron and Vogelsang (1992) and Perron (1997) test for unit root are specified below in the following equations.

$H_0: \rho = 0$ (There is unit root/ non-stationarity)

$H_1: \rho \neq 0$ (No unit root/ There is stationarity)

$$\Delta Y_t = \alpha + \delta t + \rho Y_{t-1} + \sum_{i=1}^{P} \gamma_i \Delta Y_{t-1} + \varepsilon_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .3.5$$

Where; Δ represents the first difference operator, Y_t represents the variable at time (t), δ, α, ρ, γ are the parameters to be estimated and ε is the random error term. The lag length selection procedure follows the Akaike Information Criteria (AIC) lag length selection of Augmented Dickey Fuller (ADF) unit root test. This specification takes care of the problem of serial correlation since it incorporates lags of the first difference of the dependent variable. The null hypothesis states a condition of non-stationarity against an alternative hypothesis of stationarity.

Phillips and Perron (1988) unit root test is a test statistic that is made robust to serial correlation and heteroskedasticity problems. An advantage of the Phillip-Perron (PP) unit root test is that there is no need specifying the lag length. Therefore Phillips-Perron (PP) unit root test can be viewed as the Dickey Fuller (DF) test that is made robust to account for autocorrelation and heteroskedasticity problem. The specification process and equation is therefore written as;

$$\Delta y_t = \alpha + \rho y_{t-1} + u_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . . \dots 3.6$$

Δ is the difference operator, y_t and y_{t-1} is the series at time (t) and (t-1) respectively. α and ρ are the parameters to be estimated. (u) is the random disturbance term. The null hypothesis states the presence of unit root while the alternative states the presence of stationarity.

Perron and Vogelsang (1992) and Perron (1997) test for unit root with the presence of structural breaks in the data set. Depending on the interest of the researcher, this technique permits the researcher to test for sudden changes using Additive Outlier (AO) models or testing for more gradual changes using Innovational Outlier (IO) models. These two models were first applied by Perron and Vogelsang (1992) for non-trending data. They were later modified by Perron (1997) for trending data. This study adopts the minimal t-statistic and the f-test statistic to either reject or accept the null hypothesis. The specification procedure and equation is written as;

$$y_t = \propto + \alpha y_{t-1} + \beta t + \theta DU_t + \mu DT_t + \sum_{j=1}^{k} \rho_i \Delta y_{t-j} + \in_t \qquad \text{.............................3.7}$$

DT_t and DU_t represent dummy variables that denote trend shift and mean shift respectively. DT_t= t- TB given that t > TB; 0 otherwise and DU_t=1. TB is a

representation of when the structural break occurs. α,β , θ, μ and ρ are parameters to be estimated. Δ is the difference operator and $\in$ is the disturbance term. One major advantage of this method is that it locates where the structural break occurs which allows the researcher to relate the structural breaks possible changes in policy.

3.5.1.2 Cointegration Test Procedure

The rational for testing the cointegration among the variables is to assist in adopting the appropriate model to estimate the variables that are studied. The VAR or the VECM models of estimation can only be applied after testing for the cointegration among the variables. For instance, the Vector Auto-Regression can on be extended to the Vector Error Correction Model when the order of intergration among the variables is clearly established. Due to dynamic nature of the variables, Vector Error Correction Model is applied when there is evidence of cointegration among the series. In view of this, the VECM is viewed as an extended for of the VAR. Establishing the long term relationship among the variables is needed before their parameters can be estimated with the Vector Error Correction Model. The rational is to ensure that non-stationary group in a series are stationary/cointegrated and exhibit evidence of equilibrium relationship in the long run.

The bounds test procedure via the auto-regressive distributed lag (ARDL) estimation technique is conducted to test for cointegration. The use of bounds test via ARDL is justified on the grounds that; the ARDL technique is appropriate for finite samples, unlike the Engle and Granger and the Johansen maximum likelihood which suffers from sample bias. The process involved in modeling in ARDL is dynamic such that the lags of the dependent variables and lags of the independent variable incorporated (Perasan et al., 2001). Both the short-run and long-run coefficients are obtained within the system of analysis. The study applies the bounds test for cointegration within the framework of the ARDL estimation procedure. The specification of the ARDL equation that is used for estimation using an unrestricted error correction presented in the appendix.

3.5.2 Estimation of Variables

In addition to the Johansen cointegrating criteria specified in the above, the long-run and short-run relationship among the variables is estimated using the Vector Error Correcting Model (VECM). The VECM is employed because it is more appropriate to model the relationships among the variables. The dynamic nature of variable such as oil price and exchange rates, and how they impact oil consumption makes VECM the suitable technique of estimation. The technique has a unique dynamic solution in the steady state that is able to establish the equilibrium position that oil price, incomes, exchange rates and the quantity of oil consumed will converge to a steady state. A robust check estimation procedure is also conducted using ARDL

3.5.2.1 The Vector Error Correction Model (VECM)

The baseline representation of the variables (oil consumption, oil price, real GDP per capita, real effective exchange rates, and time) can be represented in a matrix notation using the functional form in 3.2 and the specification in 3.3 as;

Z_t □ □□ VZ VZ VZ VZ VZ_1 $_{t□1}$□ $_{2\ t□2}$ □ $_{3\ t□3}$□ $_{4\ t□4}$ □ $_{5\ t□5}$ □□$_t$
……………………………………… 3.8

Z_t is a matrix of five variables included in the model. The formulation in 3.10 can be rewritten in a vector error correction model (VECM) as;

□ □ □□□ □□□ □□□ □□□ □□□ □□ □Z_t □ $_1 Z_{t□1}$ $_2 Z_{t□2}$ $_3 Z_{t□3}$ $_4 Z_{t□4}$ $_5 Z_{t□5}$
$Z_{t□1}$ □$_t$ ……………..3.9

From 3.11, □ □□ □ □ □ □ □$_i$(A_1 A_2 A_3 A_4 A_5 I) where i □1,2,3,4,5, and

□□ □ □ □ □ □A_1 A_2 A_3 A_4 A_5 I

Z_t is a vector of variables integrated of order one {I(1)} of dimension $n \times 1$. □ is the impact matrix and also a square coefficient matrix with dimension 5×5. It estimates the degree of cointegration in the system and has information about the long-run relationships among the variables. The disturbance term (□$_t$) is a representation for a vector of innovations with dimension $n \times 1$. The assumption is that, □Z_t is stationary, therefore all the variables and as well as the residuals are also stationary. The implication is that, $\square V_{t\square 1}$ has an integration order of zero. The 5×5 matrix (□) has a rank of 5, and hence a 5-dimension vector space is created. Therefore a 5×1 vector space can be created as a linear combination of its rows. Stationary is achieved in the linear combination of the rows. The stationary component has a rank *(r)*, which is less than 5 *(r<5)*. The rank of the matrix determine the number of independent rows in □, and this also determines the number of cointegrating vectors. The rank is determined by the number of significant eigenvalues.

If we impose the assumption that $\square\square\square\square^{I}$ for matrix of dimension $(m \times r)$, the speed at which the model will adjust to equilibrium after external shocks is denoted by □. The long-run matrix of coefficients is represented by $\square^{I}$. This implies that $\square^{I} V_{t\square 1}$ is an equivalent of the error correction term and has up to a maximum of $(n-1)$ vectors. An equivalent of the Vector Error Correction Model (VECM) in equation 3.10 can be expressed as;

$$\square\ \square\ \square\square\square\ \square\square\square\ \square\square\square\ \square\square\square\ \square\square\square\ \square Z_t\ \square\ _1 Z_{t\square 1}\ _2 Z_{t\square 2}\ _3 Z_{t\square 3}\ _4 Z_{t\square 4}\ _5 Z_{t\square 5}\ \square\square\ \square_I Z_{t\square 1} \square\ _t \ldots\ldots\ldots\ldots..3.10$$

The study expects the coefficient of the speed of adjustment to equilibrium (□) to be negative and significantly different from zero. An equivalent of the error correction term is represented by $\square^{I} V_{t\square 1}$. The study expects this coefficient to be statistically significant should there be the existence of long-run relationships.

3.5.2.2 Impulse Response Function and Variance Decomposition Function

The impulse response function (IRF) and the variance decomposition function (VDF) employed in the study measure the effects of shocks (innovation) in the independent variables captured in the model and their effect on crude oil demand. Both the VDF and IRF are applied in the framework of vector autoregressive (VAR). The VDF and IRF do two things; information on the time paths of the variables is revealed and the effect of how the dependent variable responds to shocks from the independent variables is captured correctly. The VDF and the IRF in the VAR framework estimates the dynamic relationships among the variables. The impulse response function is carried to examine the response of the dependent variable to sudden changes in any of the independent variables included in the model to be estimated, whereas the variance decomposition function estimates a proportion of the forecast variance of the dependent variable ascribed to changes in one of the independent variables.

The VAR model is estimated first before the VDFs and IRFs can be evaluated. The equation to estimate the VAR model is written as;

$$V_t = \alpha + \delta_1 V_{t-1} + \delta_2 V_{t-2} + \ldots + \delta_q V_{t-q} + \varepsilon_t \quad \ldots\ldots 3.11$$

Where V represents the dependent variable, α is the vector, δ’s are the parameters, t represents the time trend, q is the optimal lag length and ε represent the disturbance term. Pesaran and Shin (1998) and Koop et al (1996) postulated the generalized forecast error variance, an alternative of the cholesky decomposition. According to Pesaran and Shin (1998), the generalized forecast variance decomposition technique identifies the proportion of response in the dependent variable due to shocks emanating from the independent variables. The generalized forecast variance is invariant to the arrangement of the variables estimated in VAR. This approach also simultaneously estimate innovation effects among the variables. The generalized forecast variance technique is used to estimate the IRFs and VDFs.

CHAPTER FOUR ANALYSIS AND DISCUSSION OF EMPIRICAL RESULTS

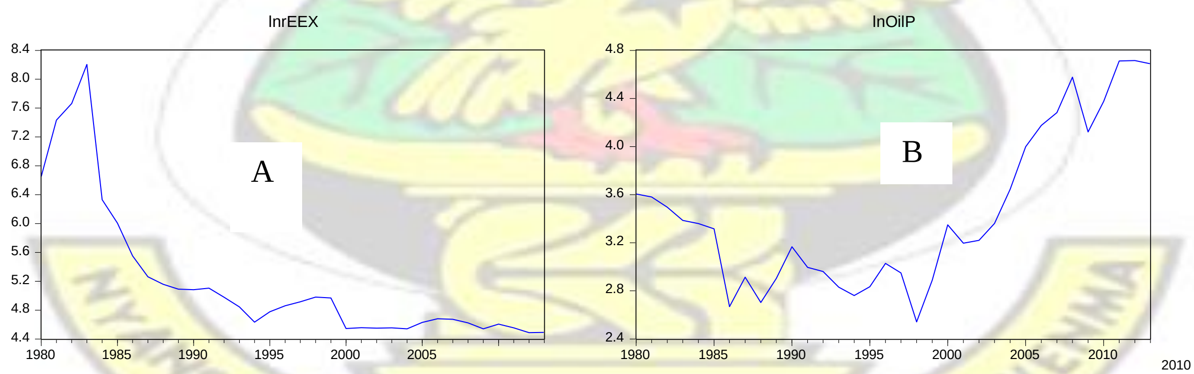
4.1 Introduction

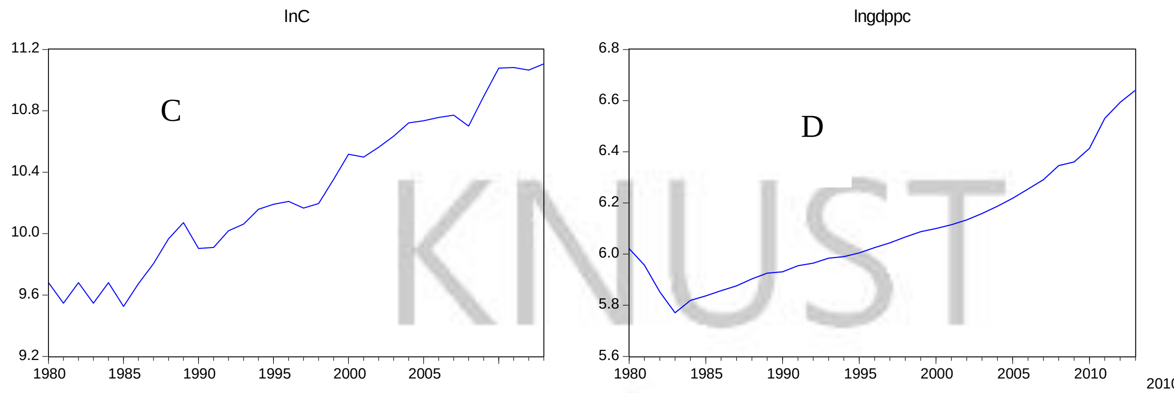
The models specified in previous chapter are analyzed and the empirical results presented in this chapter. The estimation of empirical results as described by the models is to enable the researcher answer the research questions and also measure the study objectives appropriately. The test results of the time series properties and as well the model diagnostic tests are presented in this chapter. The VECM results for both the long-run and short run determinants of oil consumption in Ghana is also presented and discussed in this chapter.

