THE UNIVERSITY OF HULL

# Crude Oil Price Volatility and its Impact on Export Dependent Economies

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Abstract

Motivated by the problem of crude oil price volatility, this research is examining interdependences between crude oil price and each of GDP, foreign account, gold price, futures price, and also, stock markets. The research was mainly directed at examining the impact of oil price volatility on the economic variables of the commodity's export dependent economies, with particular reference to Nigeria. However the outcomes provide a framework for extensions and application to the economic conditions of net oil importing countries, other primary commodities, Sovereign Wealth Funds (SWFs) and crude oil revenue management. As the research is motivated by the behaviour of a commodity (oil), economy or share (indices) over time, the study applies time series analysis in order to address the research questions.

In examining if crude oil price volatility has any impact on the commodity's export dependent economies such as Nigeria, chapter 4's analysis found evidence of oil price volatility impact on the Bonny Light (BL) spot, GDP and also, foreign reserve account. In trying to identify an efficient price hedging mechanism for the BL, chapter 5 found that the West Texas Intermediate's futures price is able to predict the BL spot. Chapter 6 examined potentials for market efficiency and volatility transmission between crude oil spot and the stock markets of selected oil export dependent countries. The results suggest evidence of volatility transmission in most tested series pairs. Thus, given the examined variables in this research, the overall outcome suggest a widening influence of crude oil price volatility on the commodity's export dependent economies at large.

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# List of Abbreviations

ADF - Augmented Dickey-Fuller

ADIA - Abu Dhabi Investment Authority

AIC - Akeike Information Criterion

API - American Petroleum Institute

AR - Autoregressive

ARCH - Autoregressive Conditional Heteroskedasticity

ARMA - Autoregressive Moving Average

BBC – British Broadcasting Corporation

BEKK - Positive Definite Parameterisation

BL - Bonny Light Spot

BLA - Bonny Light Spot in Moving Average

BLS - Bonny Light Spot's Standard Deviation

BNM – Bank Negara Malaysia

CAPM - Capital Asset Pricing Model

CBN - Central Bank of Nigeria

CCC - Constant Conditional Correlation

CCR - Canonical Cointegrating Regression

CF1 - Western Texas Intermediate First Month Futures Contract Price

CF2 – Western Texas Intermediate Second Month Futures Contract Price

CF3 – Western Texas Intermediate Third Month Futures Contract Price

CF4 - Western Texas Intermediate Fourth Month Futures Contract Price

CGARCH - Component Generalized Autoregressive Conditional Heteroskedasticity

CIA – Central Intelligence Agency

DOLS - Dynamic Ordinary Least Square

DoS - United States of American Department of State

ECM - Error Correction Model

EIA - Energy Information Administration

EMH - Efficient Market Hypothesis

FMOLS - Fully Modified OLS

FRA - Nigeria's Foreign Account

FT – Financial Times

GARCH – Generalized Autoregressive Conditional Heteroskedasticity

GCC – Gulf Corporation Council

GDP - Gross Domestic Product

GIRF - Generalised Impulse Response Function

GLD - Gold Spot Price

ICIS - Independent Chemical Information Service

IGARCH – Integrated Generalized Autoregressive Conditional Heteroskedasticity

IMF - International Monetary Fund

KIA – Kuwait Investment Authority

KPSS - Phillips, Schmidt, and Shin

LM - Langrage multiplier

MA - Moving Average

MDC - Mubadala Development Company

MGARCH – Multivariate Generalized Autoregressive Conditional Heteroskedasticity

MSCI - Morgan Stanley Capital International

MSI - Malaysian Stock Index

NBIM - Norges Bank Investment Management

NDE - Naira/US Dollars Exchange rate

NECA – Nigeria Excess Crude Account

NIR - Nigeria's Inflation Rate

NP - Ng and Perron

NSI - Norwegian Stock Index

NSIA - Nigeria Sovereign Investment Authority

NSP – Nigerian Stock Index

NYMEX – New York Mercantile Exchange

OECD - Organisation for Economic Co-operation and Development

OIL - Crude Oil Spot Price

OLS - Ordinary Least Square

OPEC - Organisation of Petroleum Exporting Countries

PP - Phillips-Perron

QIA - Qatar Investment Authority

SE - Standard Error

SIC - Schwarz Information Criterion

SWF – Sovereign Wealth Fund

SWFI – Sovereign Wealth Fund Institute

TRD - Thomson Reuter's Datastream

UAE – United Arab Emirates

US - United States of America

USD - United States of American Dollar

USI - United States of American Treasury Rate

VAR - Vector Autoregression

VECH - Full Parameterisation

VECM - Vector Error Correction Model

WSI - World Stock Index

WT - Western Texas Intermediate Spot

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# Chapter 1: General Background

## 1.1 Introduction

Crude oil, like other primary commodities, is a source of income for its exporting countries. Nevertheless, price volatility constitutes a problem in the commodity's market, with adverse consequences for both consumers and producers (Jiménez-Rodríguez and Sánchez, 2005; Malik and Ewing, 2009). However, what has mostly captured the attention of academic researchers in the past is the impact on the economies of importing rather than exporting countries. This is because most empirical and academic literature tends to pay more attention to testing the interdependences between oil price and the economic variables of the commodity's net importing countries (as was seen in Malik and Ewing, 2009; Rafiq et al., 2009). Jiménez-Rodríguez and Sánchez (2005) found oil price increase to cause GDP growth impact in most of the OECD countries studied for oil price volatility impact.

For some oil exporting countries, the revenue from the commodity provides them with almost all their foreign income. Nigeria, for instance, receives over 91% of its foreign exchange from crude oil (CBN, 2011b). Based on figures from the Energy Information Administration (EIA, 2010b), the Nigerian 'Bonny Light' [1] (BL) oil sold for $146.15/barrel in July 2008, whereas in December 1998 the same commodity was $9.45/barrel. Oil price volatility of this form is a problem for oil producing governments' revenue earning, culminating in difficulty in both budgetary and economic planning. Hence, the Central Bank of Nigeria (CBN) pointed to volatility as the main challenge to managing the country's foreign reserves (CBN, 2011b).

However, despite the highlighted significance of crude oil to Nigeria's foreign export earnings, there is currently not much empirical work that examines the impacts of such price volatility on the country's foreign reserve account. Again, the BL spot market largely remains empirically unexamined within the academic literature, especially with regard to understanding price movements in relation to any futures prices. Also, the BL

[1] the spot price of Nigeria's high quality crude oil grade

as a grade of crude oil is still without its own futures market. Moreover, despite the high exposure of the country's revenue to crude oil volatility, there is still no research that has attempted to capture directly the impact of price shocks on oil price volatility.

Based on information available from the Sovereign Wealth Fund Institute (SWFI), an increasing number of crude oil endowed countries have in recent times instituted crude oil Sovereign Wealth Funds (SWFs) to invest income from the commodity (SWFI, 2012b). This is largely in response to the threats of the commodity's price volatility and other related issues. However, some oil export dependent countries like Nigeria have still not done much in this regard (Mehlum et al., 2006b), despite recognition of the challenge posed by oil price volatility management of the country's foreign reserve account (CBN, 2011b). In their classification of growth winners and losers among natural resource rich countries, Mehlum et al. (2006b) classified Nigeria among the growth losers, because the country's economic growth over the years is not commensurate with her oil revenue earning. The same point is made by the CBN (2011b), which attributes this position partly to the lack of trained personnel capable of handling sustained rises oil prices.

Nigeria's effort towards managing its oil proceeds is still at an early stage, with the establishment of Nigeria Sovereign Investment Authority in April 2011 (SWFI, 2012a). The fact that CBN (2011b) pointed out sustained high international oil prices as a reason prompting the need for oil revenue management, suggests that the existence of oil surpluses is responsible for the country's SWF creation, rather than pressures from the pursuit of future financial security and mitigation of oil price volatility's negative impact. This option recalls van der Ploeg and Venables' (2011) three potential choices for a government faced with decisions on management of natural resources. These options are saving or consumption, investment in domestic economy or in foreign assets and finally, the balance between private and public domestic investment. Reflecting of the need to better invest the proceeds of any given natural resource abundant country, these sets of choices may be considered. This position has exposed the need to shape a sound policy direction for the Nigeria Sovereign Investment Authority (NSIA), especially as the drive to manage the inflow from surplus oil revenue alone may not sustain itself.

The increasing numbers of oil dependent countries establishing Sovereign Wealth Funds (SWFs) has recently seen SWFs rising to prominence, as 60% of the present global investments portfolio of SWFs is from crude oil and gas sources (SWFI, 2012b). This statistic helps to highlight how important crude oil and gas related SWFs are in global investment circles and the potential they hold for influencing the future outlook as well. The likes of Government Pension Fund of Norway, Mubadala Development Company's (MDC), Abu Dhabi Investment Authority's (ADIA), Qatar Investment Authority (QIA), etc are among the worlds' notable oil based SWFs (SWFI, 2012b).

Against this background, this research explores the impact of crude oil price volatility on export-dependent economies and various mechanisms for managing revenue. This chapter introduces the context, motivation and scope of the research. It is organised into two parts: an introduction to the research in part 1 and thesis summary in part 2. Part 1 discusses; oil price volatility and its consequences, the significance of oil to export dependent economies and oil revenue management. Part 2 discusses the research motivation, questions, objectives, methodology, hypotheses and contribution. This is followed by an overview of the entire thesis motivation captured through the remaining six chapters.

## 1.2 Part 1: Research Background

### 1.2.1 Oil Price Volatility and Resulting Consequences

Although price shocks in the crude oil market are characterised by both booms and slumps, the two issues are often treated as the same, usually under the name of oil price shocks. Hence, separation of the two features of positive and negative shocks is important. Theoretically, a positive crude oil price shock will normally result in an advantageous situation for oil exporting countries and a disadvantageous situation to the importing countries (see Hamilton, 2003). Price volatility has been increasingly studied as an academic problem, with large concentration of empirical studies over the years focusing more on testing its impacts on the economic fundamentals of importing than exporting countries. The majority of such studies focused on understanding the manner in which oil price volatility impacts on developed or net importing countries (Malik and Ewing, 2009; Rafiq et al., 2009).

However, the economic consequences of oil price volatility are just as far reaching for the commodity's exporting countries as for the importing (Jiménez-Rodríguez and Sánchez, 2005; Malik and Ewing, 2009; CBN, 2011b). Arguably the situation could be more severe for the commodity exporting countries since in many cases the exporters are more reliant on oil than the importers. Hamilton (2003) identified oil price shocks as more inclined to price increase than decrease. It could be said that oil price increase creates more distortionary effects for importing countries than decrease does to exporting countries. For the commodity's exporting countries there is an impact on their ability to plan with expected revenue, culminating in difficulty in both budgetary and economic planning (CBN, 2011b). Also, Jiménez-Rodríguez and Sánchez (2005) has confirmed that oil price volatility is a source of problems for economies of both net producing and consuming countries. However, the problem of crude oil price volatility is particularly worrisome for the producing countries, especially as the problem is associated with an irregular revenue pattern, which is reflected in distorted budgetary and economic planning.