4.2 Trend Analysis of Variables

Analyzing the trend of the variables gives you a pictorial depiction of the behavior of the variables over time. It reveals the peaks and troughs of the variables and as well as periods of breaks in the variables. Analyzing the trend of variable is a casual way of testing the stationarity properties of the variables, such that its mean, variance etc are constant over time. The study investigates the trend of the variables to understand how the variables respond to temporal shift effects (shocks). A trend analysis of the variables is presented in the figure below;

Figure 4.1: Trend analysis of variable





4.2.1 Trend in real effective exchange rates

It can be inferred from Figure 4.1 (A) that; there was a sudden peak in real effective exchange rates in the year 1983. Thereafter, there has since been a downwards trend in real effective exchange rates from 1985 through to 2013 with a few intermittent short spikes recorded within that same time period. The downwards trend in real effective exchange rate variable after 1983 can be explained by the introduction of the economic recovery program in the same year followed by a subsequent implementation of alternative economic management schemes.

4.2.2 Trend in oil prices

The price of Brent crude oil in the world market has been through several periods of downturns and upswings from 1980 to 2013. Notable factors that might have contributed to these price dynamics has been the production behavior of OPEC and Non-OPEC countries. From Figure 4.1 (B), there are some observed few spikes along the trend in oil prices for the period under study. The lowest price of Brent world crude oil was recorded in the year 1998, followed by a gradual peak from the year 2000 through the year 2013.

4.2.3 Trend in crude oil demand

Figure 4.1 (C) shows a rising trend in oil consumption in Ghana. The graph shows that Ghana has increasingly demanded and consumed higher quantities oil. Two key factors could account for this ever increasing consumption of oil in Ghana; first, is the industrialization drive that was launched immediately after independence in 1957 and second is the generation of power from thermal plants. Oil is demanded for refining at Tema Oil Refinery (TOR) to serve industries and also for domestic purposes. Nonetheless, this ever increasing can be mitigated if measures are adopted to improve the efficiency of domestic consumption of oil.

4.2.4 Trend in gross domestic product per capita

The trend in gross domestic product per capita is presented in Figure 4.1 (D). Gross domestic product per capita declined to its lowest in 1983. It grew steadily thereafter when the Economic Recovery Program was implemented in that year. It however averaged 5.85 from 1984 to 1994 and then after peaked to an average of 6.3 at a period when the country was experiencing some considerable among of growth. The highest gross domestic product per capita values was recorded in the year 2011 through to 2013 when the country experienced a growth rate of 15% in 2011, 8.78% in 2012 and 7.13% in 2013.

4.3 Analysis and Results of stationarity properties of variables

In studying the variables that affect domestic consumption of oil, a formal test is conducted using the Augmented Dickey Fuller (ADF) Phillips Perron (PP) to test for the presence of unit root in each series. Perron and Vogelsang and Perron unit root test with structural breaks is also applied to test for the presence of unit root with structural breaks. In each case, a null hypothesis of non-stationarity in in the individual series is tested against an alternative of stationarity. The results are presented in Table 4.1 and Table 4.2.

It can be inferred from Table 4.1 that the ADF and the Phillips Perron test at the levels accept the null hypothesis of non-stationarity (unit root) for each series at 5% and 10% significance levels. However, both the ADF and Phillips Perron test significantly rejected the null hypothesis of non-stationarity after the first-difference of each of the series. The study concludes that the series that are employed in this study have an integrating order of one [I (1)]. Economically, the implication of each series attaining stationarity after first difference is that, shocks to each of the variables will not have a lasting effect since there is the presence of mean reversion after first difference. Statistically, this is also to ensure that the likelihood of obtaining spurious results is checked.

Table 4.1: Stationarity test results for all variables

	Levels				
Variable	ADF- nit Root Test		PP- it Root Test		Order of integration
	Intercept	Intercept and T	Intercept	Intercept and T	
LnC					
	0.042026	-5.216015	1.389161	-7.228223	
	0.9450	0.5555	0.8901	0.4572	
LnGDPPC	0.939074	-2.006984	3.097775	-2.372341	
	0.9948	0.5755	1.0000	0.3862	
LnOilP	-0.240231	-1.802041	-0.175173	-1.627126	
	0.9233	0.6809	0.9322	0.7601	
LnrEEx	-1.577719	-2.205203	-1.427283	-1.748826	
	0.4824	0.4708	0.5570	0.7063	

First Difference					
LnC	-5.5926*** 0.0001	-5.51440*** 0.0005	-13.966*** 0.0000	-15.1287*** 0.0000	I(1)
LnGDPPC	-3.0349*** 0.0423	-4.927563*** 0.0021	-2.576550** 0.0593	-3.405053** 0.0685	I(1)
LnOilP	-5.9284*** 0.0000	-5.506144*** 0.0005	-5.93062*** 0.0000	-8.592828*** 0.0000	I(1)
LnrEEx	-5.8631*** 0.0000	-6.795427*** 0.0000	-5.8631*** 0.0000	-6.712282*** 0.0000	I(1)

Authors construction (2016) **, ***significant at 10% and 5% significance level

The study also conducted a unit root with structural breaks to check for structural breaks in the series from 1980 to 2013. The result is presented in Table 4.2. The results show that oil consumption, gross domestic product per capita and real effective rate have an integrating order of zero [I (0)] while oil price has an integrating order of one [I(1)]. The study strictly employed the series properties of the variables suggested by the ADF and Phillips Perron unit root test results.

Table 2.2: Structural breaks unit root test

Variable	Levels	Break Date	1ST DIFFERENCE	Break Date	Decision
LnC	-5.855700***	2002	-6.462675	1989	I(0)
LnGDPPC	7.894446***	2006	-4.949314	2008	I(0)
LnOilP	-3.989495	1996	-7.394922***	1998	I(1)
LnrEEx	-8.289704***	1989	-14.50485	1992	I(0)

Authors construction (2016) ***and ** significant at 5% and 1% significance level,
(2) lag length

The structural break in oil consumption series was the result of the expansion of TOR's capacity to about 120 tonnes per day from a previous capacity of 60 tonnes in 2002. The installation of this new capacity according to Energy Ministry was funded by Samsung Corporation of South Korea. The structural break which occurred in the real effective exchange rate series in 1989 could be explained by Bank of Ghana decision to move away from the dual exchange rate system to the Dutch auction system in 1988. The new system brought about a compound currency practice which was carried out in US dollars. The structural breaks in the GDPPC series in 2006 could be accounted for by structural changes. In 2006 the industrial sector outperformed the Agricultural and Service sectors with the country experiencing its fastest real GDP growth rate of 6.2% (Economic Review and Outlook, 2007). However, the structural break in oil price in 1998 is as a result of the 1998 oil price crises. According to (Mabru, 1998), the price of Brent which is marker for crude oil export had dipped down to $11.29 per barrel in the year 1998.

4.4 Analysis and Results of Cointegration

From Table 4.3 which presents the bounds test cointegration results. The four critical value bounds for the upper and the lower bound are the bench mark critical values for testing for the presence of cointegration. The F-statistic of 10.87001 exceeds both the upper and lower bounds at 1%, 2.5%, 5% and 10% significance level. Thus if oil consumption is modeled as the independent variable, then all the independent variables are said to be drivers of oil demand in the long-run. Based on these results, the study concludes that coingration is present and hence there is a stable long-run equilibrium relationship among the variables and the VECM procedure otherwise known as the restricted VAR can be used to estimate the variables in the model.

Table 4.3: Bounds test cointegration results (Robust check)

Test statistic	Value	K
F-statistic	10.87001	4
Critical value bounds		
Significance	Lower bound	Upper bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.75	5.06

4.5 Empirical result for long-run estimates from VECM model

The results in Table 4.5 are representation of the long-run relationship between oil consumption, income, oil price, real effective exchange rate and exogenous technical change estimated via the vector error correction.

Table 4.4: VECM model for long-run elasticities

Variable	Coefficient	Standard Error	t-value
LNGDPPC	0.206880***	0.24770	4.33710
LNOILP	0.300042***	0.05221	5.74646
LNREEX	0.418294***	0.09703	4.31112
LNT	-2.897419***	0.26144	-11.0824

Authors construction, 2016 ***Significant at 5% significance level

The coefficient of GDPPC which is a proxy for income gives the long-run effect of income on oil consumption. The coefficient estimate of GDPPC is 0.2068 and statistically significant at 5% significance level. This is an indication that in the long-run there is a positive relationship between crude oil demand and income. Crude oil demand in Ghana in the long-run is income inelastic. The results further posit that oil demand in the long-run is price inelastic and the coefficient of oil price is statistically non-zero at 5%

significance level. These findings are consistent with the evidence views by Royfaisal (20011). However the coefficient of real effective exchange is positive and statistically significant at 5% significance level. The coefficient of REEX is 0.4182. This implies that currency depreciation will cause an increase in crude demand in Ghana. Lastly, oil consumption in Ghana is technological improving in the long-run in Ghana. The coefficient of exogenous technical progress is negative and elastic. The coefficient of time trend (T), a proxy for exogenous technical progress is -2.897419 and statistically significant at 5% significance level. The negative coefficient of the time trend variable means there is evidence of exogenous technical progress in the long-run. Oil demand in Ghana is expected to reduce with an improvement in technology that enhances oil consumption efficiency in the long-run.

4.6 Empirical results for short-run estimates from VECM model

Table 4.5: VECM model results for short-run estimates

Dependent Variable: Oil Consumption   Lags: 2 (AIC Criteria)   2-Cointegration equations

Variable	D(LNC)	D(LNGDPPC)	D(LNOILP)	D(LNREEX)	D(LNT)
ECM (-1)	-0.931115***	-0.009866	2.977533	1.294367	-0.000146
	(0.31589)	(0.07537)	(0.69963)	(0.65283)	(0.00063)
	[-2.94762]	[-0.13091]	[4.25587]	[1.98270]	[-0.2325]
D(LNC(-1))	0.686260	0.047782	-0.297915	-0.792237	0.001108
	(0.28522)	(0.06805)	(0.63170)	(0.58944)	(0.00057)
	[2.40611]	[0.70218]	[-0.47161]	[-1.34405]	[1.96053]
D(LNC(-2))	-0.057009	0.059735	-1.061953	-0.272819	0.000107