Thus, Jiménez-Rodríguez and Sánchez (2005) examined how crude oil price volatility impacts the economic conditions of some selected OECD members. The research examined the reaction of both net exporting and importing countries' economies to oil price volatility. For a contrasting view, a similar research was carried out in Rafiq et al. (2009) examining the Thai economy's reaction to oil price changes. Given that the country is a non OECD member and also a net importer of oil, this offers a different platform for understanding the problem of oil price volatility, given the different economic environment from those examined in Jiménez-Rodríguez and Sánchez. Thus, the empirical process in chapter 4 extended the empirical principles of both Jiménez-Rodríguez and Sánchez (2005) and also, Rafiq et al. (2009) among others, by asking the research questions: *Does crude oil price volatility impact on Nigeria's GDP? Does an oil market shock alter the commodity's price volatility for Nigeria? Is the Nigerian foreign reserve account sensitive to crude oil price volatility*? Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect the government's financial position?*

Given that previous empirical studies suggested oil price shock is a source of problems for economies of both net exporting and importing countries (Jiménez-Rodríguez and Sánchez, 2005; Rafiq et al., 2009), finding a potential hedging mechanism is a natural way forward. Thus, chapter 5 examines whether an efficient hedging tool for BL spot prices is present in West Texas Intermediate (WT) futures or otherwise. This is given that through the Efficient Market Hypothesis (EMH) assumption (Fama, 1965; Fama et al., 1969), we understand an efficient futures market to imply the futures price is an unbiased predictor of the spot. Quan (1992) and also, Schwarz and Szakmary (1994) are among the earliest examples of empirical studies which tested the existence of price discovery in crude oil by using futures market information. Also, information on other primary commodities price movement is able to provide insight on determining the direction of crude oil price. Chaudhuri (2001) has earlier demonstrated that oil and other commodities prices have a long-run relationship, and argued that volatility in oil price affects other commodities. Also, Roache and Rossi (2010) attempted to use gold as an investment alternative by analysing responses of other commodities prices, which included oil. In this regard, Wei and Zhang (2010) examined oil and gold spot and found the two commodities' prices to be cointegrated.

Also, as an increasing number of empirical studies are being geared towards understanding relationships between crude oil price volatility and stock market returns (Jones and Kaul, 1996; Sadorsky, 1999; Malik and Ewing, 2009), various extensions are possible. Some level of extension in the direction of specific stock markets to oil price changes is already in place. Basher and Sadorsky (2006) and Basher et al. (2012) examine the case of emerging stock markets, while other research concentrates on key oil producing countries of the GCC (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011; Mohanty et al., 2011). Zhang and Wei (2010) equally investigated crude oil and gold spot for evidence of integration. Crude oil dependent economies' interdependences with the oil market and also world stock indices has, however, not been adequately covered.

### 1.2.2 Significance of Crude Oil to Export Dependent Economies

Like many other oil dependent economies, Malaysia, Nigeria and Norway are greatly dependent on proceeds from crude oil revenue (CBN, 2011b; CIA, 2012; DoS, 2012), also academic studies supporting this argument are available (Ayadi et al., 2000; Caner and Grennes, 2010). However, the degree of each country's dependence on the commodity for economic sustenance differs depending on personal economic characteristics. For instance, while Malaysia has a well diversified primary commodities sources and economic structure (BNM, 2009: p.37, 2011: p.11), Nigeria almost entirely is dependent on crude oil for foreign revenue (CBN, 2011b). Oil and Gas also has a dominant input to the Norwegian economy, with the highest GDP contribution of 20% in 2010 (DoS, 2012).

This sort of dependence on a single commodity for export earning exposes the countries to foreign income and revenue risk, especially with oil facing price volatility. However, as seen in the above introduction section, some countries have responded with management of earned oil income while some are yet to respond. Given that Nigeria, for example, has up to 91% of its foreign reserve account coming from crude oil source (CBN, 2011b), the commodity is thus crucial for the country's revenue generation. This position is critical, given the level of significance the commodity has as the country's dominant source of foreign earnings. This position is expected to continue for a long time in the future as no any meaningful effort is devoted towards diversification of the country's export earnings. This is in spite of the existence of other potential revenue sources, which include mineral deposits, agricultural potential, tax avenues, and a vast population. Thus, the huge reliance on crude oil proceeds is hampering these potentials from being developed.

Prior to the discovery of crude oil, Nigeria's economic base was agriculture, with groundnut, cocoa, cotton, etc accounting for large exports proceeds, but this position has changed since oil discovery (CBN, 2011b). When the case of Nigeria is compared with Malaysia's export earning sources, which is well diversified, with other commodities such as palm oil and tin being exported in abundance (BNM, 2011: p.11). Also, the possibility of Nigeria learning from the diversified nature of the Malaysia's well developed service sector (BNM, 2009: p.37) needs to be considered, given the benefits of economic growth and income security Malaysia enjoys from a diversified economy, as compared to the single commodity export source profile of the Nigerian economy.

As for Norway, the country is already seen to be at the forefront of managing its oil proceeds, but the country will also have other things to learn for an improved process. This is indicated by Caner and Grennes' (2010) finding that despite the fund's investment return being higher than the stock market average, the portfolio risk was riskier than the stock market risk. In the light of the criticisms regarding SWFs' lack of openness, the Norwegian SWF (the government pension fund of Norway) stands out as a model of transparency, due to the way it publishes its transactions, adopting global standards in reporting. This development has earned the fund a rating of 10/10 in the Sovereign Wealth Institute's SWF rating for transparency (SWFI, 2011). Also, the diversified nature of its investments portfolio has seen the fund recover faster from the negative downturn of the global financial crisis of 2007-2009.

### 1.2.3 Oil Revenue Management

Having introduced the significance of crude oil revenue to the commodity's exporting countries in the above section, the oil revenue management drive of some of these countries is examined here, having regard to the potential implications for other countries and the lessons to be learned from other countries. Such experiences could be extendable to other oil producing countries facing problems with the issue of revenue management. Therefore, Nigeria as a country just starting SWF (SWFI, 2012a) could learn from the experiences of Norway and the GCC countries in managing its newly formed SWFs. Also, Malaysia's experience, given the approach adopted with its PETRONAS[2], could be useful.

[2] Short for ***Petroliam Nasional Berhad***, or National Oil Company of Malaysia in English

#### 1.2.3.1 Creation of Nigeria Sovereign Investment Authority

Prior to the recent establishment of the Nigeria Sovereign Investment Authority (NSIA), the country struggled with the issue of crude oil revenue management. Before NSIA, the country used to run a petroleum excess revenue account called the Nigerian Excess Crude Account (NECA) whose root was the surpluses of crude oil price pegged in the country's annual budget. This is the money from the difference between actual and budgeted amounts of expected oil revenue, which in recent years has been favourable, thus at surplus. Largely, the NECA had no defined role in the country’s fiscal structure, with the government using the account mainly to stabilise budgets, engaging in undefined spending patterns, etc. This manner of unguarded expenditure caused the account to dwindle from $20 billion in 2007 (Oxford, 2011) to the present position of $1billion (SWFI, 2012a). Other issues responsible for the big drop in the NECA value includes a fall in global crude oil price due to the world recession, increasing budgetary spending, and lack of sound fiscal measures. However, above all, the lack in sound management of the NECA to the level exhibited by other global SWFs could be a dominant cause. This pointed lack of sound management of NECA is equally shared by the country’s central bank (CBN, 2011b), a position the bank said resulted from the sustained high international oil prices.

Thus, even though Nigeria has set up an SWF, this effort has come as a reaction to increased crude oil prices, rather than the precautionary stand motivating other notable SWFs such as Norway’s SWF. For Nigeria, the existence of surpluses from crude oil revenue was responsible for the move to form NSIA, rather than pressures from the pursuit of future financial security and mitigation of potential negative effect of alternative energy sources that usually characterise the formation of SWF. This position has exposed the need to shape a sound policy direction, especially as the drive to manage the inflow from surplus oil revenue alone may not sustain itself. Moreover, the question that seems to require an answer is; why should a country like Nigeria have such an account when other sectors of the country’s economy are begging for monetary investments? It may be argued that the country has remained largely undeveloped because of lack of the needed investments in infrastructure, education, capacity building and the like. These endeavours could easily be financed with proceeds from the oil resources.

Investment alternatives also exist in depositing oil revenue at home with local financial institutions, which in turn could be used in financing the real sector. This approach could stimulate lending to the private sector, that could help it grow in size, activities and equally guarantee job creation. The central bank of Nigeria (CBN) once considered this option by issuing a guideline for local banks to fulfil before being considered for such opportunity. Part of the guideline is for the local banks to form an alliance with strong foreign banks. However this move was short lived, due to the global financial crisis that started in 2007. This situation made the health of the local banks and even their foreign counterparts a big source of concern.

The political wrangling in the build up to and following the NSIA creation has been a setback as there was a clear lack of agreement between the federal and the state governments on the need for such a fund (Oxford, 2011). While the state governments would prefer the excess oil revenue to be shared and applied for immediate consumption, the federal government is more inclined to the idea of investing for the future. This disagreement contributed to the amount of time it took the country to finalise and agree on the bill setting up the fund. As van der Ploeg and Venables (2011) pointed out government can choose to invest in the domestic economy or in foreign assets. Thus, investing inward or outward are both seen as available options to natural resource-endowed countries. The choice of investing inward could sensibly be linked with the fact that Nigeria has in the past decade been canvassing for foreign investments into its economy. On the other hand, the country commands a large foreign reserve, currently at $38billion (CBN, 2011a) which is invested in developed Western economies. This action could be seen as double standard; a simple look around all sectors of the country's economy will reveal other avenues requiring investment intervention. The infrastructure area, just to mention one aspect represents a system in complete decay as the power supply of the country manifest systemic collapse (AfDB, 2010).

However, getting the Nigerian crude oil revenue invested at home either directly through economic expansion such as infrastructural upgrade or investments in human capital development or indirectly through investing with local financial institutions is an extraordinary task. Taking the direct economic option, as a potential window, Nigeria is seen as a country where existence of high level corruption among both politicians and civil servants may not allow this to work. Transparency International ranked the country 143rd in its corruption perception index (TI, 2011), which is exemplified by the electricity redevelopment projects, that swallowed $16bn between 1999 and 2007, yet the country still has no electricity. Records indicate that the Nigerian Excess Crude Account (NECA) had $20billion in 2007 (Oxford, 2010), but with incessant withdrawals purportedly meant to be for developmental projects that are never seen, the account has currently dwindled to $1bn (SWFI, 2012a).

#### 1.2.3.2 The Government Pension Fund of Norway

The government pension fund of Norway is the Norwegian government's petroleum Sovereign Wealth Fund (SWF), which according to Sovereign Wealth Fund Institute's SWFs fund rankings is world's second largest (SWFI, 2012b). Based on information from the Norges Bank Investment Management (the fund's manager), the fund operates an investments ratio of 60% invested in equities, 35% fixed income securities and 5% invested in real estate and has a mixed asset policy spanning across all continents (NBIM, 2011). This strategy of adopting a diverse portfolio which includes other assets class could help to insulate the fund from the risk of loss. However, as Caner and Grennes (2010) found, despite the fund's investment return being higher than the stock market average, the portfolio risk was riskier than the stock market risk. This outcome suggests that the country's fund will also have other things to learn from an empirical point of view for an improved process.

Thus, as the empirical outcome in chapter 6 suggests a volatility transmission between oil and world stock index, should oil price changes lead to any distortions in the stock market returns, the resulting consequences will lead to loss of value for the Norwegian fund, as its investments of 60% in equities around the world's equity market, make it vulnerable to any negative impact on the world stock market. As the Norway fund spans across all continents and is a crude oil based SWF, this makes it important for the fund managers to have empirical understanding of volatility transmission between oil price changes and stock market returns from a global perspective. This is addressed in chapter 6 in addition to other impacts and potentials for similar empirical extensions.

Again, following chapter 6's empirical evidence of potential for cross market hedging, the Norwegian fund could learn from the two markets' information (oil and equity) in managing the ratio of its investment, as the skeweness of the fund's portfolio allocation towards equity holding exposes it to risk which even the presence of information efficiency of the EMH may not tackle. The allocation of 60% to equity alone is somewhat unhealthy, particularly as this research has found evidence of volatility transmission between oil and stock indices. This exposure to equity risk is demonstrated by the fund's high negative equity return, to a tune of -40.71% (NBIM, 2012), as a result of the global financial crisis that started in 2007. Therefore, reviewing its portfolio position could present a better risk management strategy for the Norwegian fund.

#### 1.2.3.3 Gulf Co-operation Council Countries Effort

As seen in the introduction section, the Gulf Co-operation Council (GCC) countries are making a big mark on global investment decisions with their crude oil funds. Abu Dhabi Investment Authority's (ADIA) investment of $7.5billion in Citigroup during the height of the 2007 – 2008 economic crisis (Telegraph, 2007) is an example of such influences. The move was then seen as a vital one for the survival of the banking group that had been perceived as too big to fall. Also, Mubadala Development Company (MDC) has diversified global investments interests that cut across Aerospace, Capital, Oil and Gas, Healthcare, IT and Telecoms, Real Estate and Infrastructure, among others (MDC, 2012). According to information from MDC (2012) the company's investment in world renowned companies includes 7.5% in Carlyle Group, 5% in Ferrari, 19% in Advance Micro Devices.

Again, Qatar Investment Authority (QIA) with investments of nearly 10% of total ownership in Credit Suisse is the bank's biggest shareholder (SWFI, 2010). In May 2010, a deal for the purchase of Harrods Group by the QIA was announced, this deal implies transfer of total ownership to QIA from Mohammed Al-Fayed (BBC, 2010). Also, according to a report from Bloomberg (2009) Kuwait Investment Authority (KIA) contributed $1billion to Dow Chemical Company in a joint venture arrangement with Warren Buffett, given their attempt to acquire Rohm and Haas in 2009. One thing to note here is the power of influence exerted by these GCC crude oil funds in the companies they invest, since the level of investments confers an ability to influence key decisions in the companies. This is rather better than possession of few ordinary shares without control. For example the reported investment in Citigroup by ADIA amounted to 4.9% of the total shareholding in the bank. This makes ADIA the bank's largest shareholder, giving the company power to influence decisions in the bank.

## 1.3 Part 2: Thesis Summary

### 1.3.1 Research Motivation

This research is motivated by the issues arising from the discussed literature briefly in the above sections and also the literature review chapter. These issues could be summarised as problems revolving around crude oil price volatility, crude oil revenue risk and crude oil revenue management. Thus, the motivations for the research are summarised below;

- Understanding the impact of crude oil price volatility on the economies of export dependent countries, such as Nigeria, whose fundamental economic existence is based on crude oil revenue, which is exposed to price volatility.
- Identifying a hedging mechanism for crude oil revenues of oil export dependent economies, particularly as for examples Nigeria relies on crude oil for 91% of its foreign income, thus exposing the country to revenue risk.
- Understanding the wider economic implication of crude oil price volatility through broad economic indicators such as stock market returns. This is in order to inform better oil revenue management policies for export dependent economies.

The above issues are central to the research questions and objectives to which the empirical section provides answers using appropriate methodologies, as explained in chapter 3.

### 1.3.2 Research Questions

Below are the questions to which this research provides clear answers, presented in the manner in which they feature in the empirical chapters;

1. *Does crude oil price volatility impact on Nigeria's GDP? Does an oil market shock alter the commodity's price volatility for Nigeria? Is the Nigerian foreign reserve account sensitive to crude oil price volatility*? Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect the government's financial position?*
2. *Is the West Texas Intermediate (WT) futures price able to efficiently predict Bonny Light (BL) spot price?* Consequently this serves to address the questions of whether; *there is any need for a BL futures market? Also, at what point is the need tenable?*
3. *What is the nature of different crude oil export dependent economies' reaction to the commodity price changes? Is there any volatility transmission between crude oil prices and global stock market returns? Could gold reserves serve as an alternative to the equity market?*

The above questions and other considerations stimulated the research objectives below.

### 1.3.3 Research Objectives

The main aim of this research is to provide answers to the research questions raised above, by specifically attaining the following objectives;

1. To confirm whether crude oil price volatility has any impact on the commodity's export dependent economies as Nigeria, by investigating foreign income earnings as well as the country's economic variables, which include GDP and inflation rates.

2. To identify a hedging mechanism for crude oil revenues of oil export dependent economies.
3. To ascertain the suitability of West Texas Intermediate (WT) futures contract as a hedging instrument for Bonny Light (BL) spot price.
4. To investigate if there is any need for establishing a Bonny Light futures market.
5. To examine interdependencies between crude oil price and the stock markets of selected oil export dependent countries (Nigeria, Norway and Malaysia).
6. To examine the interdependence between gold and oil spots.
7. To assess whether gold reserves can serve as an alternative to the equity market
8. To determine suitable academic extensions for the empirical investigation of crude oil based sovereign wealth funds.
9. To provide academic contributions capable of identifying empirical avenues for further research.
10. To provide practical impact useful for policy considerations.

### 1. 3.4 Research Methodology

The methodology in this thesis employs econometric analysis of time series models to examine the interdependence between oil price and other variables. This offers an understanding of the long run relationship, impacts and other form of dependences among the investigated variables. Significantly, other preliminary data analysis are undertaken to ensure that the estimated models are reliable.

### 1.3.5 Research Hypotheses

In pursuit of the above objectives, the research questions were carefully channelled through sets of research hypotheses in the empirical chapters 4, 5 and 6. These hypotheses are summarised below in their traditional null of no effect against an alternative of effect.

Chapter 4 hypotheses:

Hypothesis ***H4A***-

$\boldsymbol{H_0}$: *Crude oil price volatility has no impact on Nigeria's GDP.*

$\boldsymbol{H_1}$: Crude *oil price volatility has impact on Nigeria's GDP.*

Hypothesis ***H4B***-

$\boldsymbol{H_0}$: *Oil market shocks do not increase oil price volatility for Nigeria*

$\boldsymbol{H_1}$: *Oil market shocks increases oil price volatility for Nigeria*

Hypothesis ***H4C***-

$\boldsymbol{H_0}$: *Nigeria's foreign reserve account is not sensitive to oil price volatility*.

$\boldsymbol{H_1}$: *Nigeria's foreign reserve account is sensitive to oil price volatility*.

Chapter 5 hypotheses:

Hypothesis ***H5A*** -

$\boldsymbol{H_0}$: *West Texas Intermediate futures are not an efficient means of managing price risk in Bonny Light spot.*

$\boldsymbol{H_1}$: *West Texas Intermediate futures are an efficient means of managing price risk in Bonny Light spot.*

Hypothesis ***H5B***-

$\boldsymbol{H_0}$: *There is no short-run adjustment back to long-run equilibrium in the variables relationships from* ***H5A****.*

$\boldsymbol{H_1}$: *There is short-run adjustment back to long-run equilibrium in the variables relationships from* ***H5A****.*

Chapter 6 hypotheses:

Hypothesis ***H6A***-

$\boldsymbol{H_0}$: *Crude oil export dependent countries' stock indices react differently to oil price volatility.*

$\boldsymbol{H_1}$*: Crude oil export dependent countries' stock indices react to oil price volatility in a similar manner.*

Hypothesis ***H6B***-

$\boldsymbol{H_0}$: *No volatility transmissions exist between crude oil price changes and world stock market returns.*

$\boldsymbol{H_1}$ *: Crude oil price changes and world stock market returns exhibit volatility transmission.*

Hypothesis ***H6C***-

$\boldsymbol{H_0}$: *Gold reserve cannot be used as an alternative investment for crude oil revenue.*

$\boldsymbol{H_1}$*: Gold reserve could provide an alternative investment for crude oil revenue.*

### 1.3.6 Original Research Contributions

Three closely linked empirical chapters are presented, constituting the principal contributions of the work. They serve to address the following;

- The research found crude oil price volatility to have impact on Nigeria, this finding helped to confirmed similar preceding research.
- Examines whether West Texas Intermediate futures is an unbiased predictor of Bonny Light spot, first study to do this.
- The relationship between spot and futures markets is characterised, allowing the appropriate hedging mechanism for Bonny Light and other light crude oil spots to be possibly constructed.
- Wider economic implications for crude oil price volatility are uncovered. For instance, volatility transmission between oil, equity and the gold markets had been confirmed, becoming the first time these three markets are jointly examined.

- The analysis between oil, gold and equity markets are both undertaken for a developed economy (Norway) and further developing economies (Nigeria and Malaysia) jointly, the first of such study to do so.
- Provides implications for crude oil revenue optimisation and extension to sovereign wealth funds.
- Policy implications for crude oil export dependent economies and including cartels such as OPEC are examined in detailed. For instance the discovery that the Bonny Light spot is a price taker (having no influence on oil price determination) paves the way for understanding of external price determination.
- Extendable outcomes are reached from the research empirical process in chapters 4, 5 and 6. For instance, the outcomes in empirical chapter 6 that suggested volatility transmission between oil and the equity market could be applied to further study of whether the information could be said to help provide hedging potentials.

### 1.3.7 Thesis Overview

As already pointed out in the introduction section, this thesis is organised into seven chapters: general background, literature review, methodology, empirical chapters 4, 5, 6, general discussion and conclusion. The chapters are further grouped into three broader parts: introduction, empirical and conclusion. The following subsections briefly summarise the remaining chapters of the thesis.

#### 1.3.7.1 Chapter 2: Literature Review

This chapter reviews literature relating to crude oil price volatility, revenue management and other extensions associated with the research topic of this thesis. Specific links are made between relevant theories (such as the efficient market hypothesis) and situations relating to the research area. Also, the crude oil revenue management approaches of different oil endowed countries are examined, in an attempt to ensure relevance to the problem areas. Specific problems relating to the impacts of crude oil price volatility, oil revenue management, oil price determination and oil revenue influence on global investments, etc, were identified. Identification of these problems leads to various questions being formulated, that are subsequently empirically examined.

#### 1.3.7.2 Chapter 3: Research Methodology

This chapter describes and specifies the empirical models adopted in the empirical component (chapters 4, 5 and 6) of this thesis. The models are identified based on their relevance to answering the research questions in this thesis and also due to their past applications in related scenarios. Quantitative method is seen as the suitable approach, and time series econometrics application is the primary procedure identified as applicable in the overall empirical analysis of the thesis. This is motivated based on the overall set of research questions being built around crude oil price volatility, that which naturally makes time series data suitable. A clear focus is on linking the selected models with the research questions which emanate from the frame of literature reviewed in the previous chapter, demonstrating clear linkage among the research topic, literature, data and ultimately the analytical framework.

#### 1.3.7.3 Chapter 4: Price Volatility Impact on Oil Dependent Economies

This chapter is intended to answer the questions: *does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility*? Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect government financial position?* Bonny Light spot, its standard deviation, Nigerian foreign account, Nigerian gross domestic product, Nigeria's currency/US dollars exchange rate, Nigerian inflation rate and US treasury rates are examined. Vector autoregration (VAR), is employed, given its associated impulse response functions and variance decompositions analysis. On the side of the applied data, Bonny Light spot price and its standard deviation represented oil prices shocks and volatility. The main empirical finding is that crude oil price shocks have positive impacts on the Nigerian GDP, Bonny Light's (BL) standard deviation and foreign account, but negative on inflation rate and exchange rate.