	(0.22702)	(0.05416)	(0.50281)	(0.46918)	(0.00045)
	[-0.25112]	[1.10286]	[-2.11204]	[-0.58148]	[0.23888]
D(LNGDPPC(-1)	-1.310033**	0.151338	3.278389	3.784225	0.008946
	(0.81217)	(0.19377)	(1.79879)	(1.67847)	(0.00161)
	[-1.67301]	[0.78102]	[1.82255]	[2.25457]	[5.55748]
D(LNGDPPC(-2)	-1.564101***	-0.096019	2.498028	3.850134	0.008410
	(0.82153)	(0.19600)	(1.81953)	(1.69782)	(0.00163)
	[-1.99388]	[-0.48988]	[1.37289]	[2.26769]	[5.16463]
D(LNOILP(-1)	0.004272	-0.010162	-0.307409	-0.223298	-0.000379
	(0.07954)	(0.01898)	(0.17617)	(0.16438)	(0.00016)
	[0.05370]	[-0.53547]	[-1.74499]	[-1.35841]	[-2.4023]
D(LNOILP(-2)	0.017198	-0.012075	-0.268474	-0.075931	-0.000210
	(0.06942)	(0.01656)	(0.15375)	(0.14347)	(0.00014)
	[0.24773]	[-0.72905]	[-1.74613]	[-0.52925]	[-1.5287]
D(LNREEX(-1)	0.155602***	0.018237	0.149187	-0.456847	0.000382
	(0.06471)	(0.01544)	(0.14332)	(0.13373)	(0.00013)
	[2.40458]	[1.18123]	[1.04093]	[-3.41608]	[2.97845]
D(LNREEX(-2)	-0.109346***	0.000904	0.080569	-0.073528	8.24E-05
	(0.05568)	(0.01328)	(0.12332)	(0.11507)	(0.00011)
	[-1.96392]	[0.06806]	[0.65336]	[-0.63901]	[0.74704]
D(LNT(-1)	11.28944***	3.278343	-9.354930	-67.53180	0.966646
	(3.66435)	(0.87425)	(8.11581)	(7.57294)	(0.00726)
	[3.08089]	[3.74988]	[-1.15268]	[-8.91752]	[133.089]
D(LNT(-2)	-5.111163***	-1.620040	1.760382	33.34493	-0.181628
	(1.72513)	(0.41159)	(3.82082)	(3.56524)	(0.00342)
	[-2.96278]	[-3.93608]	[0.46073]	[9.35279]	[-53.116]
C	-0.375328	-0.093871	0.682325	2.149425	0.010887
	(0.14946)	(0.03566)	(0.33102)	(0.30887)	(0.00030)
	[-2.51130]	[-2.63254]	[2.06131]	[6.95891]	[36.7523]
R-squared	0.696711	0.818787	0.792745	0.915750	0.999997
Adj. R-squared	0.494519	0.697978	0.654575	0.859584	0.999995
F-statistic	3.445780	6.777550	5.737465	16.30423	518509.0

***significant at 5% significant level, **significant at 10% significance level ( ) standard errors

The short-run equilibrium and dynamic relationships among the variables in the multivariate specification between the dependent and independent variables are estimated with the Error Correction Model. Applying VECM, the speed of adjustment and short-run parameters of the multi-variable cointegration VECM model is shown in Table 4.7.

We can infer from Table 4.7 that the ECM (-1) coefficient for the oil consumption function is negative as expected. The coefficient is statistically significant at 5% significance level. The ECM (-1) coefficient -0.931115 is a measure of the speed of adjustment to long-run equilibrium value. The rate at which oil consumption variable will respond to changes in any of the independent variables specified in the model before converging to its long-run equilibrium is captured in the error correction coefficient. The economic intuition of its negative coefficient is that, the system is very effective at restoring itself to equilibrium and hence the model has a stable equilibrium. However, it will take 93% for any disequilibrium to be corrected within the period of a year. A high coefficient value for the adjustment coefficient matrix means that convergence to equilibrium is very fast. For that matter, it will take the country a period of at least one year to correct any shock to ensure that long-run equilibrium is achieved. Shocks emanating from the any of independent variables to the endogenous variable are not expected to last more than a year before they are corrected for equilibrium to be achieved in the long-run.

From the short-run estimates, the coefficients of income for both lag periods are statistically differently from zero at 10% and 5% significance level respectively. Oil consumption is income elastic in the short-run for both lag periods. The coefficients of income are -1.310033 for lag period one and -1.564101 for lag period two. This implies that every 1% increase in income will cause a cause a decline in oil consumption. The negative coefficients indicate that as countries grow, they tend to opt for cleaner energy sources which in effect reduce the amount of oil that is demanded. Alternatively, countries also explore their oil-saving potential by adopting diverse technologies that will in effect reduce the amount of oil that is consumed. It is assume that technical change is output augmenting.

On the hand, the coefficients of oil prices for both lag periods are statistically insignificant at 5% significance level in the short-run. The country to larger extent is completely oil dependent to the extent that in the short-run it will demand any quantity of oil regardless of the price of oil in the international market. This explains why the country has since remained a net oil importer.

Again 0.155602 and -0.109346 are the coefficients of real effective exchange for lag period one and lag period two respectively. Both coefficients are significant at 5% significance level in the short-run. The sign of the coefficient of the REEX for one lag period is not consistent with prior expectations. Oil consumption in the short-run is exchange rate inelastic. 1% depreciation in the value of REEX in lag period one will result in 0.15% increase in oil consumption but 1% depreciation in REEX in lag period two will result in 0.10% decrease in oil consumption.

Lastly, the coefficients of exogenous technical progress in the short-run for one lag period and two lag periods are 11.28944 and -5.111163 respectively. The coefficients are statistically significant at 5% level, signifying that technical progress has an impact on oil consumption in Ghana. The positive coefficient for lag period one means that crude oil consumption is not technological improving in the short-run. Oil consumption in Ghana is only technical improving at lag period two. An investment in technical progress at time (t) will only improve oil consumption at time (t+2). The coefficient of determination is 0.696711. This means that about 69% of variation in oil consumption in Ghana is explained by all the independent variables.

4.7 VECM Causality test estimates/ Block Exogeneity Wald Tests

To measure the causality between oil demand and explanatory variables, the VECM Granger causality test, otherwise known the block exogeneity Wald test was applied to test the causality between oil consumption and economic growth. The null hypothesis states that lnGDPPC, lnOILP, lnREEX and LnT do not Granger cause lnC.

Table 4.6: **VECM Granger Causality/Block Exogeneity Wald Tests**

Dependent variable: D(LNC)		Dependent variable: D(LNGDPPC)	
Variable	Chi-squared	Variable	Chi-squared
D(LNGDPPC)	7.637904*** (0.0220)	D(LNC)	1.527977 (0.4658)
D(LNOILP)	0.064391 (0.9683)	D(LNOILP)	0.595933 (0.7423)
D(LNREEX)	8.261586*** (0.0161)	D(LNREEX)	1.470835 (0.4793)
D(LNT)	9.643450*** (0.0081)	D(LNT)	15.97755*** (0.0003)
All	32.98647*** (0.0001)	All	37.46910*** (0.0000)

All values in bracket are probability value, ***significant at 5% significance level

From table 4.8, a *p-value* of 0.0220 shows that the coefficients of lnGDPPC are jointly non-zero in the equation in which lnC is the dependent variable. We strongly reject the hypothesis that lnGDPPC does not Granger cause lnC. Likewise a *p-value* of 0.9683 shows that the coefficients of lnOILP are jointly zero in the equation in which lnC is the dependent variable, we therefore accept the hypothesis that lnOILP does not Granger causes lnC. The study also accepts the hypothesis that the coefficients of lnREEX exchange rate are jointly not equal to zero, since a probability value of 0.0161 indicate that they are jointly significant at 5% significance level. Also, the coefficients of lnT are jointly not equal to zero, since a probability value of 0.0081 indicates that they are significant at 5% level of significance level. In effect, incomes, oil price and real effective exchange rates causes crude oil demand in Ghana.

We can conclude from the VECM estimates that; oil price, real effective exchange rate, gross domestic product per capita and the trend variables individually had a significant impact on oil consumption in Ghana in long-run. The coefficient of income in the longrun is consistent with theory but same is not found with the price coefficient in the longrun. The negative coefficient of the exogenous trend variable is an indication of technical progress. Again, evidence from the short run estimates revealed that all the coefficients were statistical significant except the coefficient of oil price.

4.7 Variance Decomposition and Impulse Response Function Results

In order to examine the effects of shocks from real gross domestic product per capita, crude oil price, real effective exchange and exogenous technical progress on crude oil demand, the study estimated the IRF and the VDF. The effect of shocks or innovations in one variable is observed to identify the direction of response of a variable to a unit standard deviation in shocks emanating from the variable itself or from other variables. Table 4.9 reports the VDF of the variables included in the estimated equation in the previous chapter in a 10 year horizon.

Table 4.7: Variance decomposition results

32 Observations, VAR=2
% Generalized forecast error variance decomposition for Variable LnC

		d by shocks/inno			
Horizon	LNC	LNGDPPC	LNOILP	LNREEX	LNT
1	90.827	6.8799	1.5289	23.865	6.2243
2	89.044	7.2343	2.7713	23.273	6.0117
3	84.650	9.1489	5.9181	22.731	6.0250
4	81.401	10.805	7.2998	21.786	5.6704
5	79.380	10.911	7.8450	20.515	5.6817
6	77.722	10.499	8.4887	19.363	5.8344
7	76.084	10.111	9.4603	18.473	5.8683
8	74.498	9.7681	10.520	17.728	5.8631
9	73.049	9.4123	11.435	17.045	5.9132
10	71.734	9.0533	12.173	16.408	6.0420

Researcher's estimates, 2016

From Table 4.7, we can infer that within a ten year horizon, the forecast error variance in crude oil consumption (LNC) which measures crude oil demand is as a result of its own shocks. In horizon one, the results show that about 90.827% of the forecast error variance in LNC is as a result of its own innovations. From horizon two through to horizon seven, the innovations reduced gradually to 89.04%, 84.65%, 81.40%, 79.38%, 77.72% and 76.08% respectively. The own shock crude consumptions further declined to 74.49%, 73.04% and 71.73% in the eighth, ninth and tenth horizon respectively. The changes in Ghana's crude oil demand within the sample period may be as results of changes in the structure of the Ghanaian economy. We can again infer from column 5 of Table 4.9 that real effective exchange rate (LNREEX) contributed the highest in terms of forecast error variance to LNC.

In horizon one and two the forecast error variance of LNGDPPC to LNC is 6.87% and 7.23% respectively. From horizon three through to horizon five, the contributions of shocks from LNGDPPC to forecast error variance of LNC gradually increased to 9.14%, 10.8% and 10.91% respectively. From the sixth through to the tenth horizon, the contribution of shocks from LNGDPPC to the forecast error variance of LNC further declined to 10.1%, 9.76%, 9.41% and to 9.05% respectively. On average LNGDPPC contributed about 10% to error forecast variance of LNC over the defined time horizon.

This implies that shocks from changes in incomes did not affect Ghana's demand for crude oil greatly. On the hand, shocks from LNOILP to error forecast variance of LNC witnessed an ever increasing trend over the 10 year time horizon. LNOILP recorded its highest contribution to the forecast error variance of 10.5%, 11.4% and 12.17% in the eighth, ninth and tenth year respectively. Shocks in crude oil prices did not impact greatly on the demand for crude oil in Ghana.

From Table 4.9, we can also conclude that shocks from real effective exchange rate are the highest contributor to forecast error variance of oil consumption. In horizon one, innovations in LNREEX contributed about 23.8% in the forecast error variance of LNC.

Its explanatory power further declined slightly to 23.27% in the second horizon. In horizon 3, horizon 4, horizon 5 and horizon 6, the contributions in shocks from LNREEX further declined to 22.7%, 21.7%, 20.5% and 19.36% respectively. By the seventh horizon through to the tenth horizon, shock in LNREEX contributed 18.4%, 17.72%, 17.04% and 16.4% respectively to the forecast error variance of LNC. However, shocks in time trend variable only contributed an average of 6.5% of the shocks to the forecast error variance of LNC in the entire study horizon. From the discussions in the above, it is

evident that LNGDPPC, LNOILP, LNREEX and LNT play a significant role in accounting for the fluctuations in forecast error variance of Ghana's crude oil demand over the 10year horizon. Innovations in technical progress least explains Ghana's crude oil demand compared with the other variables in the model. The percent of variations in oil demand explained by real gross domestic product per capita, crude oil price, real effective exchange rate and technical progress increased over the specified time horizon. Innovations in real effective exchange rate accounted for the highest percentage.

Therefore dynamics in Ghana's crude oil demand is attributed to shocks in real effective exchange rates.