#### 1.3.7.4 Chapter 5: Exploring Price Discovery for Bonny Light oil Spot

This chapter provides answers to the research question: *Are* West Texas Intermediate *(WT) futures price efficient predictor of Bonny Light (BL) spot price?* Secondary questions addressed are: *is there any need for BL futures market?* Also, *at what point is the need tenable?* Bonny light (BL) vis-à-vis West Texas Intermediate (WT) spot price in relation to the futures price of WT are analysed in that regard. The empirical analysis mainly employs cointegration tests, for which both Engle-Granger two-step method and Johansen test in relation to their respective error correction models (ECMs) were adopted. These are in addition to other procedures for Granger causality, impulse responses and other diagnostic experiments aimed at increasing the robustness of the analysis. The findings suggest that WT futures price or futures market can be used to hedge price risk for *BL* spot.

#### 1.3.7.5 Chapter 6: The Interdependences between Oil, Equity and Gold Markets

This chapter empirically examines the potential for LR equilibrium relationship, market efficiency and volatility transmission between crude oil price and the stock markets of selected oil export dependent countries (Nigeria, Norway and Malaysia). It also examines similar interaction between the oil price and global stock index and also, gold spot price. These investigations and related hypotheses testing address the research questions: *What is the nature of different crude oil export dependent economies reaction to the commodity price changes? Is there any volatility transmission between crude oil prices and global stock market return? Could gold reserve serve as an alternative to equity market?* To answer these questions, the adopted empirical procedure is the diagonal BEKK. This procedure was used to establish the existence of conditional mean, variance and covariance in the given variables of daily oil and gold spot prices, and also, the closing prices of Malaysia, Nigeria and Norway stock markets, in addition to the world stock index.

#### 1.3.7.6 Chapter 7: General Discussion and Conclusion

This chapter presents a general discussion of the empirical findings obtained by addressing the research questions. It reflects on the implications of the findings for both academic work and policy directions. Where appropriate, personal opinion supported by practical experience and academic knowledge are also prominently expressed. However, the results of the empirical findings are the main source of the conclusions drawn.

## 1.4 Conclusion

This chapter has introduced the entire research idea and provided an overall picture of thesis. The general research content was presented indicating in brief all the issues presented in the subsequent chapters 2 – 7. The chapter was, organised into two parts, with part 1 being the research introduction and part 2 summarising the overall thesis. Broadly, part 1 introduces the major research problems in this thesis by discussing crude oil price volatility and its consequences, oil revenue management as a hedge, and the significance of oil to its export dependent economies. Part 2 provided a synopsis of the entire thesis, the research motivation, questions, objectives, methodology, hypotheses and contributions. This essentially provides an overview of the thesis from conception to implementation.

The major research motivation in this thesis is crude oil price volatility and its impact on the commodity's export dependent economies, especially as preceding empirical studies focused on understanding such impact on the economies of net oil import dependent economies. As such, a scrutiny of interdependences between oil price volatility and economic variables of export dependent countries as; GDP, foreign account, oil futures market, stock indices and gold spot is seen as desirable. Research directions were identified in terms of oil revenue management, given the existing surge seen in sovereign wealth funds effort. Oil revenue's significance for export dependent countries, as a researchable problem was also highlighted.

Oil price volatility was argued to expose the commodity export dependent economies to revenue risk. Nigeria, for instance, has 91% of its foreign exports revenue coming from crude oil export. Hence, with volatility of the commodity, budget, economic planning, as well as revenue forecasting is exposed to uncertainties, as confirmed by the Central Bank of Nigeria.  Thus, as some oil export dependent countries are seen to have responded to similar threats, Nigeria and others could learn from their processes and the countries too could learn to do better in investing their oil proceeds.

Therefore, as the identified research problem requires sound counteractive action by oil export dependent countries such as Nigeria, the next chapter will examine related literature with a view to identifying specific researchable problems and refining the questions to be examined. Hence, the existing empirical studies in this and related areas will be crucial in this regard, especially those indicating scope for extension. Thus, as much as possible, the motivation for this research is developed based on previous empirical findings.

# Chapter 2: Literature Review

## 2.1 Introduction

Crude oil price volatility has long been a problem for both net exporters and importers of the commodity. The exporting countries have found it increasingly difficult to budget and effectively plan their economies based on the future income from the commodity. As the Central Bank of Nigeria (CBN) pointed out, volatility is the main challenge to managing the country's foreign reserve account (CBN, 2011b). This is due to the irregular pattern of revenues, which is largely associated with price volatility. Arouri et al. (2011) discovered evidence of volatility transmission between oil price and the stock markets of the main oil producing countries in the Gulf Corporation Council (GCC). Also, the importing countries suffer from problems arising from unstable prices. As incessant increase in oil price tends to distort inflationary expectations, this has the tendency to damage economic growth and stability for importing countries. Jiménez-Rodríguez and Sánchez (2005) found oil price increase to cause larger GDP growth impact in most of the OECD countries studied for oil price volatility impact, among which are net suppliers of the commodity. Also, Rafiq et al. (2009) found evidence of crude oil price volatility on the budget of Thailand as a net consumer of crude oil.

Therefore, in this regard, the volatility problem could be seen to extend to specific issues of crude oil revenue risk and management, among few. Even as the crude oil price volatility problem seems to largely emanate from price shocks, it is seen as being caused by a combination of different factors, including political, economic, etc. A typical example was the major crude oil market shock of 1973, commonly referred to in academic literature, which resulted from the Organisation of Petroleum Exporting Countries (OPEC) oil embargo (Smith, 2009). Also, the 1979 oil shock coming based on the crisis resulting from the Iranian revolution, and the 1990 oil shock as a consequence of the Gulf war, are among historical oil shocks.

The general crude oil price volatility problems as extensively researched and empirically tested in academic finance are normally specific to impacts on different economic variables. These usually revolve round problems as GDP, exchange rates, stock market performance, reaction of other commodities prices, etc, see for instance; Jiménez-Rodríguez and Sánchez (2005), Kilian and Park (2009) and Chaudhuri, (2001), among others. Another area is price determination, usually through the commodity price discovery with vast empirical applications. Quan (1992) tried to determine if a stable long run relationship exists between crude oil spots and futures prices, as have many others (Schwarz and Szakmary, 1994; Hammoudeh et al., 2003; Maslyuk and Smyth, 2009). As problems associated with crude oil price volatility have very wide dimensions, this chapter focuses on areas relating to crude oil price volatility leading to crude oil revenue risk and management.

Narrowing the problem of crude oil price volatility to the country level, Nigeria for instance is the world's 7th exporter of crude oil (EIA, 2012) and the commodity provides the country with over 91% of its foreign reserve. As pointed out above, the CBN has pointed to volatility as the main challenge to managing the country's foreign reserve. Highlighting this further, the country's high grade of crude oil, the 'Bonny Light' (BL) spot remains largely unexamined within the academic literature. Ayadi et al. (2000) and Ayadi (2005) are among the few available empirical studies that examined the BL spot price and also the impact of the energy sector on the country's economy.

Given the above highlighted problems, van der Ploeg and Venables (2011) identified three potential choices for a government faced with decision on management of natural resources. These options are saving or consumption, investment in domestic economy or in foreign assets and domestic investment. As the study pointed out, the choice depends on country specifics; one could infer that the first two choices are preferred for an underdeveloped oil producing country like Nigeria; with the first choice required as such countries need to develop their economy, while the second decision point is required for future consumption. This second decision point categorically portrays the sovereign wealth fund (SWF) investments approach. Recent developments around the investments world have seen SWF rising to prominence, with nearly 60% of global SWFs being oil and gas related (SWFI, 2012b). Nigeria recently established the Nigeria Sovereign Investment Authority (SWFI, 2012a).

Therefore, as this literature review looked closely at the crude oil price volatility issues relating to revenue problems, numerous questions came up. These questions were refined in a specific manner whereby answers could be empirically attained. A few of the questions are; *does crude oil price volatility impact on Nigeria's GDP?* Also, *is the West Texas Intermediate (WT) futures price able to efficiently predict the Bonny Light (BL) spot price?* Others are; *what is the nature of different crude oil revenue dependent economies' reaction to the commodity price changes?* Thus, this review will pave way for the questions this research will be examining in the methodology section that will occupy chapters 3, 4, 5 and 6 of this thesis. Among the issues examined in detail in this chapter are; understanding oil market shock in relation to price volatility, economic impacts of oil price volatility and their control, and the global influences of crude oil on investments.

## 2.2 Understanding Oil Market Shock in Relation to Price Volatility

The existence of crude oil prices volatility has long been confirmed. Empirical evidence from Jiménez-Rodríguez and Sánchez (2005) has confirmed the commodity price volatility as a source of problems for economies of both net producing and consuming countries. Pindyck (2001) emphasised the volatile pattern of crude oil price behaviour while attributing it to shift in demand and unexplained factors. Several factors could be jointly or separately responsible for the volatile pattern, among which are political, economic, technological, social. Others could be due to sudden shocks that may not have been foreseen or explained, as asserted by Pindyck. Hamilton (2003) identified oil price shocks as more inclined to price increase than decrease, this is because price increase creates more distortionary effects within the economy than decrease. However, as Chaudhuri (2001) attributed the problems of price movements in primary commodities to oil price shocks, it could be seen that the problem is more widespread than is ordinarily imagined.

The basic feature that normally precedes crude oil price volatility comes from the existence of oil market shocks. This point has, over time, led to the two different issues being increasingly used interchangeably. A large body of both theoretical and empirical literature exists which seeks to explain the sources and/or types of oil market shocks

(Hamilton, 2009; Kilian, 2009; Smith, 2009; Büyüksahin and Harris, 2011; Kilian and Murphy, 2011). There seems to be a general consensus among these studies regarding demand and supply led shocks, with Kilian (2009) and Kilian (2010) recognising demand factors as being the major historical source of oil shocks. Although speculation and inventory activities are also seen as other sources of oil price shocks, empirical evidence in recent times has failed to substantiate claims of speculation activities (Büyüksahin and Harris, 2011; Kilian and Murphy, 2011).

Lescaroux (2009) confirmed there to be high correlation between commodities prices movements (crude oil included) and attributed that situation to the common shocks in inventory level. For crude oil as a commodity, given that it does not deal in physical inventory level, but rather reserve capacities that are scientifically projected, it could be said that a level of uncertainty regarding the reserves already exists. Kilian and Murphy (2011) examined the role speculation and inventory level could have in increasing volatility in the oil market. The study particularly focused on the upward price hike experienced in the commodity market during the period between 2003 and 2008. The finding was that rather than speculation and supply change, increases in oil consumption due to increases in world business activities were responsible for the price increase. In the same vein, Büyüksahin and Harris (2011) also, empirically found no evidence linking activities of speculation to oil price hikes.

The 1973 oil market shock is the one most commonly cited in academic literature. The incident dramatically resulted in a sharp increase in global price of the commodity, which brought in different sets of economic reactions in both consumer and producing countries. However, as much as the difference between the two concepts of price volatility and market shocks is highlighted, it is important to study the two together as they are hardly ever separated. Jiménez-Rodríguez and Sánchez (2005) studied the impact of crude oil price shocks on the GDP growth of industrialised countries, among which are some net suppliers of the commodity. As the results suggested different outcomes for the net exporting and importing countries due to responses to oil shock, extending the empirical research to focus on other sets of countries as oil revenue dependent economies may yield similar or different types of reactions.

Getting a clear picture of crude oil market shocks is particularly relevant in establishing the root cause of frequent changes in crude oil price that largely bedevils the market. This is reflected in the oil prices response generated as a consequence of each given market shock. This aspect is largely explained in academic literature in terms of the theoretical approach originating from Sims (1980). Understandably, this rapid application of the theory to crude oil as a commodity could be due to the incessant volatility pattern in the market that is mostly attributed to periodic shocks. Thus, understanding these shocks in relation to increase or decrease in revenues for the commodity exporting countries will be an important area to cover.

Although price shocks in the crude oil market are characterised by both booms and slumps, the two issues are often treated as the same, usually under the name of oil price shocks. Using general commodities as an example, Cashin et al. (2002) typically examined commodities shocks and found a disequilibrium in the cycles between their booms and slumps. The empirical finding suggested that periods of price slump last longer than those of price boom. Thus, understanding the two issues separately is important as their impact on the economies of commodity importing and exporting countries differs. Again, much could be attained by considering booms and slumps in positive or negative perspectives. Theoretically, a positive crude oil price shock will normally result in an advantageous situation for oil producing countries and disadvantage to the importing countries (see Hamilton, 2003). Hence, separation of the two features of positive and negative shocks is important.

Again, aspects of commodity price shock could be seen as being precipitated by news in the market, especially as the market is seen as efficient in information dissemination. Therefore, the impact of the efficient market hypothesis (EMH) is not easily discounted. Roache and Rossi (2010) examined this matter and discovered an imbalance regarding how commodity prices respond to economic news. The responses of other commodities prices (gas, crude and refined oil included), deemed as vulnerable to bad economic news in relation to gold, usually seen as a resort for other commodities hedging during an economic downturn, was analysed. This finding shows the power of news (good or bad) in determining the directional responses of commodities prices. This is especially so for crude oil, a commodity that is far more vulnerable to price volatility, as it is always in the news. Most importantly, empirical efforts such as this go a long way in adding an extra perspective, that is, '*news*' as the cause of commodity price volatility, as against focusing narrowly on shocks alone.

The primary existence of crude oil price volatility has been increasingly studied as an academic problem, with large concentration of empirical studies over the years focusing more on testing their impacts on the economic fundamentals of both exporting and importing countries. Chaudhuri (2001) empirically attempted to explain the role of real crude oil prices in explaining the volatility in other commodities. In essence, the study examined the cross impact of crude oil price volatility on other commodities, specifically taking into account well-publicised periods of oil price shocks. Again, Chen et al. (2009) examined the impact of China's increased crude oil demand on the instability of global crude oil prices. These approaches are fundamental to determining the effect of crude oil price volatility, an outcome which is a useful input in controlling the negative effects of such impacts. Thus, as a practical step, identification of crude oil price volatility impact as a means of controlling, curtailing and even evading the problem of crude oil price volatility is essential.

Quan (1992) investigated crude oil spot prices and futures contracts to determine if the latter could predict the former. One problem area the research attempted to confirm is the power of successive information exhibited by futures prices in determining spot prices. A surprising revelation from the finding suggests inability of the futures market to make any impact on price discovery. This finding is unexpected and it challenges the fundamental theoretical assumption of EMH that suggests futures contracts will largely provide information about the spots market. This seeming deviation could be empirically reviewed, as we know from our knowledge of the literature that the overwhelming position is tilted towards the view that crude oil futures contracts can determine spots.

### 2.2.1 The Role Played by the Organisation of Petroleum Exporting Countries

Empirical studies are continuously seeking to address the question of whether the Organisation of Petroleum Exporting Countries (OPEC) plays any role in precipitating crude oil price shocks. This is following a widespread belief that political factors linked to cartels such as OPEC are responsible for oil price volatility, but Kilian (2010) sees this view as an easy explanation of the oil price shock situation. The view largely originates from the events leading to the 1973 oil market shock, which emanated from the decision by some members of the organisation to place an oil embargo on the United States of America (Smith, 2009). Although the current level of political influence of the United States of America (US) on some key members of the organisation such as Saudi Arabia and Kuwait seems to be working to curtail OPEC's powers, the organisation still regulates oil exports of its members. Thus, OPEC as a cartel still influences the supply side of crude oil, a point which, if conflicted with the demand side, could cause market shock that would result in price volatility.

Kilian (2010) noted that the general belief that Middle East political disturbances and OPEC's influences on producer countries are the source of increases in oil price may not hold as there is little empirical evidence to support this view. However, the empirical evidence in Horan et al. (2004) and also Kaufmann et al. (2004) supports the hypothesis of OPEC's influence on global oil price. This is in contrast to extensive empirical evidence suggesting otherwise (Smith, 2005; Bentzen, 2007; Brémond et al., 2012). Thus, with the contrasting evidence against OPEC influence hypothesis, it could be seen that the organisation does little to determine oil price. Then one question that still remains is; *what determines oil price globally?* Another question that arises is; *where lies the influence of OPEC in determining global oil price and could the organisation still be regarded as a cartel?* This is given the over bearing political influence of the world's greatest consumer (USA) of oil on OPEC's biggest exporters like Saudi Arabia and Kuwait.

Even the production quota OPEC sets for its members is fundamentally questioned, given that some key members could have the incentive to cheat and influence quota agreements (Alhajji and Huettner, 2000). Also, there are empirical evidences against the organisation's quota system (Horn, 2004; Gately, 2007). Alhajji and Huettner (2000) suggested that the OPEC quota system does not conform to the normal production quota setting in an ideal cartel. This and other lapses give room for members to deviate as enforcement and monitoring are not adequate. Gately (2007) analysed the potential optimal profit OPEC could generate by allowing for more production than will be enough to take its share of world oil production. The results suggest a potential profit increase. Horn (2004) also analysed OPEC's oil price stabilisation regime and concluded that the policy is not optimal.

Therefore, as Brémond et al. (2012) found OPEC to be price taker, it is very difficult to say if the organisation does anything in terms of influencing global oil price, thus, the more glaring forces that determine the commodity's price are those of demand and supply. Hence as an instance, Nigeria as an OPEC member is not expected to influence oil price, despite being the world's 7th exporter of the commodity. Again, seeing the country's production capacity in terms of the two (2) million barrel/day in the face of global requirement or comparatively with the seven (7) million barrel/day of Saudi Arabia (EIA, 2012), the country's production may not influence oil price in the world. Thus, the question that may be asked here is; *is the Nigerian crude oil spot (BL) a price taker or a price setter?*

## 2.3 Economic Impact of Crude Oil Price Volatility

The impact of crude oil price shock on both the economies of net exporters and importers of the commodity is being increasingly studied. The targeted variables for empirical examination are usually economic indices of GDP, stock markets, employment, inflation, exchange rate and reaction of other commodities prices. Chaudhuri (2001), Jiménez-Rodríguez and Sánchez (2005), Kilian and Park (2009) are a few instances of studies with empirical applications in that direction. However, large number of these efforts tend to focus more on the resulting impacts of such shocks on macroeconomic variables; see, for example; Hamilton (1983), Ferderer (1996), Ayadi (2005), Jiménez-Rodríguez and Sánchez (2005), Berument et al. (2010) to name a few. Other studies also extended the focus to target the extended impact of oil price volatility to the reaction of other commodities prices (Chaudhuri, 2001; Roache and Rossi, 2010).

As increasing amount of academic literature suggests crude oil price volatility affects the economic wellbeing of both net producers and consumers, Jiménez-Rodríguez and Sánchez (2005) examined the impact of crude oil shocks on the GDP growth of industrialised countries. Also, Berument et al. (2010) investigated how the output growth of some Middle East and North African crude oil producing countries is affected by commodities price volatility. Similarly, Rafiq et al. (2009) analysed the impact of crude oil price volatility on the economic indicators of the Thai economy and found evidence of an impact on the country's budgets. Again as the above cited studies did, the authors targeted key macroeconomic indicators of the country. In the case of the Nigerian economy, Ayadi (2005) examined whether an increase in oil prices leads to an increase of industrial production in the country. As the outcomes of these studies tend to generate different results and given that this research is interested in the economies of oil producing countries, the question that arises is: *How does crude oil price volatility impact on the economies of the commodity's producers like Nigeria?*

Earlier, certain empirical efforts attempted to understand the pattern of volatility by investigating the directional impacts. Lee et al. (1995) and Hamilton (1996) concentrated on finding out what happens when there are positive or negative crude oil price shocks? An attempt to understand similar pattern of impact by extending such analysis to include period tranches as short, medium and long term coverage, could provide better appreciation of the problem. This is in addition to the generic impacts of crude oil shocks already investigated by the previously-cited studies. The extension this research hopes for in this direction will be to see if oil price volatility could have any impact on certain key variables in the case of oil revenue dependent countries like Nigeria. Specific researchable questions that could be asked in this regard are: *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?*

Price interdependence between oil and stock markets is also studied with a view to understanding the extended impact of oil price volatility. This is because stock markets normally have an influence on the economy of a country, largely due to their role in capital market investments. Several empirical studies into the extent of interdependence between crude oil price changes and stock market returns have suggested different interesting outcomes (Jones and Kaul, 1996; Sadorsky, 1999; Malik and Ewing, 2009). Also, some empirical studies were interested in the behaviour of specific stock markets in response to oil price changes. Basher and Sadorsky (2006) and Basher et al. (2012) examine the case of emerging stock markets, while other studies concentrated on key oil producing countries of the Gulf Cooperation Council (GCC) (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011; Mohanty et al., 2011). Zhang and Wei (2010) equally investigated crude oil and gold spots for evidence of integration.

Basher and Sadorsky (2006) and also, Hammoudeh and Choi (2006), examined the impact of oil price changes in the case of emerging economies stock market returns. Given that the majority of world oil exporting countries are either emerging or developing economies, this focus could greatly bring out the real effect where it matters most. In extending Basher and Sadorsky (2006), Basher et al. (2012) introduced the exchange variable in the analysis of relationships between emerging stock markets and oil prices. This latest effort could be seen as a better approach to capturing the economic impacts of oil price changes on emerging economies. This could be explained given the degree of foreign exchange reliance in such economies, the least of which sees the oil price being globally traded in US dollars. Again, Malik and Ewing (2009) investigated volatility transmission between oil prices and different equity sectors of the US's Dow Jones. The findings suggested existence of volatility transmission across the equity sectors and oil prices. Although the authors claimed the results could be useful for cross-market hedging and sharing market information among investors, this claim may be further examined.

Although some studies (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011) have addressed the interdependence between crude oil price changes and stock markets of the GCC countries, still not much has been achieved in terms of studying the impacts of such interdependences on the stock market returns of crude oil revenue dependent economies (oil exporting countries). Jones and Kaul (1996) have already found the stock market cash flows of the crude oil net importing countries, US and Canada, to be affected by oil price shocks. However, the Japanese and United Kingdom stock markets manifested different sets of responses. Thus, with the case of oil importing countries being addressed empirically, there is a real need for broader expansion that would integrate other oil exporting countries' stock market returns into this body of research. This is essentially due to their economies' common tendency to depend on crude oil revenue for growth. Also, such an endeavour would enable comparison different oil producing economies' (through stock markets) ability to deal with the issue of crude oil price changes, particularly given countries' different economic characteristics.

For instance, Norway as an oil dependent economy has a different mode of dependence on crude oil as a commodity, as compared with other oil dependent economies such as Nigeria or even Malaysia. While Norway's economy is self sufficient in alternative energy sources and it exports almost all its crude oil, the same may not be said about Nigeria. Again, Norway with a population size of less than 5 million people presents a country with a small size economy, Nigeria, with a population of over 160 million, is a bigger economy with potentially broader activities than Norway. Given this diverse nature of interdependence, the different stock market indices could be examined for a wider variety of reactions to crude oil price changes. Essential elements of business activities and health of the different economies under crude oil price changes could be understood via this means. Thus, understanding the importance of crude oil spot prices of these countries, such as the BL price in Nigeria to determining stock market activities is crucial.