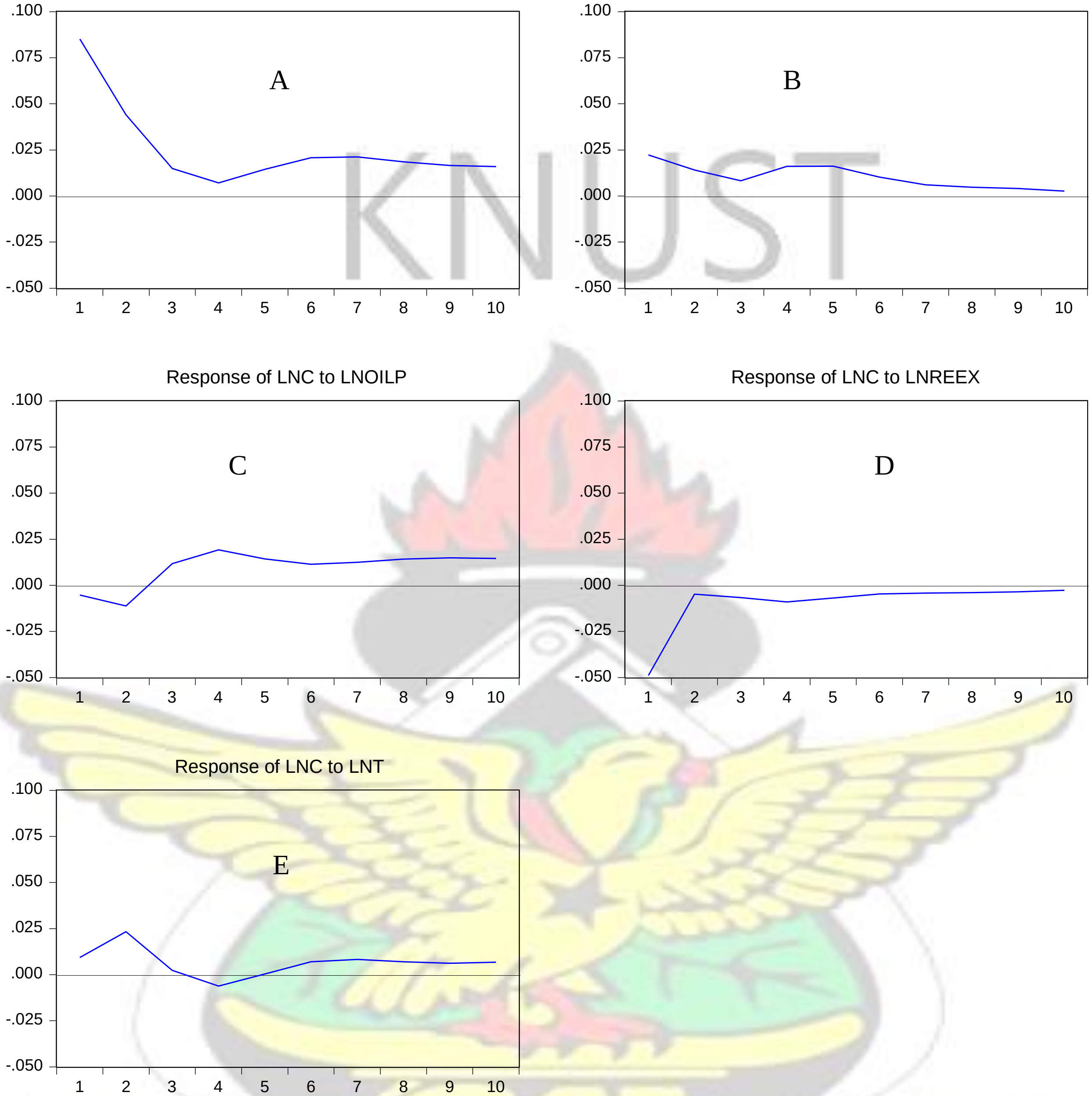
Figure 4.2 plots the generalized IRF of Ghana's crude oil consumption (LNC) with respect to the effect of one standard deviation shocks and innovations in real gross domestic product per capita (LNGDPPC), crude oil price (OILP), real effective exchange rate (LNREEX) and time trend (T) within a ten year horizon. The generalized IRF gives an understanding of the dynamic relationships between the variable as it demonstrates how oil demand responds to changes in shocks and innovations emanating from each of the independent variables.

Figure 3.2: Impulse Response results

Response to Generalized One S.D. Innovations

Response of LNC to LNC

Response of LNC to LNGDPPC



Source: Researcher's construct 2016

Figure 4.2 (B) through to figure 4.2 (E) discusses graphically how crude oil demand in Ghana responds to innovations and shocks in real gross domestic product per capita, crude oil price, real effective exchange rate and time trend. From Table 4.2 (B), shocks in LNGDPPC caused a decline in crude oil demand in Ghana in the early time horizon and in the latter time horizon. From period 1 to period 3, shocks in LNGDPPC caused a decline in LNC. Between period 4 and period 6, shocks in LNGDPPC caused crude oil demand in Ghana to peak slightly and thereafter declined after period 6 through to period 10.

From Figure 4.2 (C), shocks from crude oil price caused deterioration in crude oil consumption in Ghana from period 1 to period 2. Crude oil price shocks however resulted in a sustained increase in crude oil demand from period 3 to period 5. From period 6 through to period 10, crude oil price shocks did not have any significant impact on crude oil consumption. This is consistent with the long-run inelastic coefficient for crude oil price reported in Table 4.5 above. From Figure 4.2 (D), we can infer that shocks from LNREEX caused deterioration in LNC throughout the ten year period. From Figure 4.2 (E), shocks from technical progress however resulted in improvement in Ghana's crude oil demand from period 1 to period 3. LNT however caused a slight deterioration in LNC between the third and fifth period. From period 6 through to period 10, innovations from LNT did not have any significant impact on LNC. In conclusion, shocks to LNC from each of the independent variables were mostly transitory with their effect fading out with time.

The study therefore concludes from the variance decomposition results and the impulse response function that shocks and innovations in real effective exchange rate had the dominant effects on crude oil demand. Therefore dynamics in Ghana's crude oil demand is attributed to shocks in real effective exchange rates.

4.8 Models Diagnostic Test

The VECM model specification and the cointegration equation specification are checked to ensure that both models are stable. For stability to achieved, the restriction requires that moduli of *r* remaining eigenvalues must be strictly less than 1 (one). The Vector Error Correction Model has a 3 unit moduli (we can infer from Table 6 of appendix). The absence of a general theory of distribution to decide how close the unit roots are to 1 (one), makes it a difficult task to determine whether the moduli approach a unit or not. Making a graphical representation of the eigenvalues of the companion matrix as depicted in figure 1 (one) (see appendix) reveals that the remaining eigenvalues do not appear close to the unit circle. The check proves that the Vector Error Correction Model is a correct specification.

Table 4.8: Diagnostic and stability test results

Test criteria	Results
Serial Correlation	0.5002
Heteroskedasticity	0.5635
Normality Tests	Residuals are multivariate normal
Stability Test	Stable

Researcher's estimates, 2016

The normality test is also used to test if the errors are *iid* (independently, identically and normally distributed) with a zero mean and finite variance. The normality is presented in table 4 of the appendix. It is evident from the results that the errors of both equations are kurtotic and skewed. A null hypothesis that states the absence of serial autocorrelation is tested against an alternative hypothesis of the presence of serial autocorrelation. The LM test in table 3 of the appendix accepts the null hypothesis of no serial autocorrelation. The conclusion is that the disturbances have no evidence of serial correlation. The heteroskedasticity test in table 5 of the appendix also shows the absence of heteroskedasticity.

CHAPTER FIVE SUMMARY OF FINDINGS, CONCLUSION, AND POLICY IMPLICATIONS

5.1 Introduction

This chapter summarizes all the major findings that seek to measure the objectives of the study. It also provides a detailed conclusion of the study and as well outlines various policy implications. All the recommendations made in this chapter are based on the findings of the study.

5.2 Summary of findings

This study adopts the VECM approach to make an in-depth analysis of the determinants of crude oil demand in Ghana. The study after testing for the stationarity and nonstationarity properties of the variables also did test for the presence of structural breaks in the series applies the unit root test procedure suggested by Perron and Volgelsang (1992) and Perron (1997). The VECM method together with the bounds test procedure via ARDL is employed to explain the short-run and long-run relationships among the variables that are incorporated in the model. The VECM technique used in this study provided a check that isolated the short-run estimates from that of the long-run. The variance decomposition function (VDFs) and the impulse response function (IRFs) via the VAR approach examine the effect of shocks and innovations emanating from the independent and their effect on crude oil demand. Finding from annual time series data from 1980 to 2013 used to make an empirical estimation of crude oil demand in Ghana revealed the following; firstly, there are significance evidence of structural breaks in oil consumption, real effective exchange rate and gross domestic product per capita for Ghana. This was as a result of change in policy or structural changes of the economy.

The outcomes from the bounds test procedure via ARDL revealed the presence of a stable long-run equilibrium relationship among the variables. This is an indication that, oil consumption, oil prices, gross domestic product per capita, real effective exchange rate and technical progress in the long-run must converge to a stable equilibrium. A VECM estimate of the long-run coefficients of the variables revealed that; oil price, real effective exchange rate, gross domestic product per capita and the trend variables individually had a significant impact on oil consumption in Ghana. The coefficient of income in the longrun is consistent with the prior expectations but same is not found with the price coefficient in the long-run. The price elasticity coefficient is positive and inelastic. The inability of the country to explore for varied and alternative energy sources is the reason why an increase in oil prices drives oil demand in the long term. The real effective exchange rate elasticity is also consistent with the priori expectations. An improvement in our exchange rate position will improve the countries demand for oil in the long term. The negative coefficient of the exogenous trend variable is an indication of technical progress. An improvement in technology will in effect in the long term reduce the amount of oil that is consumed in Ghana.

Again, evidence from the short run estimates revealed the following; the coefficient of income in the short-run was statistically inconsistent with the prior expectations. An increase in income reduces our demand for oil in the short term. The negative coefficient implies that the country tends to opt for more efficient energy consumption appliance that reduces the amount of crude oil that is consumed. Another key interesting result is the insignificance of oil prices in the short-run. The conclusion arrived at based on this result is that, for a net oil importer like Ghana, the price of oil does not influence the amount of oil that is demanded since the economy depends heavily on crude oil. An improvement in real effective exchange rate increases the demand for crude oil for one lag period. Finally, the country experience technological regresses for one lag period and technological progress for two lag period. Therefore an improvement in technology at time (t) will reduce the demand for crude oil at time (t+2).

Finally, results from the variance decomposition function and the impulse response function revealed that, shocks and innovations from income, crude oil price, real effective exchange rate and technical progress significantly affected Ghana's crude oil demand with real effective exchange rate being the highest contributor to the forecast error variance of crude oil demand in Ghana.

5.3 Conclusions

The study based on the summary of findings in the above makes the following conclusions; evidence from the long run VECM results showed that incomes, the price of crude oil, real effective exchange rate and exogenous technical progress were the long run determinants of crude oil demand in Ghana. Again results from the short run estimates via VECM showed that incomes, real effective exchange rates and technical progress were the determinants of crude oil demand in Ghana. The coefficient of oil price was insignificant in the short run.

Again, there is evidence of exogenous technical progress in the long run for Ghana, such that an improvement in technology will cause a reduction in crude oil demand in Ghana in the long run. On the other hand, the country experienced technological regresses for one lag period and technological progress for two lag period in the short run. Therefore an improvement in technology at time (t) will reduce the demand for crude oil at time (t+2).

Finally shocks from incomes, real effective exchange rates, crude oil price, and exogenous technical progress affected crude oil demand in Ghana with shocks from real effective exchange rates haven the dominant and negative impact on crude oil demand in

Ghana.

5.4 Policy implications

This section gives a highlight of recommendations based on the major findings summarized in the previous section. Recommendations are made based on objectives that are considered in the study. It is expected that the recommendations of this study will inform policy makers on the determinants of crude oil demand in Ghana.

It is therefore recommended on the base of the findings that, Ghana adopt a strategic oil demand security policy by establishing and sustaining a planned oil reserve system that the country can depend solely on in times of disruptions in the international crude oil market. There is also the need for the country to shop for alternative sources of energy to reduce the countries dependence on imported crude oil. Stakeholders must make it a priority to either build or revive Ghana's refinery capabilities so that Ghana can enjoy the full benefits of domestic production of crude oil. Instead government exporting the entire crude produced in Ghana and rather importing more expensive petroleum products, government should rather rely solely on domestically produced crude oil for power generation and for refining at TOR. This can only be possible provided the country has upgraded its refinery facility to the level where it can refine crude from the Jubilee fields.

An increase in per capita real GDP is also expected to drive oil consumption in the long run. The implication is that, increasing domestic production is accompanied with an increase in crude oil demand. To this end, policies such as industrialization that cause an increase in productivity and incomes in general must be pursued. Again the coefficient of real exchange rate is positive and significant in the long run and short run for two lag periods but the reverse in the short run for one lag period. Therefore an improvement in the domestic currency against major currencies will improve Ghana's demand for crude oil. The study strongly recommends fiscal and monetary policy instruments that toughen the Cedi against major currencies must be implemented by the Bank of Ghana and the Ministry of Finance.

The study also found evidence of technical progress. The study therefore recommends measures that are aims improving oil efficiency in industry and in automobiles. The Ghana National Petroleum Commission and the National Petroleum Authority could also give incentive packages in the form of subsidies to industries that invest in technical progress will significantly impact the amount of oil that is demanded in Ghana. The study, based on the results from the variance decomposition function in the context of the VAR over a 10 year horizon, the relative contributions of shocks and innovations to forecast error variance of oil consumption from real effective exchange rate is dominant compared with the other variables. Crude oil demand in Ghana responds more to exchange rate dynamics. Positive real effective exchange shocks have a positive impact on crude oil consumption, implying that appreciation of the real effective exchange rate will improve crude oil demand in Ghana. Again, measures that strengthen the domestic currency against major currencies are strongly recommended.

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APPENDIX

Table A1: Vector Error Correction Estimates

Vector Error Correction Estimates
Date: 11/20/15 Time: 15:11
Sample (adjusted): 1983 2013
Included observations: 31 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	CointEq2
LNC(-1)	1.000000	0.000000
LNGDPPC(-1)	0.000000	1.000000
LNOILP(-1)	-0.300042	-0.209926
	(0.05221)	(0.03552)
	[-5.74646]	[-5.90953]
LNREEX(-1)	0.418294	0.271169
	(0.09703)	(0.06601)
	[4.31112]	[4.10787]
LNT(-1)	2.897419	3.140616
	(0.26144)	(0.17787)
	[11.0824]	[17.6566]
C	-19.29045	-15.29810

Error Correction:	D(LNC)	D(LNGDPPC)	D(LNOILP)	D(LNREEX)	D(LNT)
CointEq1	-0.931115	-0.009866	2.977533	1.294367	-0.000146
	(0.31589)	(0.07537)	(0.69963)	(0.65283)	(0.00063)
	[-2.94762]	[-0.13091]	[4.25587]	[1.98270]	[-0.23255]
CointEq2	1.087164	0.049935	-3.173993	-1.940976	-0.002421
	(0.34944)	(0.08337)	(0.77395)	(0.72218)	(0.00069)
	[3.11113]	[0.59895]	[-4.10104]	[-2.68767]	[-3.49476]
D(LNC(-1))	0.686260	0.047782	-0.297915	-0.792237	0.001108
	(0.28522)	(0.06805)	(0.63170)	(0.58944)	(0.00057)
	[2.40611]	[0.70218]	[-0.47161]	[-1.34405]	[1.96053]
D(LNC(-2))	-0.057009	0.059735	-1.061953	-0.272819	0.000107
	(0.22702)	(0.05416)	(0.50281)	(0.46918)	(0.00045)
	[-0.25112]	[1.10286]	[-2.11204]	[-0.58148]	[0.23888]
D(LNGDPPC(-1))	-1.310033	0.151338	3.278389	3.784225	0.008946
	(0.81217)	(0.19377)	(1.79879)	(1.67847)	(0.00161)

	[-1.67301]	[0.78102]	[1.82255]	[2.25457]	[5.55748]
D(LNGDPPC(-2))	-1.564101	-0.096019	2.498028	3.850134	0.008410
	(0.82153)	(0.19600)	(1.81953)	(1.69782)	(0.00163)
	[-1.99388]	[-0.48988]	[1.37289]	[2.26769]	[5.16463]
D(LNOILP(-1))	0.004272	-0.010162	-0.307409	-0.223298	-0.000379
	(0.07954)	(0.01898)	(0.17617)	(0.16438)	(0.00016)
	[0.05370]	[-0.53547]	[-1.74499]	[-1.35841]	[-2.40230]
D(LNOILP(-2))	0.017198	-0.012075	-0.268474	-0.075931	-0.000210
	(0.06942)	(0.01656)	(0.15375)	(0.14347)	(0.00014)
	[0.24773]	[-0.72905]	[-1.74613]	[-0.52925]	[-1.52872]
D(LNREEX(-1))	0.155602	0.018237	0.149187	-0.456847	0.000382
	(0.06471)	(0.01544)	(0.14332)	(0.13373)	(0.00013)
	[2.40458]	[1.18123]	[1.04093]	[-3.41608]	[2.97845]
D(LNREEX(-2))	-0.109346	0.000904	0.080569	-0.073528	8.24E-05
	(0.05568)	(0.01328)	(0.12332)	(0.11507)	(0.00011)
	[-1.96392]	[0.06806]	[0.65336]	[-0.63901]	[0.74704]
D(LNT(-1))	11.28944	3.278343	-9.354930	-67.53180	0.966646
	(3.66435)	(0.87425)	(8.11581)	(7.57294)	(0.00726)
	[3.08089]	[3.74988]	[-1.15268]	[-8.91752]	[133.089]
D(LNT(-2))	-5.111163	-1.620040	1.760382	33.34493	-0.181628
	(1.72513)	(0.41159)	(3.82082)	(3.56524)	(0.00342)
	[-2.96278]	[-3.93608]	[0.46073]	[9.35279]	[-53.1169]
C	-0.375328	-0.093871	0.682325	2.149425	0.010887
	(0.14946)	(0.03566)	(0.33102)	(0.30887)	(0.00030)
	[-2.51130]	[-2.63254]	[2.06131]	[6.95891]	[36.7523]
R-squared	0.696711	0.818787	0.792745	0.915750	0.999997
Adj. R-squared	0.494519	0.697978	0.654575	0.859584	0.999995
Sum sq. resids	0.083055	0.004728	0.407416	0.354734	3.26E-07
S.E. equation	0.067928	0.016206	0.150447	0.140383	0.000135
F-statistic	3.445780	6.777550	5.737465	16.30423	518509.0
Log likelihood	47.80755	92.23165	23.15747	25.30371	240.7389
Akaike AIC	-2.245649	-5.111720	-0.655321	-0.793788	-14.69283
Schwarz SC	-1.644299	-4.510370	-0.053971	-0.192438	-14.09148
Mean dependent	0.045989	0.025451	0.038471	-0.102293	0.078314
S.D. dependent	0.095542	0.029490	0.255980	0.374634	0.061318

Determinant resid covariance (dof adj.)	2.69 E-18
Determinant resid covariance	1.77E-19
Log likelihood	449.3057
Akaike information criterion	-24.14875
Schwarz criterion	-20.67943

Table A2: VEC Granger Causality/Block Exogeneity Wald Tests

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 11/20/15 Time: 15:12
Sample: 1980 2013
Included observations: 31

Dependent variable: D(LNC)

Excluded	Chi -sq	df	Prob.
D(LNGDPPC)	7.637904	2	0.0220
D(LNOILP)	0.064391	2	0.9683
D(LNREEX)	8.261586	2	0.0161
D(LNT)	9.643450	2	0.0081
All	32.98647	8	0.0001

Dependent variable: D(LNGDPPC)

Excluded	Chi -sq	df	Prob.
D(LNC)	1.527977	2	0.4658
D(LNOILP)	0.595933	2	0.7423
D(LNREEX)	1.470835	2	0.4793
D(LNT)	15.97755	2	0.0003
All	37.46910	8	0.0000

Table A3: VEC Residual Serial Correlation LM Tests

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 11/20/15 Time: 15:16
Sample: 1980 2013
Included observations: 31

Lags	LM- Stat	Prob
1	24.33341	0.5002

Probs from chi-square with 25 df.

Table A4: VEC Residual Normality Tests

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 11/20/15 Time: 15:17
Sample: 1980 2013
Included observations: 31

Component	Skewness	Chi-sq	df	Prob.
1	-0.307546	0.488687	1	0.4845
2	0.948005	4.643349	1	0.0312
3	-0.263956	0.359975	1	0.5485
4	-0.091245	0.043016	1	0.8357
5	-0.379862	0.745525	1	0.3879
Joint		6.280553	5	0.2799

Component	Kurtosis	Chi-sq	df	Prob.
1	2.499379	0.323719	1	0.5694
2	5.214112	6.332126	1	0.0119
3	3.938300	1.137192	1	0.2862

4	3.053956	0.003760	1	0.9511
5	3.162123	0.033950	1	0.8538
Joint		7.830747	5	0.1658

Component	Jarque-Bera	df	Prob.
1	0.812406	2	0.6662
2	10.97548	2	0.0041
3	1.497167	2	0.4730
4	0.046776	2	0.9769
5	0.779475	2	0.6772
Joint	14.11130	10	0.1680

Table A5: VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 11/20/15 Time: 15:18
Sample: 1980 2013
Included observations: 31

Joint test:

Chi-sq	Df	Prob.
355.0642	360	0.5635

Individual components:

Dependent	R-squared	F(24,6)	Prob.	Chi-sq(24)	Prob.
res1*res1	0.815446	1.104615	0.4925	25.27882	0.3907
res2*res2	0.958966	5.842449	0.0179	29.72793	0.1939
res3*res3	0.801987	1.012545	0.5445	24.86160	0.4133
res4*res4	0.665924	0.498332	0.8957	20.64363	0.6596
res5*res5	0.893687	2.101555	0.1805	27.70431	0.2727
res2*res1	0.920614	2.899178	0.0941	28.53904	0.2380
res3*res1	0.916135	2.730991	0.1069	28.40019	0.2435
res3*res2	0.963227	6.548410	0.0133	29.86003	0.1894
res4*res1	0.796340	0.977534	0.5656	24.68653	0.4230

res4*res2	0.808475	1.055311	0.5197	25.06272	0.4024
res4*res3	0.761046	0.796225	0.6859	23.59242	0.4851
res5*res1	0.937794	3.768927	0.0523	29.07162	0.2174
res5*res2	0.975635	10.01048	0.0043	30.24467	0.1768
res5*res3	0.820269	1.140971	0.4733	25.42835	0.3828
res5*res4	0.899117	2.228110	0.1614	27.87262	0.2654

Table A6: Stability Test

Roots of Characteristic Polynomial
Endogenous variables: LNC LNGDPPC LNOILP LNREEX LNT
Exogenous variables:
Lag specification: 1 2
Date: 11/20/15 Time: 15:19

Root	Modulus
1.000000	1.000000
1.000000 - 1.65e-15i	1.000000
1.000000 + 1.65e-15i	1.000000
0.979847	0.979847
0.361982 - 0.772966i	0.853527
0.361982 + 0.772966i	0.853527
0.816123	0.816123
-0.163699 - 0.625077i	0.646156
-0.163699 + 0.625077i	0.646156
-0.522869 - 0.271016i	0.588932
-0.522869 + 0.271016i	0.588932
0.588768	0.588768
-0.032352 - 0.504524i	0.505560
-0.032352 + 0.504524i	0.505560
0.267934	0.267934

VEC specification imposes 3 unit root(s).