Oil and gold price interdependence too is being increasingly explored empirically with the intention of understanding the impact of one on the other. Wei and Zhang (2010) have found evidence of cointegration between crude oil and gold market, which suggests the two commodities' prices move together and have long term equilibrium. Also, Roache and Rossi (2010) examined the impact of gas, crude and refined oil alongside other commodities' prices due to bad news in relation to gold, especially during economic downturn. Such research endeavours go a long way in identifying the level of extended impacts crude oil price volatility may have on other aspects of the global economy. Thus, research effort in this direction could be extended to examining wider issues involving gold price in relation to oil revenues. For instance, this could be in the direction of exploiting further the knowledge of cointegration between gold and oil prices identified in preceding studies such as Wei and Zhang (2010).

## 2.4 Controlling the Impacts of Crude Oil Price Volatility

As the problem of crude oil price volatility continues to capture the attention of academic researchers, most noticeable of the empirical responses in this regard are those geared towards crude oil price stabilisation, normally through price discovery, hedging, and other mechanisms. More practical steps for a government faced with management decision of natural resource were identified in van der Ploeg and Venables (2011). These steps are: saving or consumption, investment in domestic economy or in foreign assets and domestic investment. However, both practical as well as empirical approaches are relevant in the quest for having better managed revenues of depleting natural resources like oil.

### 2.4.1 Relevance of Efficient-Market Hypothesis in Crude Oil Price Discovery

Under the efficient market hypothesis (Fama, 1965; Fama et al., 1969), it is assumed that the financial markets are up to date with information. Using event studies, Fama et al. (1969) examined the process in which the market responds to information using stock splits. Belief in the efficient market hypothesis (EMH) was fundamental as far back as Fama and MacBeth (1973), as it partly accounted for the essential theoretical underpinning in testing for the relationship between average return and risk for the New York stock market. Thus, the EMH assumption of perfect information could be applied in attaining a stable crude oil price. This is because the hypothesis' assumption of free information flow could aid the understanding of the market's volatility. However, it is known that if market information were in perfect order, crude oil price volatility could not be a problem.

The complete absence of information cost in the assumption of the Capital Assets Pricing Model (CAPM) of Sharpe (1964) gives an essential credibility to the EMH. The CAPM, which commands a dominant position in empirical testing of risk and return from the mid 1960s to date, could be seen as partly linked in this regard with the EMH. Fama and MacBeth (1973) seem to have corroborated this point when they tested for a relationship between average return and risk for the New York stock market by jointly utilising the theoretical assumptions of both the CAPM and the EMH. Essentially, the notion that information is free and instantly available to all investors in the CAPM depicts a level of linkage with the EMH. Thus, confirming how interlinked the two theories are and the success of the CAPM in empirical finance (despite all criticisms) will support any decision to adopt the EMH as a theoretical base in controlling oil price volatility.

Despite some criticisms, the EMH seems to hold ground in the light of market information necessary for arriving at commodities price prediction. As the EMH is established in the case of crude oil futures (Crowder and Hamed, 1993 among others) it could then be seen as a hypothesis that derives the assumption in empirical analysis relating to oil price stability. Part of the empirical analysis in this research will rely on the futures market as an important source of information. This will be in the direction of predicting what the oil spot prices could be from the futures market. However, Quan (1992) suggested that futures prices need to have accurate and quick reaction to market information. The main hope in exploring a price discovery for crude oil spots is to attain a prediction power that will constitute the ability of reaching an informed decision on crude oil pricing, the lack of which has largely exposed crude oil to the problem of market price volatility. Ultimately, the EMH could be the theoretical underpinning which may relevantly capture the essence of this required information symmetry. Therefore, a key element in guaranteeing crude oil revenue stability is perfect information availability, but in reality not even theoretical elements in the EMH may guarantee just that.

The application of the futures market as a mechanism of commodity price discovery is widely adopted in empirical finance. In the context of crude oil pricing as examined in this research, the approach has numerous empirical precedents (Antoniou and Foster, 1992; Quan, 1992; Schwarz and Szakmary, 1994; Sequeira and McAleer, 2000; Moosa, 2002; Lin and Tamvakis, 2005). Some of these empirical efforts are specific to co-movements between crude oil spots and futures prices, thus signalling attempts at price discovery in crude oil. Quan (1992) and Schwarz and Szakmary (1994) are among the earliest examples of such studies which tested the existence of price discovery in crude oil, utilising information from the futures market to attain potential knowledge of the spots market. In the case of other commodities, Pindyck and Rotemberg (1990) estimated co-movements among different commodity prices, but did not include crude oil. Since then, various sets of follow up studies have continued to estimate the case of crude oil price co-movements, even by way of comparison with other commodities. Lescaroux (2009) examined numerous commodities for co-movements, while focusing on prices of crude oil in relation to metal prices.

Extending the price discovery for crude oil revenue dependent countries, as was done with the above cited empirical studies, could potentially help to guard against the negative impact of price volatility. This is so, as not even the optimal decision points analysed by van der Ploeg and Venables (2011) could be as helpful in a situation of a volatile revenue source such as crude oil. Ultimately, without such a mechanism, guaranteeing such oil revenue inflow in normal proportion based on an anticipated regime is not foreseeable. Therefore, a price discovery mechanism for crude oil revenue dependent economies could serve as a crude oil revenue uncertainty management tool. A potential research question in this regard may be: *is the West Texas Intermediate (WT) futures price able to efficiently predict Bonny Light (BL) spot price?* Other secondary questions that may develop following this could be in the direction of finding out; *is there any need for BL futures market?*

However, as much as we see the potential of the price discovery mechanism as a solution to crude oil price uncertainty, it is difficult to say that it will directly remedy the issue of crude oil price volatility. As a matter of fact, far from the hope of creating price discovery, there is a compounding amount of empirical evidence claiming that the existence of the crude oil future market increases the volatility in the spot market (Alquist and Kilian, 2010). Thus, attractive as it may be to claim that future market as an information source could be a place for controlling crude oil and other commodity price turbulences, it could also undermine the same stability. This is as using future price as a mechanism of commodity price discovery is widely adopted in empirical finance (of which some examples were above). Therefore, as this research aims to extend those empirical evidences in support of potential price discovery from the future market, it will at the same time be confirming the contrary empirical findings.

### 2.4.2 Hedging to Control Price Volatility

In addition to hedging against price volatility as usually carried out using the futures market (reviewed in the above section), practical hedging is often thought of and applied as a tool for achieving an optimal investment strategy. Investing in capital market and derivatives are often used in this direction, while the option of a portfolio approach is also open. For crude oil price hedging, the use of other commodities more stable than oil could be adopted, as the principle of hedging in practical finance is normally applied to reduce the risk associated with price volatility. This is achieved by taking an investment position that reduces any potential price risk exposure. In addition to the practical steps that are taken, academic studies also play a vital role in unveiling useful theories modelled through empirical approaches, with enormous practical implications. Similarly, relevant empirical studies of crude oil prices hedging exist, Chaudhuri (2001) thought transforming primary commodities like crude oil into a semi finished level before their export could help to reduce the issue of price volatility. However even if this were to be achieved, the bottom line of ensuring long run stability in the pricing of such commodities is still far from being reached.

Among the early studies that provided the essential motivation for assets pricing integration to crude oil price volatility is Bollerslev et al. (1988). This is largely due to the adoption of time-varying volatility in the empirical processes. Other later studies followed suit by extending such ideas to studying crude oil price volatility, given that the commodity suffers from persistent price volatility. The manner of oil price dependence on other commodities and even, broadly speaking, on stock market's price has already been reviewed. Galvani and Plourde (2010) employed the *mean-variance* optimisation framework to study portfolio diversification in the energy market. The approach by Galvani and Plourde primarily investigated whether energy futures improve the investment potential of crude oil firms. The result found evidence of risk minimising potentials for investors, thus, introducing volatility theory to the asset pricing situation.

A capital market investor is concerned with the two issues of risk minimisation and optimal return. These issues are central to the *mean-variance* efficiency consideration of Markowitz (1952). Empirical application of this theory was effectively enshrined in the capital assets pricing model (CAPM), whose origin is widely linked to Sharpe (1964) and Lintner (1965). One fundamental assumption behind Sharpe's CAPM is that of an investment's return depending principally on its associated risk and market beta ($\boldsymbol{\beta}$) as a relative measure of sensitivity in the asset's return. To this day, the essential element of studying risk and return is largely linked to the stock market activities. Quite relevantly, this is extended to understanding the effect of oil price volatility to stock market activities. Again, Malik and Ewing (2009) highlighted the potential usefulness of their approach to estimating the *mean* and *variance.* Similarly, Karolyi (1995) when estimating the volatility transmissions between the United States and Canada, highlighted the implication of such study on asset pricing.

Following Kothari et al.'s (1995) confirmation of the $\boldsymbol{\beta}$ as good compensation for risk level, it was shown empirically by Malevergne and Sornette (2005) that with the multi-factor, it is possible to increase the expected return of a portfolio while lowering its large risks. This finding; among others lent further credibility to the multi-factor asset price model, which sought to expand the mean-variance point of reference in capital market analysis. This point of argument further broadens the prospects for analysing the capital markets with more variables than the original mean-variance focus. Looking beyond the capital market, further interaction of market risk and return with other key economic variables and major commodities such as GDP and crude oil has been examined empirically. Sadorsky (1999) jointly estimated oil price and oil price volatility's impact on real stock returns. The approach could be seen as important in isolating each set of impact, so that the relative nature of each variable's impact on the economy could be dealt with accordingly.

Malik and Ewing (2009) claimed to have found a potential for cross-market hedging between crude oil and the stock market. Focusing on confirming such claim could bring further empirical development in that direction. Another direction would be to extend the stock markets being examined to a global coverage, as against limiting to a specific stock market such as the Dow Jones stock exchange, analysed by Malik and Ewing. Thus, such investigation will find out if any potential cross-volatility transmission between crude oil prices and global stock market returns exists. This direction could raise such researchable questions as: *Is there any cross volatility transmissions between* *crude oil prices and global stock market returns?* If yes, a further dimension of development will be an examination of the outcome to see if such information could provide any useful means of hedging crude oil revenue. This new research development could be adequately covered by research question as: *Could the information of volatility transmission between oil price and stock market as discovered here provide any useful means of hedging crude oil revenue?*, also, *could such information be applied in building an asset pricing model for oil revenue?*

Also, Wei and Zhang (2010) found evidence of cointegration between crude oil and gold market which suggested the two commodities prices move together and have long term equilibrium. This level of information suggests that the gold market may provide an alternative hedging potential for crude oil revenue. Therefore, looking beyond the stock markets, investing in other government stocks, holding foreign reserve accounts, etc gold reserve could potentially provide an alternative for countries looking to invest their oil proceeds. One reason for looking towards gold reserves is the ability of its spot prices to remain more stable over time as compared with stock market indices and crude oil spots prices. That is to say even in a period of rise or fall in price, gold could rather have a steady and far more predictable price change than oil. Hence, one such research avenue in this direction could be to understand whether investing in gold spots may be able to provide an alternative to for crude oil proceeds.

## 2.5 Influence of Crude Oil Revenues on Global Investment Market

Although crude oil revenue tends to dwindle during economic downturn owing to slowing down of economic activities, which amounts to a fall in the commodity demand, recent developments in the world of investment have seen sovereign wealth funds (SWFs) rising to prominence. Up to 60% of the global SWFs source is from crude oil proceeds (SWFI, 2012b) and the funds are increasingly playing a prominent role in global investments circles. Even though the development of SWFs as funds could date back to the nineteenth century as Dewenter et al. (2010) reported, the concept still remains new in academic circle. The majority of available literature is still limited to a descriptive approach. Thus, there is an apparent lack of in empirical models and research dealing with sound issues of interest to the SWFs. This gap in academic literature could be due to the majority of the funds being new, highlighting the problem of data availability.