Figure 1: Stability test: Inverse Roots of AR characteristic Polynomial

Inverse Roots of AR Characteristic Polynomial

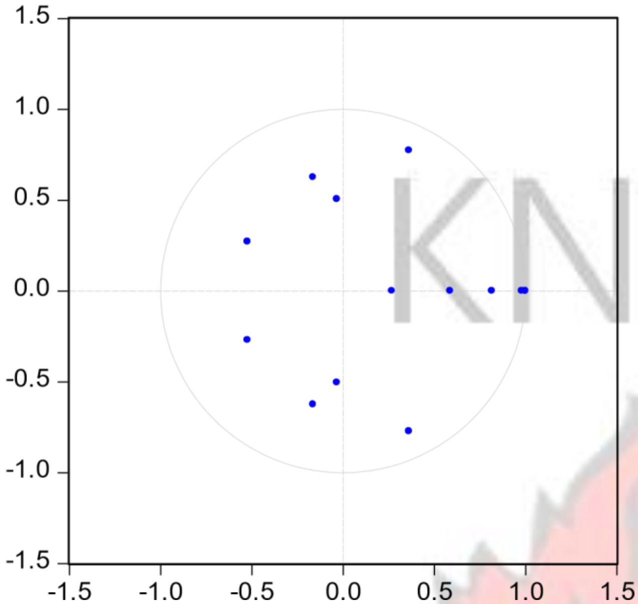


Table A7: COINTEGRATION RESULTS

Date: 11/20/15 Time: 15:00
Sample (adjusted): 1982 2013
Included observations: 32 after adjustments
Trend assumption: Linear deterministic trend
Series: LNC LNGDPPC LNOILP LNREEX LNT
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 *	0.993349	211.2154	69.81889	0.0000
At most 1 *	0.548755	50.80139	47.85613	0.0258
At most 2	0.369495	25.33758	29.79707	0.1497
At most 3	0.272143	10.57808	15.49471	0.2388
At most 4	0.012831	0.413244	3.841466	0.5203

Trace test indicates 2 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 *	0.993349	160.4140	69.81889	0.0001
At most 1	0.548755	25.46381	47.85613	0.0911
At most 2	0.369495	14.75949	29.79707	0.3061
At most 3	0.272143	10.16484	15.49471	0.2013
At most 4	0.012831	0.413244	3.841466	0.5203

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):

LNC	LNGDPPC	LNOILP	LNREEX	LNT
-2.032672	0.420520	-0.154456	-1.134342	4.661932
-9.699843	12.40213	1.545107	-2.452201	-1.168165
-11.34965	1.724689	-0.280346	2.606777	11.52496
9.086569	-2.243723	-3.317635	-0.471158	-5.195599
-0.860347	29.96060	-4.328529	0.771948	-5.873951

Unrestricted Adjustment Coefficients (alpha):

D(LNC)	0.007206	0.018870	0.033895	-0.011646	-0.005271
D(LNGDPPC)	-0.009493	-0.009222	-0.002681	-0.007232	-0.000940
D(LNOILP)	0.007343	-0.104864	-0.003162	0.052897	-0.007020
D(LNREEX)	0.195908	0.122943	-0.110185	0.056576	0.005162
D(LNT)	-0.008690	0.001112	-0.000170	0.000208	-2.32E-05

1 Cointegrating Equation(s): Log likelihood 316.2641

Normalized cointegrating coefficients (standard error in parentheses)

LNC	LNGDPPC	LNOILP	LNREEX	LNT
1.000000	-0.206880	0.075987	0.558054	-2.293499
	(0.08932)	(0.24778)	(0.04230)	(0.03085)

Adjustment coefficients (standard error in parentheses)

D(LNC)	-0.014647
	(0.03258)
D(LNGDPPC)	0.019297
	(0.00849)
D(LNOILP)	-0.014925
	(0.07517)
D(LNREEX)	-0.398217
	(0.11096)
D(LNT)	0.017663
	(0.00071)

2 Cointegrating Equation(s):
Log likelihood 328.9960

Normalized cointegrating coefficients (standard error in parentheses)

LNC	LNGDPPC	LNOILP	LNREEX	LNT
1.000000	0.000000	0.121404	0.616978	-2.759478
		(0.03359)	(0.03925)	(0.07377)
0.000000	1.000000	0.219536	0.284821	-2.252408
		(0.06218)	(0.07265)	(0.13657)

Adjustment coefficients (standard error in parentheses)

D(LNC)	-0.197688	0.237064
	(0.15438)	(0.19331)
D(LNGDPPC)	0.108751	-0.118367
	(0.03714)	(0.04650)
D(LNOILP)	1.002239	-1.297449
	(0.30186)	(0.37797)
D(LNREEX)	-1.590745	1.607139
	(0.48301)	(0.60479)
D(LNT)	0.006873	0.010142
	(0.00266)	(0.00333)

3 Cointegrating Equation(s): Log likelihood 336.3758

Normalized cointegrating coefficients (standard error in parentheses)

LNC	LNGDPPC	LNOILP	LNREEX	LNT
1.000000	0.000000	0.000000	-0.922786	-0.072846
			(0.12989)	(0.19461)
0.000000	1.000000	0.000000	-2.499535	2.605829
			(0.24410)	(0.36574)
0.000000	0.000000	1.000000	12.68293	-22.12960
			(1.12725)	(1.68898)

Adjustment coefficients (standard error in parentheses)

D(LNC)	-0.582387	0.295523	0.018541

	(0.21133)	(0.17572)	(0.02213)
D(LNGDPPC)	0.139176	-0.122991	-0.012031
	(0.05588)	(0.04647)	(0.00585)
D(LNOILP)	1.038126	-1.302903	-0.162274
	(0.45884)	(0.38152)	(0.04805)
D(LNREEX)	-0.340187	1.417105	0.190591
	(0.65499)	(0.54462)	(0.06859)
D(LNT)	0.008806	0.009849	0.003109
	(0.00401)	(0.00334)	(0.00042)

4 Cointegrating Equation(s): Log likelihood 341.4582

Normalized cointegrating coefficients (standard error in parentheses)

LNC	LNGDPPC	LNOILP	LNREEX	LNT
1.000000	0.000000	0.000000	0.000000	-1.572014
				(0.06688)

0.000000	1.000000	0.000000	0.000000	-1.454940
				(0.10499)
0.000000	0.000000	1.000000	0.000000	-1.524785
				(0.41993)
0.000000	0.000000	0.000000	1.000000	-1.624609
				(0.14008)

Adjustment coefficients (standard error in parentheses)

D(LNC)	-0.688210	0.321653	0.057179	0.039396
	(0.24335)	(0.17603)	(0.05081)	(0.05233)
D(LNGDPPC)	0.073466	-0.106765	0.011960	0.029802
	(0.06009)	(0.04347)	(0.01255)	(0.01292)
D(LNOILP)	1.518779	-1.421589	-0.337767	0.215653
	(0.50244)	(0.36344)	(0.10490)	(0.10805)
D(LNREEX)	0.173894	1.290164	0.002892	-0.837591
	(0.73851)	(0.53421)	(0.15419)	(0.15881)
D(LNT)	0.010692	0.009383	0.002420	0.006587
	(0.00463)	(0.00335)	(0.00097)	(0.00100)

Table 8: BREAKPOINT UNIT ROOT TEST

Null Hypothesis: LNC has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 2002
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 2 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-5.855700	< 0.01
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	

10% level -4.893950

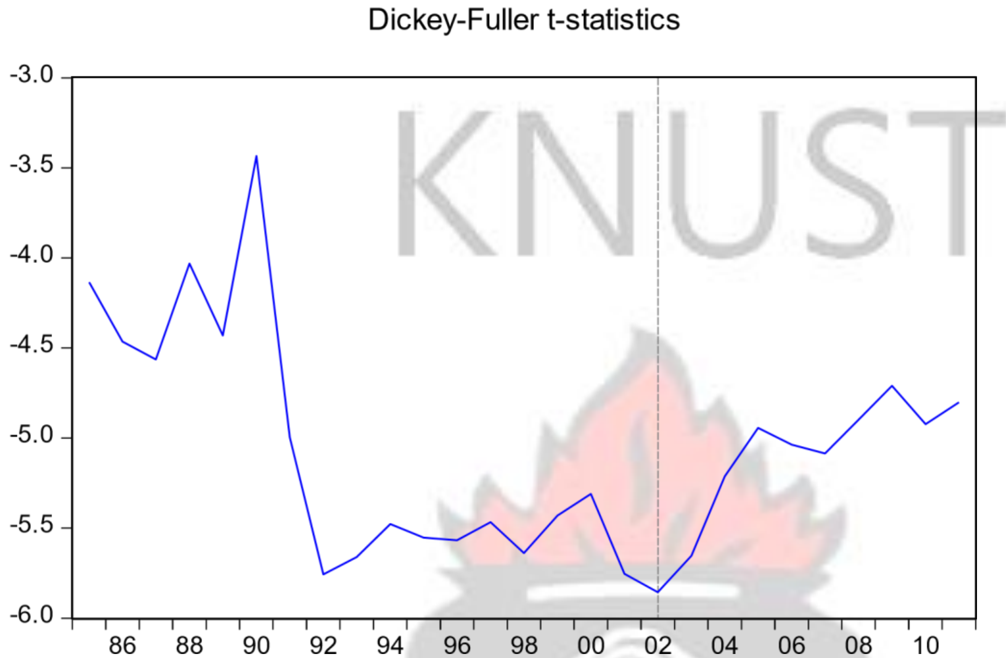
*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: LNC
Method: Least Squares
Date: 12/20/15 Time: 22:26
Sample (adjusted): 1983 2013
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
LNC(-1)	-0.399945	0.239074	-1.672893	0.1079
D(LNC(-1))	0.679002	0.195653	3.470436	0.0021
D(LNC(-2))	0.469359	0.158767	2.956275	0.0071
C	13.32236	2.272198	5.863205	0.0000
TREND	0.064210	0.010747	5.974466	0.0000
INCPTBREAK	0.111338	0.062360	1.785416	0.0874
TRENDBREAK	0.004627	0.007199	0.642747	0.5267
BREAKDUM	-0.025629	0.082875	-0.309245	0.7599

R-squared 0.984743 Mean dependent var
10.34078 Adjusted R-squared 0.980100 S.D. dependent var
0.477803 S.E. of regression 0.067403 Akaike info criterion -2.338628

Sum squared resid	0.104492	Schwarz criterion	-1.968567
Log likelihood	44.24873	Hannan-Quinn criter.	-2.217997
F-statistic	212.0747	Durbin-Watson stat	2.085442
Prob(F-statistic)	0.000000		



Null Hypothesis: D(LNC) has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 1989
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 2 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

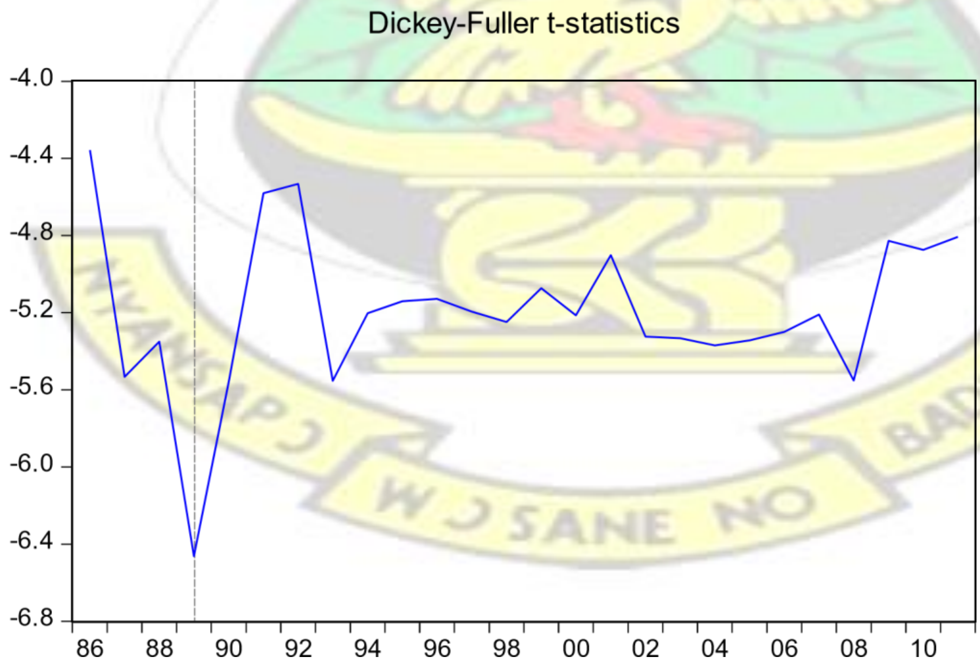
		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-6.462675	< 0.01
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNC)
Method: Least Squares
Date: 12/21/15 Time: 11:22
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LNC(-1))	-1.241130	0.346781	-3.579007	0.0017
D(LNC(-1), 2)	0.886649	0.261687	3.388209	0.0026
D(LNC(-2), 2)	0.517094	0.159609	3.239756	0.0038
C	-0.068455	0.084225	-0.812759	0.4251
TREND	0.051546	0.026061	1.977918	0.0606
INCPTBREAK	-0.124609	0.072201	-1.725861	0.0984
TRENDBREAK	-0.048243	0.026059	-1.851298	0.0776
BREAKDUM	0.219355	0.091825	2.388842	0.0259

R-squared	0.454795	Mean dependent var	0.051973
Adjusted R-squared	0.281321	S.D. dependent var	0.091075
S.E. of regression	0.077209	Akaike info criterion	-2.061420
Sum squared resid	0.131147	Schwarz criterion	-1.687767
Log likelihood	38.92130	Hannan-Quinn criter.	-1.941885
F-statistic	2.621688	Durbin-Watson stat	1.899956
Prob(F-statistic)	0.039498		



Null Hypothesis: LNGDPPC has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 2006
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 1 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-7.894446	< 0.01
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

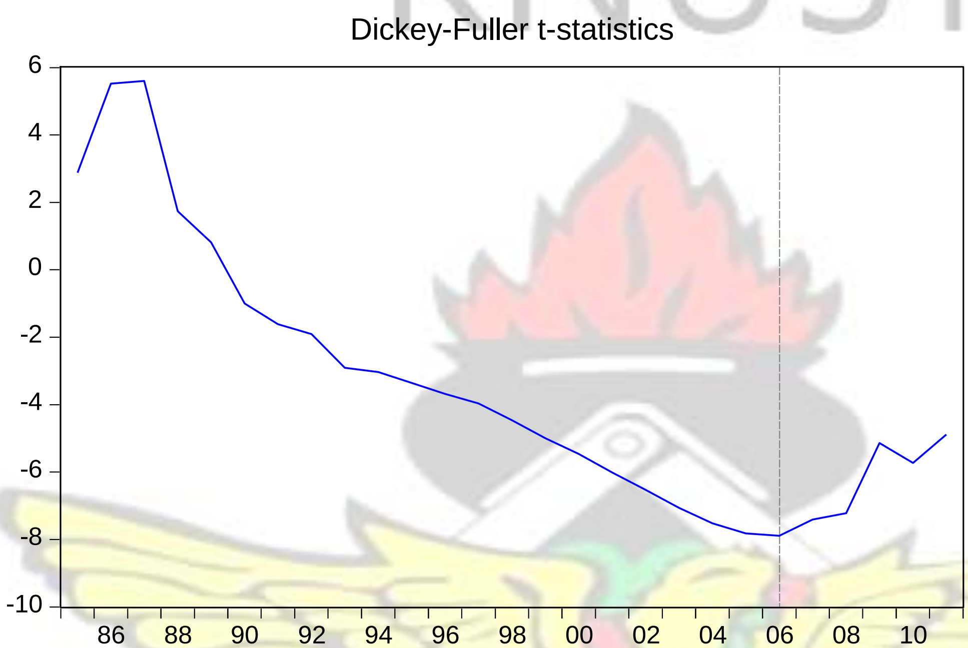
*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: LNGDPPC
Method: Least Squares
Date: 12/21/15 Time: 11:48
Sample (adjusted): 1982 2013
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
LNGDPPC(-1)	0.346778	0.082744	4.190957	0.0003
D(LNGDPPC(-1))	0.205976	0.098957	2.081459	0.0478
C	3.772081	0.478530	7.882650	0.0000
TREND	0.011547	0.001428	8.086804	0.0000
INCPTBREAK	-0.025955	0.017726	-1.464253	0.1556
TRENDBREAK	0.028588	0.004644	6.156066	0.0000
BREAKDUM	0.028115	0.020947	1.342208	0.1916

R-squared	0.996252	Mean dependent var	6.101182

Adjusted R-squared	0.995352	S.D. dependent var	0.230302
S.E. of regression	0.015701	Akaike info criterion	-5.279502
Sum squared resid	0.006163	Schwarz criterion	-4.958872
Log likelihood	91.47203	Hannan-Quinn criter.	-5.173222
F-statistic	1107.389	Durbin-Watson stat	2.495264
Prob(F-statistic)	0.000000		



Null Hypothesis: D(LNGDPPC) has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 2008
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 1 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-4.949314	0.0871
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

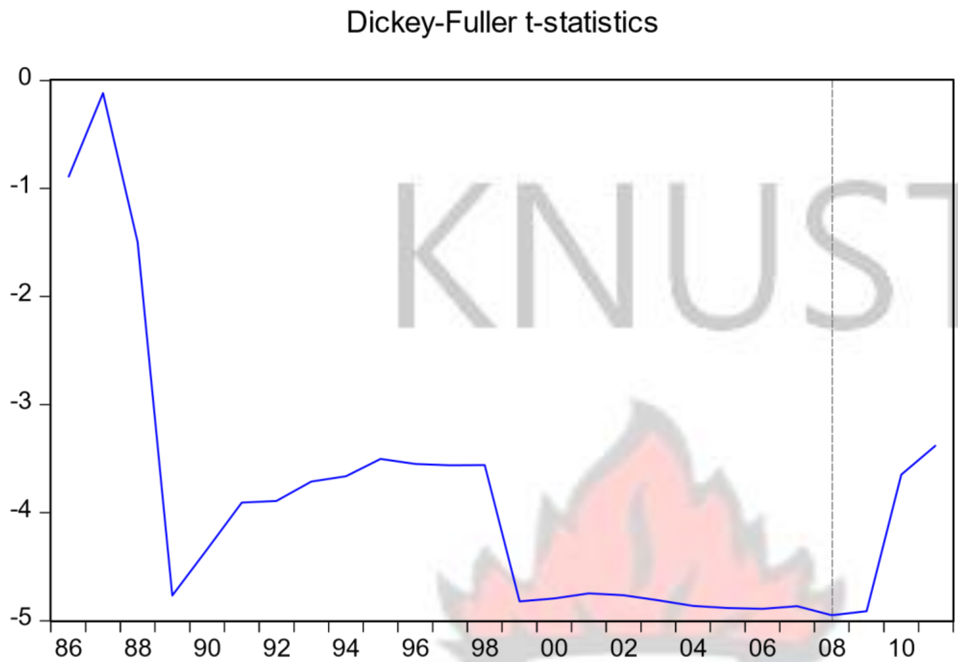
*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDPPC)
Method: Least Squares
Date: 12/21/15 Time: 11:53
Sample (adjusted): 1983 2013
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LNGDPPC(-1))	0.116404	0.178529	0.652015	0.5206
C	0.002167	0.010438	0.207634	0.8373
TREND	0.001013	0.000776	1.305901	0.2040
INCPTBREAK	-0.005187	0.033598	-0.154373	0.8786
TRENDBREAK	0.006134	0.007760	0.790477	0.4370
BREAKDUM	0.021491	0.034362	0.625439	0.5376

D(LNGDPPC(-1), 2) 0.205983 0.158318 1.301070
0.2056 R-squared 0.490327 Mean dependent var 0.025451 Adjusted R-
squared 0.362909 S.D. dependent var 0.029490

S.E. of regression	0.023538	Akaike info criterion	-4.464721
Sum squared resid	0.013297	Schwarz criterion	-4.140918
Log likelihood	76.20318	Hannan-Quinn criter.	-4.359169
F-statistic	3.848176	Durbin-Watson stat	2.425252
Prob(F-statistic)	0.007877		



Null Hypothesis: LNOILP has a unit root

Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 1996
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 0 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

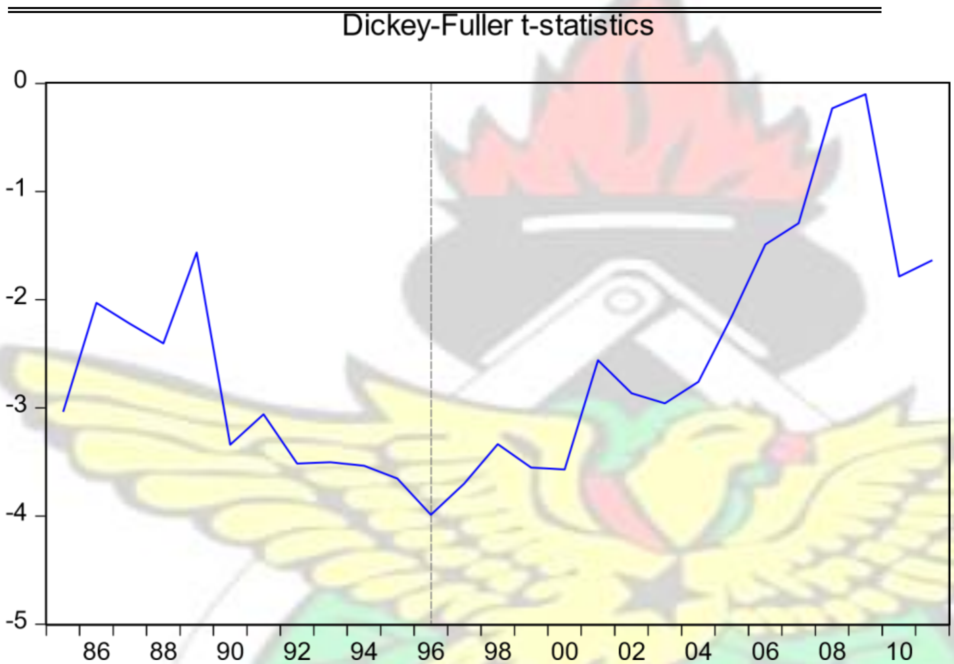
		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-3.989495	0.5286
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

*Vogelsang (1993) asymptotic one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: LNOILP
Method: Least Squares
Date: 12/21/15 Time: 11:58
Sample (adjusted): 1981 2013
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
LNOILP(-1)	0.301283	0.175139	1.720246	0.0968
C	2.383208	0.634481	3.756155	0.0008
TREND	-0.032701	0.015710	-2.081569	0.0470
INCPTBREAK	-0.159550	0.159196	-1.002225	0.3251
TRENDBREAK	0.128665	0.036620	3.513490	0.0016
BREAKDUM	0.345616	0.233197	1.482075	0.1499

R-squared	0.921697	Mean dependent var	3.445704
Adjusted R-squared	0.907196	S.D. dependent var	0.664532
S.E. of regression	0.202441	Akaike info criterion	-0.193768
Sum squared resid	1.106527	Schwarz criterion	0.078325
Log likelihood	9.197166	Hannan-Quinn criter.	-0.102217
F-statistic	63.56249	Durbin-Watson stat	1.936900
Prob(F-statistic)	0.000000		



Null Hypothesis: D(LNOILP) has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 1998
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 0 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-7.394922	< 0.01
Test critical values:	1% level	-5.719131	

5% level	-5.175710
10% level	-4.893950

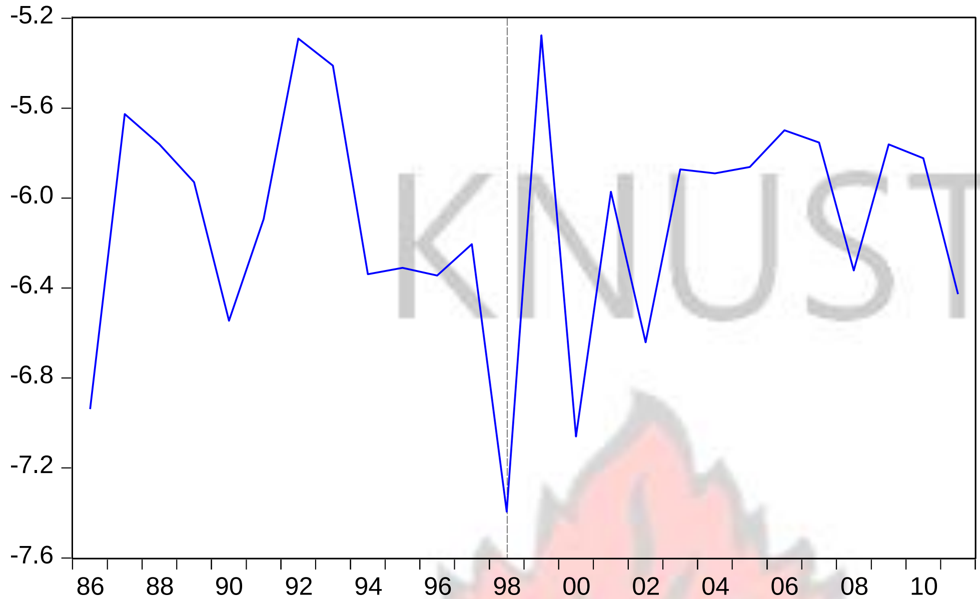
*Vogelsang (1993) asymptotic one- sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNOILP)
Method: Least Squares
Date: 12/21/15 Time: 12:05
Sample (adjusted): 1982 2013
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LNOILP(-1))	-0.259728	0.170350	-1.524670	0.1394
C	-0.165490	0.119810	-1.381267	0.1790
TREND	0.013717	0.012321	1.113319	0.2758
INCPTBREAK	0.238214	0.171495	1.389041	0.1766
TRENDBREAK	-0.026894	0.018145	-1.482184	0.1503
BREAKDUM	-0.706085	0.256811	-2.749431	0.0107