Also, transparency in terms of fund structure and performance is still missing (Caner and Grennes, 2010). Therefore, there is a tendency to subjective intuitions largely coming from practitioner rather than academic evidence, nonetheless, some academic evidence still exists. Some of these studies adopt an empirical testing approach using both complete and extrapolated data (Gintschel and Scherer, 2008; Caner and Grennes, 2010; Gasparro and Pagano, 2010). Criticisms about the rise of sovereign wealth funds (SWFs) highlight their lack of transparency, accountability, potential political inclination, state capitalism, risk of equity price bubble, potential increase of volatility in financial markets, and concentration of investments on risky assets (Datz, 2009; Monk, 2009). Although there is not a great deal of published work in this area, some authors have partly examined the problems (Gintschel and Scherer, 2008; Caner and Grennes, 2010; Dewenter et al., 2010; Gasparro and Pagano, 2010).

Gasparro and Pagano (2010) estimated the impact of news related to SWFs investments on large financial institutions. The attempt yielded a result that helps to explain how news relating to the 2007-2009 financial crises impacted on SWFs investments in the US, Europe and Canada. This direction is particularly interesting given that news also helps to heighten the issue of crude oil price volatility, a commodity which, as seen, constitutes up to 60% of the global SWFs holding. In a recent similar effort, Dewenter et al. (2010) using data for stock prices relating to SWFs purchases and sales in US and non US firms, investigated the impact such transactions could have on firm values. Using event study, the research found that announcements of SWFs stock transactions coincide with significant events in the targeted firm.

Gintschel and Scherer (2008) made use of crude oil reserves as part of a portfolio in providing a framework for SWFs optimal asset allocation. Also, attention was paid to hedging market risk. The model presented has its root in the *mean-variance* of portfolio theory (Markowitz, 1952) and was empirically tested with results suggesting risk coming from oil could considerably affect the risk of aggregate wealth and the efficient allocation of financial assets. This study could be criticised for its subjective approach in the use of oil reserves estimates as a component of the portfolio. It seems not to represent a realistic assumption, especially as monetary value was allocated to these reserves based on estimates. The proceeds of these reserves are all dependent on future events that could not be well determined, especially with the oil prices being highly volatile. Perhaps, introducing futures in determining the likely proceeds is a way forward, but this is not without changing the course of the study. Such an approach could work out the potential crude oil proceeds accruing to an oil producing country, information that could be useful in stabilising oil revenue proceeds.

In the light of the criticisms regarding the SWF’s lack of openness, the Norwegian SWF (the government pension fund of Norway) stands out as a model of transparency. This is due to the way it publishes its transactions, adopting global standards in reporting. This development earned the fund a rating of 10/10 in the Sovereign Wealth Institute’s SWF rating for transparency (SWFI, 2011). Also, the diversified nature of its investments portfolio has seen the fund recover faster from the negative downturn of the global financial crisis of 2007-2009. Caner and Grennes (2010) examined the performance of the Norwegian fund, analysing its effect on the world capital market and Norwegian investors. The study found that despite the fund’s investment return being higher than the stock market average, the portfolio risk was greater than the stock market risk. This outcome suggests that the country’s fund will also have other things to learn from an empirical point of view, for an improved process.

Despite more than 60% of global SWF composition being from crude oil, there is apparently a gap in terms of empirical studies dealing with financial market activities relating to SWF investments. This could be seen as highly detrimental to the development of the oil based SWF, its impact on the world financial markets and the potential for its risk assessment. The example of the recent global financial market crisis (2007/2008) emerged with various levels of difficulty especially to investment funds. The overnight loss of investment values became very clear even for the world’s big financial players. This period witnessed the demise of Lehman Brothers and others, with many others needing financial resuscitation. The case of CitiBank, in which Abu Dhabi Investment Authority invested $7.5 for nearly 5% of their equity, is only one of many. The resulting case of such SWFs losing money in such transactions was well published (Guardian, 2009; Telegraph, 2009). At least with the existing body of sound empirical literature in place, such loss of the SWFs could be averted. An extension of the empirical effort of Gasparro and Pagano (2010) examining the impact of news on SWF investments transactions could chart a way forward in this direction.

As seen above, the potential for making much empirical contribution in the SWF area is not helped by the lack of extensive data, thereby making the extension of even the few available empirical studies difficult. Perhaps, this is reason why the descriptive approach in the majority of papers in the area is more prevalent. Even in the case of the few existing empirical studies, it is always difficult to see where a meaningful contribution could come. For instance, in the attempt by Gintschel and Scherer (2008), in addition to making use of oil reserve estimates as a component of the portfolio, they implied SWF financial assets as a proxy of a normal investment portfolio. This is difficult to see through as it presents little distinction between SWF and conventional investment portfolios such as the unit trusts. Hence, only little empirical contribution could be achieved in the direction of SWF. At the very best, an implication for SWF and a potential for future empirical research in that direction could be achieved.

Part of this research’s empirical application could at least bring in implications for the SWF, especially with targeted applicable data being for a specific oil rich country. Largely this will aim for empirical contribution in the area of crude oil revenue stability, particularly of SWF nature. This could be welcome, especially with the present drive in SWF research focusing more on the issue of optimal investments of existing revenues, while paying little or no attention to a revenue source that is largely bedevilled by the menace of price volatility. Ostensibly, this is an area that is hitherto not covered in the specific manner being handled (at least not seen in any research so far). This could help to answer the immediate important question of how to guarantee a sustained income source for the SWF and, by extension, other related commodities with similar traits.

### 2.5.1 Nigerian Crude Oil Revenue Management

As the country of interest for this research, Nigeria according to the Energy Information Administration (EIA), is world number 7 exporter of crude oil, with approximately two million barrels of production/day (EIA, 2012). As the commodity provides the country with over 91% of its foreign reserve source, the Central Bank of Nigeria (CBN) pointed to volatility as the main challenge to managing the country's foreign reserve account (CBN, 2011b). Yet, the BL spots prices largely remain empirically untapped, especially with regard to understanding price movements in relation to any futures prices. Also, the BL as a grade of crude oil is still without its own futures market. Therefore, the country's failure to achieve optimal return on its crude oil proceeds and also the lack of guarantee of oil price is worthy of research.

According to records from the central bank of Nigeria, the country's gross reserve peaked at nearly \$65 billion in August 2008 and then lowered to just less \$37 billion during June 2010 (CBN, 2011a). Thus, as oil is the mainstay of the country's economy largely due to its accounting for almost all foreign exchange income, such a volatile pattern of revenue is unhealthy. While it could be deducted that the first referenced period (August 2008) coincided with the time when global crude oil prices were at their peak, the second period corresponded to the time of global economic meltdown. During the second period, the global crude oil prices fell sharply as demand dropped. This may be connected to the recession witnessed by the leading consumers of crude oil. This position may suggest that Nigeria's foreign reserve account responded to the decline in demand and fall in price by dropping. Given this potential scope for deduction, it should be noted here that there is not much empirical academic research in the area of Nigerian crude oil revenue behaviour to back any such claims.

Again, despite crude oil accounting for the largest proportion of Nigeria's revenue, empirical studies still do not identify meaningful impact of such income on the country's economy (Ayadi et al., 2000; Ayadi, 2005). Also, in their classification of growth winners and losers of natural resource rich countries Mehlum et al. (2006b) classified Nigeria among the growth losers. This is because the country's economic growth over the years is not in conformity with her oil proceeds. This failure largely points to a lack of sound management of both the proceeds and the market process of the country's crude oil. Empirically, the country's top trading grade of crude oil, the Bonny Light (BL) spots largely remain unexamined within the academic literature. Having known that the West Texas Intermediate (WT) has similar characteristics with the BL and the WT has a functional futures market, a potential research direction could be if the WT futures might act as an appropriate hedge for the BL spot. The natural question that could be raised here is: *Is there any need for a BL futures market?* If yes, *at what point is the need tenable?*

As pointed out above, Ayadi et al. (2000) and Ayadi (2005) are among the few available empirical studies that examined the impacts of increased revenues from crude oil on the country's economy. Ayadi (2005) examined the impact of oil price changes and the results suggested no increase in Nigerian industrial production. Also, when Ayadi et al. (2000) investigated the Nigerian crude oil income, the results suggested that crude oil had an influence on the country's economy. However, since the commodity price is determined by other forces over which the country has no control, it makes it difficult for the Nigerian economy to maximise its oil's economic potential. However, while Ayadi et al. (2000) point to the inability of the country to dictate the price of the commodity as the cause of the problem of Nigeria's failure to reap the full benefits of its oil wealth, it may be suggested that it is largely to do with lack of a coherent management. A reference to the study by Mehlum et al.(2006a) could back this argument, as the study grouped Nigeria in the category of countries of growth losers, due to lack of growth consistent with oil income.

Again, as seen in section 2.5 above, other crude oil producing countries (for example Norway, UAE, Qatar, etc) are making the most from investing their crude oil revenues. Above all, we have seen that the  Central Bank of Nigeria (CBN) pointed to volatility as the main challenge of managing Nigeria's foreign reserve account (CBN, 2011b). The CBN source, also, pointed to a lack of training and awareness in managing the crude oil proceeds by their staff as another issue of concern. In this regard, van der Ploeg and Venables (2011) analysed three sets of decision points which, according to the study, capture, choices before a government faced with management decision of natural resource windfall. As the aim was to get an optimal decision point, which is country-specific, taking off from the arguments, one could infer two choices for an underdeveloped oil producing country like Nigeria. Specifically, the choices lie within the second decision point of van der Ploeg and Venables, which is to do with investments in foreign assets, which ultimately is for future consumption. This decision point categorically portrays the SWF approach.

The lack of empirical studies and also practical measures in managing the country's crude oil revenue further highlights how Nigeria remains vulnerable to the problem of crude oil price volatility. This situation directly exposes the country to revenue risk, particularly as the country earns more than 91% of its foreign income from crude oil. Being faced with these facts, one of the questions that readily come to mind is; *how can a country survive the likely consequences of such risk?* Also; *what are the likely mechanisms such a country could devise to mitigate this sort of risk*? Thus, the likely answer is, as volatility limits the ability of the crude oil producing countries (such as Nigeria) to plan based on expected revenue, the natural fallback could be to invest the excess from the revenue (at favourable times) in a well managed manner. This action could help to smooth the future income and expenditure in such a way that unplanned budgets deficits could be avoided[3], as such, making the most of a volatile situation. These sorts of answers will need to come from an empirical angle.

Nigeria's effort towards managing its excess crude oil proceeds is still at a very early stage. The country only recently established SWF (SWFI, 2012a) captioned, Nigeria Sovereign Investment Authority (NSIA). The fund is an offshoot of the previously existing Nigeria Excess Crude Oil Account (NECA), which comes from the difference between actual and budgeted amounts of crude oil revenue expectation (very favourable in recent years). This move was largely due to the increase in the crude oil revenue surplus rather than a proactive move in response to volatility as a problem or even the potential threat of likely revenue cuts posed by the global search for alternatives to oil. Thus, the drive to manage the inflow from surplus oil revenue alone would not sustain itself, as a potential drying up of such surplus would put the country back to its earlier position. Equally, without adequately taking care of overall volatility impact as a problem on its own, the drive for surplus revenue management would be incomplete. Hence, the need to build a coherent approach that could capture all the virtual threats to the stability of oil revenue should be captured.

[3] As we know budget deficits in other instance could be as a result of deliberate budgetary planning.