R-squared	0.339404	Mean dependent var	0.034582
Adjusted R-squared	0.212367	S.D. dependent var	0.252777
S.E. of regression	0.224336	Akaike info criterion	0.016017
Sum squared resid	1.308492	Schwarz criterion	0.290842
Log likelihood	5.743733	Hannan-Quinn criter.	0.107114
F-statistic	2.671683	Durbin-Watson stat	2.207767
Prob(F-statistic)	0.044566		

Dickey-Fuller t-statistics



Null Hypothesis: LNREEX has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 1989
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 2 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

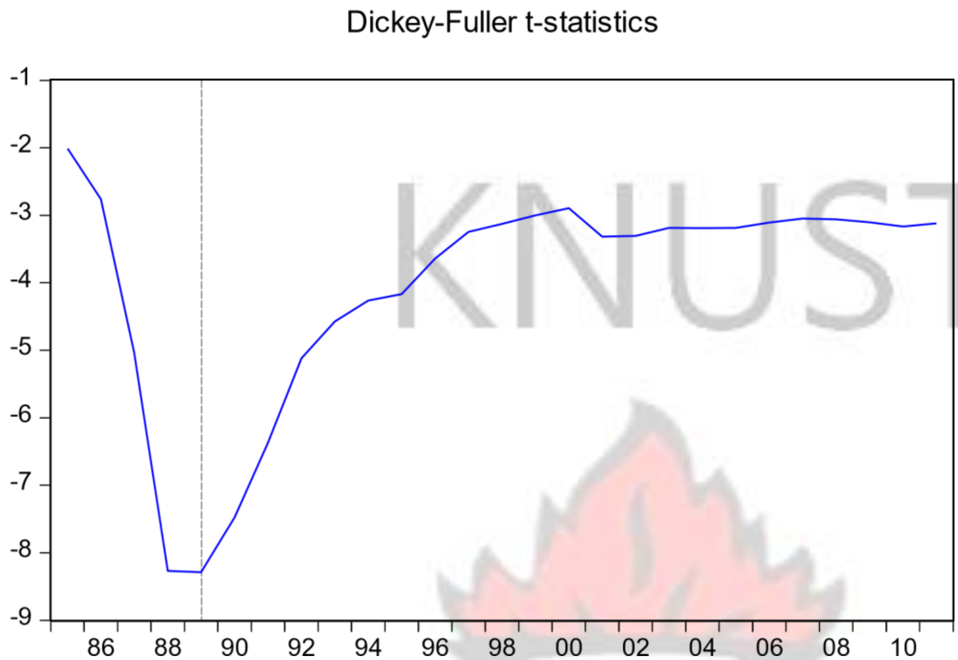
		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-8.289704	< 0.01
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: LNREEX
Method: Least Squares
Date: 12/21/15 Time: 12:09
Sample (adjusted): 1983 2013
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
LNREEX(-1)	-0.782829	0.215066	-3.639958	0.0014
D(LNREEX(-2))	0.391169	0.110627	3.535940	0.0018
C	14.29940	1.812275	7.890306	0.0000
TREND	-0.810537	0.118208	-6.856845	0.0000
INCPTBREAK	-0.410530	0.217657	-1.886135	0.0720
TRENDBREAK	0.768274	0.113873	6.746757	0.0000
BREAKDUM	0.320104	0.209334	1.529154	0.1399
D(LNREEX(-1))	0.592506	0.140014	4.231748	0.0003

R-squared	0.950239	Mean dependent var	4.993013
Adjusted R-squared	0.935095	S.D. dependent var	0.737072
S.E. of regression	0.187781	Akaike info criterion	-0.289449
Sum squared resid	0.811015	Schwarz criterion	0.080612
Log likelihood	12.48647	Hannan-Quinn criter.	-0.168819
F-statistic	62.74439	Durbin-Watson stat	1.483745
Prob(F-statistic)	0.000000		



Null Hypothesis: D(LNREEX) has a unit root
Trend Specification: Trend and intercept
Break Specification: Trend and intercept
Break Type: Innovational outlier

Break Date: 1992
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 2 (Automatic - based on F-statistic selection, lagpval=0.1, maxlag=2)

		t-Statistic	Prob.*
Augmented Dickey -Fuller test statistic		-14.50485	< 0.01
Test critical values:	1% level	-5.719131	
	5% level	-5.175710	
	10% level	-4.893950	

*Vogelsang (1993) asymptotic one - sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNREEX)
Method: Least Squares
Date: 12/21/15 Time: 12:13
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LNREEX(-1))	-0.846507	0.127303	-6.649560	0.0000
D(LNREEX(-1), 2)	0.353852	0.100345	3.526337	0.0019
D(LNREEX(-2), 2)	0.134231	0.068137	1.970018	0.0616
C	-1.580176	0.125558	-12.58524	0.0000
TREND	0.209874	0.023901	8.781088	0.0000
INCPTBREAK	-0.188396	0.119905	-1.571216	0.1304
TRENDBREAK	-0.206263	0.024430	-8.443163	0.0000
BREAKDUM	-0.040196	0.152322	-0.263888	0.7943

R-squared	0.888299	Mean dependent var	-0.123707
Adjusted R-squared	0.852758	S.D. dependent var	0.361228
S.E. of regression	0.138611	Akaike info criterion	-0.891114
Sum squared resid	0.422685	Schwarz criterion	-0.517462
Log likelihood	21.36672	Hannan-Quinn criter.	-0.771580
F-statistic	24.99351	Durbin-Watson stat	1.325262
Prob(F-statistic)	0.000000		

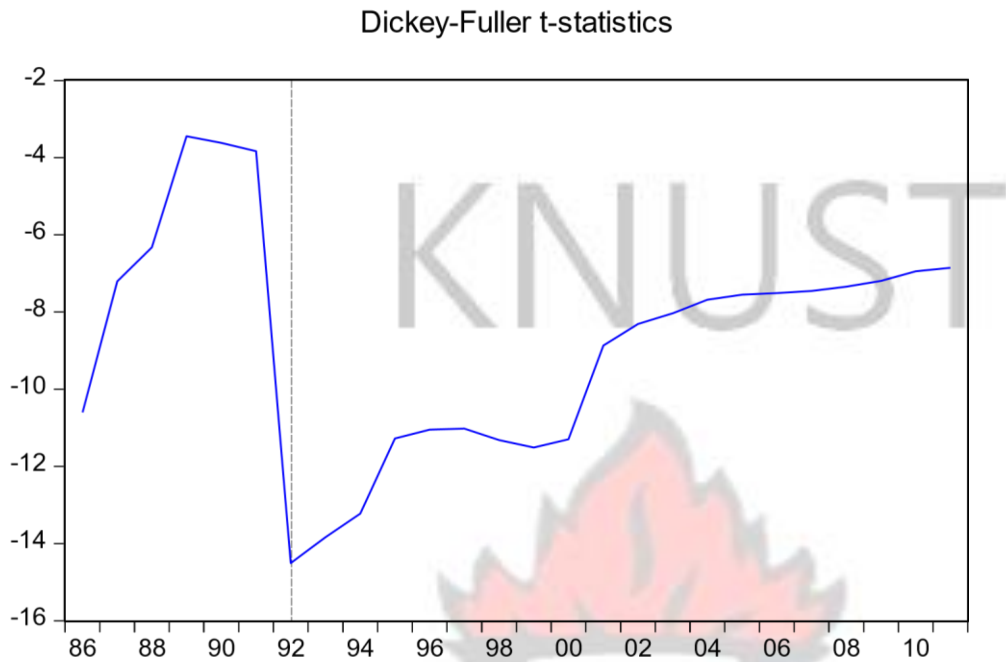


Table 9: Bounds tests (ARDL Robust check results)

ARDL Bounds Test
Date: 01/26/16 Time: 20:32
Sample: 1982 2013
Included observations: 32
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	10.87001	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Test Equation:
Dependent Variable: D(LNC)
Method: Least Squares
Date: 01/26/16 Time: 20:32
Sample: 1982 2013
Included observations: 32

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNC(-1))	0.458606	0.169119	2.711738	0.0131
D(LNREEX)	-0.311002	0.052105	-5.968718	0.0000
D(LNREEX(-1))	0.177993	0.039914	4.459358	0.0002
D(LNT)	33.80363	7.876579	4.291664	0.0003
D(LNT(-1))	-11.72433	3.010689	-3.894235	0.0008
C	4.090952	1.458119	2.805637	0.0106
LNGDPPC(-1)	0.376991	0.229529	1.642457	0.1154
LNOILP(-1)	-0.016529	0.053639	-0.308145	0.7610
LNREEX(-1)	-0.446341	0.094590	-4.718704	0.0001
LNT(-1)	1.744075	0.340491	5.122233	0.0000
LNC(-1)	-1.008136	0.170382	-5.916905	0.0000

R-squared	0.785029	Mean dependent var	0.048725
Adjusted R-squared	0.682662	S.D. dependent var	0.095254
S.E. of regression	0.053659	Akaike info criterion	-2.746040
Sum squared resid	0.060466	Schwarz criterion	-2.242194
Log likelihood	54.93664	Hannan-Quinn criter.	-2.579029
F-statistic	7.668758	Durbin-Watson stat	2.129185
Prob(F-statistic)	0.000048		

Table 10: Long run and short run ARDL results

ARDL Cointegrating And Long Run Form
Dependent Variable: LNC
Selected Model: ARDL(2, 0, 0, 2, 2)
Date: 01/26/16 Time: 20:42

Sample: 1980 2013
Included observations: 32

Cointegrating Form				
Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LNC(-1))	0.481215	0.138364	3.477894	0.0022
D(LNGDPPC)	0.335236	0.195690	1.713092	0.1014
D(LNOILP)	-0.016625	0.051192	-0.324758	0.7486
D(LNREEX)	-0.297225	0.054204	-5.483497	0.0000
D(LNREEX(-1))	0.180058	0.039273	4.584740	0.0002
D(LNT)	33.667421	7.375841	4.564553	0.0002
D(LNT(-1))	-11.543943	2.809571	-4.108792	0.0005
CointEq(-1)	-0.976994	0.194260	-5.235220	0.0000

Cointeq = LNC - (0.3296*LNGDPPC -0.0163*LNOILP - 0.4342*LNREEX + 1.7377*LNT + 4.2641)

Long Run Coefficients				
Variable	Coefficient	Std. Error	t- Statistic	Prob.
LNGDPPC	0.329634	0.190865	1.727056	0.0388
LNOILP	-0.016347	0.052066	-0.313976	0.7566
LNREEX	0.434247	0.103282	4.204460	0.0004
LNT	-1.737653	0.276283	-6.289396	0.0000
C	4.264059	0.960481	4.439504	0.0002

Equation1: ARDL specification

$$\Delta lnoilC_t = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta lnrGDPPC_{t-i} + \sum_{i=0}^{n} \alpha_2 \Delta lnoil\ P_{t-i} + \sum_{i=0}^{n} \alpha_3 \Delta\ lnrEEX_{t-i}$$

$$+ \sum_{i=0}^{n} \alpha_4 \, \Delta ln \, T_{t-i} + \beta_1 lnoilC_{t-i} + \beta_2 lnrGDPPC_{t-i} + \beta_3 lnoilP_{t-i}$$

$$+ \beta_4 lnrEEX_{t-i} + \beta_5 ln \, T_{t-i} + \varphi ECM_{t-i} + \varepsilon_t$$

α_1, α_2 , α_3, α_4, α_5 are the short-run elasticities

β_1, β_2 β_3, β_4 , β_5 are the long-run elasticities

ECM is the error correction term which measures the speed of adjustment.