## 2.6 Other Commodities Influence and Potential Cross Impact

Ever since Pindyck and Rotemberg (1990) examined the co-movements among different commodities prices, evidence of co-movement among commodities prices has continued to surface (Lescaroux, 2009; Zhang and Wei, 2010). Lescaroux (2009) found evidence of high correlation among selected commodities prices also, Wei and Zhang (2010) encountered cointegration between the prices of gold and oil. It could be generalised from these evidences that commodity price behaviour tends to be similar, at least with regard to their price volatility pattern. Thus, this leads to the understanding that the behaviour of other commodities prices could be relevant in understanding the behaviour of crude oil price volatility. Essential to this research is that evidences from the highlighted preceding empirical studies could be extended into seeing potential for cross impacts.

A body of academic literature jointly examined commodities rich countries and economic growth (Deaton, 1999; Mehlum et al., 2006a, b; van der Ploeg and Venables, 2011). The conclusion from these studies is that, like crude oil, the majority of the commodities examined have failed to impact positively on the economies of their host countries. As seen in Mehlum et al. (2006b) a country like Sierra Leone considered rich in diamonds has failed to let that commodity benefit its economy; Nigeria, rich in oil, is seen to experience similar failure. The bottom line here is that the countries have failed to turn their commodities proceeds to the benefit of their economies. A good direction in this regard is an examination of Nigeria's crude oil price and its stock market activity, which could seek to explain if oil is having a positive impact on the stock market.

As pointed out above, Wei and Zhang (2010) examined price interdependence between oil and gold and concluded that the two commodities' prices are cointegrated. In essence, Chaudhuri (2001) has earlier demonstrated that prices of oil and other commodities have a long run relationship (cointegrated) as he argued that volatility in oil price affects other commodities. These sorts of findings lead to the inference that oil price may determine the prices of other commodities; essentially, with every major shock or change in the price of oil, other commodities will be affected. Also, another level of implication here, as pointed out earlier, is the possibility of using information from other commodities to hedge for oil price volatility. This is what Roache and Rossi

(2010) attempted, using gold as an investment alternative by analysing responses of other commodities prices, including oil. Thus a research question raised above is relevant here too; *could gold reserve serve as an alternative to equity markets?*

Essentially, as Lescaroux (2009) confirmed the existence of high correlation between commodities prices movements, including crude oil, it is important to think in terms of using other commodities prices behaviour in explaining oil price volatility. Since other commodities, too, could benefit from the price movements of oil, as pointed out by Chaudhuri (2001); the benefit of cross impact is highlighted. Therefore, one of the questions this research will aim to answer is if investing in gold spots may be able to offer an investment avenue for crude oil proceeds. Given this focus, expanding the investigations to include equity prices interdependence by including another primary commodity such as gold may provide further alternatives, hence, answering the question, *could gold reserve serve as an alternative to equity markets?* The essential element here is that of inferring alternative investment potential for oil revenue.

## 2.7 Specific Problems and Questions Arising

Despite increased numbers of studies aimed at understanding the impact of crude oil price volatility impact on the economies of both producing and exporting countries, other salient issues are still left uncovered. For instance, despite the highlighted significance of crude oil to Nigeria's foreign export earning, there is currently no empirical work that examines impacts of such price volatility on the country's foreign reserve account. Also, despite how exposed the country's revenue is to crude oil volatility, there is still no research that attempted to directly capture the impact of price shock to oil price volatility. This situation could help to stimulate questions as: *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?* These questions could be extended for crude oil revenue dependent countries and Nigeria in particular, as Jiménez-Rodríguez and Sánchez (2005) studied the case of Organisation for Economic Co-operation and Development (OECD) countries.

Given Nigeria's position is world number 7 exporter of crude oil, the country's management of the commodity's proceeds is seen as very poor. Also, with the commodity providing the country with over 91% of its foreign reserve source, the CBN pointed to oil price volatility as the main challenge of managing the country's foreign reserve. Again, with the country's BL spots prices largely remaining empirically unexamined, especially with regard to understanding price movements in relation to any futures prices, and the BL as a grade of crude oil still being without its own futures market, these raging issues could stimulate a set of researchable questions. For example *is the West Texas Intermediate (WT) futures price able to efficiently predict Bonny Light (BL) spots price?* Other secondary questions that will be looked into will be; *is there any need for a BL futures market?* Also, *at what point is the need tenable?* Answering these questions could provide a hedging tool for BL spot price and also help in the understanding of any need for setting up a BL futures market.

It is generally noted that the broad application of crude oil price interdependence with the global equity market index is not adequately covered within the existing body of literature. Also, not much focus has been directed on studying impacts of such interdependences with the stock market returns of crude oil revenue dependent economies. Again, expanding such investigations of crude oil impacts to simultaneously include another primary commodity such as gold together with the equity returns looking into investment alternatives has not been achieved in the past. Essentially, the general implication here for this research is that of understanding the wider economic impacts of crude oil price volatility. This is in the way it influence the broad economic indicators such as the stock market returns. Further dimension could include wider business activity measured by stock index. This could be as intermediated through the health of the banking sector, which provides a further means to address the dependence of the economy on oil. Thus, the essential element of studying risk and return, as largely linked to stock market activities could be relevantly extended to understanding the effect of oil price volatility on stock markets. Also, this may have implications to the perspective of investing proceeds of natural endowments into a fund in the future.

While other potential factors determining or contributing to the crude oil price volatility exist, as seen in the above review, this research will not focus so widely. This is because either doing so would raise another problem area or attempting to capture them as variables would be unachievable as no data exist in the area. Also, various studies in the direction of unearthing the existence, impact, effect and causes of crude oil volatility have already been conducted. Therefore, it is the intention of this research, as expressed in the title to deal with the issue of making the best out of crude oil revenue that is bedevilled by the problem of volatility. This has already been seen in the above literature review, which focused on the problems of; crude oil price volatility and its resulting revenue risk. Thus, in narrowing down to a specific problem area, the Nigerian oil export grade of BL spot was identified as the country's most traded crude oil grade, yet one that remains largely unexamined empirically. This is despite crude oil accounting for up to 91% of the country's foreign revenue and the CBN pointing the issue of volatility as the main challenge to managing the country's foreign reserve. Hence, in brief, this research's specific problem area revolves around the following issues;

- The dependence on oil and therefore the impact of volatility on oil dependent economies.
- The over reliance on crude oil for revenue by some producing countries such as Nigeria presents a revenue risk.
- There is a general lack of a sound crude oil revenue management policy for the commodity's export dependent countries.

Therefore, coming from the background of the reviewed literature and identifying the specific problem area as above naturally raises several questions, as summarised below;

1. *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?* Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect the government's financial position?*
2. *Are West Texas Intermediate (WT) futures prices an efficient predictor of Bonny Light (BL) spot price?* Other secondary questions considered are; *is there any need for a BL futures market? Also, at what point is the need tenable?*

3. *What is the nature of different crude oil revenue dependent economies' reaction to changes in the commodity price? Is there any volatility transmission between crude oil prices and global stock market returns? Could gold reserve serve as an alternative to the equity market?*

Thus, answering the above questions and other considerations are the objectives which this research hopes to accomplish.

## 2.8 Conclusion

In conclusion, this chapter reviewed literature relating to crude oil price volatility, revenue management and other extensions associated with the given research topic of this thesis. Specific links were made between relevant theories (such as the efficient market hypothesis) and situations relating to the research area. Also, crude oil revenue management approaches of different oil endowed countries were examined, all in an attempt to ensure relevance to the problem areas. Specific problems relating to impacts of crude oil price volatility, oil revenue management, oil price determination, oil revenue influence on global investments, etc, were identified. Thus, these problems lead to various researchable questions which could be empirically examined and from which specific questions are intended for analysis in this research.

Hence, through the reviewed literature, a mixture of past research interests, findings and inferences is able to generate several interesting areas requiring potential expansion. For instance, in reviewing the body of literature relating to the impact of oil price volatility, particularly on Nigeria, a question raised was; *what impact does crude oil price volatility have on the economies of the commodity's producers such as Nigeria?* Also, with Nigeria identified as being exposed to revenue risk, due to the country having about 91% of its foreign reserve from crude oil source, the questions that readily come to mind are; *how can a country survive the likely consequences of such risk*? Also, *what are the likely mechanisms that such a country will devise in mitigating such risk*? In a more broad form, given the research interest in the area of interdependences between oil and stock prices, the direction could raise such researchable questions as; *is there cross volatility transmission between oil prices and global stock market returns?*

Again, consideration was given to the price discovery mechanism for crude oil revenue dependent economies. This is based on the application of the futures market founded on the theoretical bases of the efficient market hypothesis, in which financial markets are assumed to be up to date with information. Typical of the raised questions which could lead to crude oil price discovery and revenue management are; *is the West Texas Intermediate (WT) futures price able to efficiently predict Bonny Light (BL) spots price?* Also; *is there any need for BL futures market?*

As the influence of crude oil revenue on the global investments market was reviewed, the Sovereign Wealth Funds (SWF) investment approach, given their sizes, was examined. One important discovery from the SWF literature for this research is that nearly 60% of global SWFs are crude oil and gas related (SWFI, 2012b). However, despite this finding the SWF concept still remains new in academic circles, with the majority of available literature still limited to a descriptive approach. This academic literature gap still exists despite the numerous researchable problems uncovered in the area. The exclusive criticisms about the SWF existence, including their lack of transparency, accountability, potential political inclination, state capitalism, risk of equity price bubble, potential to increase volatility of the financial markets, concentrating investments on risky assets and many more could provide a range of research questions. However, as the majority of the SWFs are new, the problem of data availability mean that not much is likely to be achievable in empirically filling the identified academic gap.

Therefore, having reviewed the literature relevant to this research's problem area and identifying specific problem channels, the next focus of this thesis is the methodology. As such the coming chapters of 3, 4, 5 and 6 will present the methodology section of this research. Within the section, chapter 3 will provide the theoretical models that will be used to tackle empirically the questions listed in section 2.6 above. Chapters 4, 5 and 6 will be devoted to empirically providing answers to each set of questions being asked. Thus, the next chapter will engage in the technical specifications of models as identified based on their relevance to answering the research questions in this thesis and also due to their past applications in related scenarios. The focus will be linking the selected models with the research questions which from the literature reviewed in this chapter.

# Chapter 3: Research Methodology

## 3.1 Introduction

The previous chapter focused on reviewing the literature relevant to this thesis topic, highlighting available theories and linkages to the main research problems and resulted in identifying the overall research questions this thesis seeks to answer. However, in academic analysis, the attempt to evaluate any chosen theory lies in matching it with adequate empirical models, whether as a unit or as a collection of different but coherent analyses. Empirical research may be undertaken through either qualitative or quantitative measures or using a combination of both approaches. However, in finance and economics, the generally accepted empirical approach is quantitative. Within the broad framework of the quantitative approach, the most suitable method for dealing with any empirical research problem will depend on various factors; Such as empirical theory, research questions, available data and model suitability.

In this chapter, the empirical models employed to answer the research questions as supported by different relevant theories are presented, paving the way for model specification in the empirical analysis chapters of 4, 5 and 6. Models were chosen either individually or jointly, in order to make each tool in the system of analysis complementary. Moreover, using different models in one analysis increase the robustness of the analysis and, hence the credibility of the findings. Thus, in the model descriptions and specifications, presented in the ensuing sections, related models are specified together, pointing their potential relevance in each case. The research questions identified in chapters 1 and 2 are repeated below, matching them with the relevant empirical models adopted.

1. *Does crude oil price volatility impact on Nigeria's GDP? Do oil market shocks alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility? Other secondary questions are; - if yes, how sensitive, in what pattern, over what period and how does it affect the government's financial position?*

2. *Are West Texas Intermediate (WT) futures prices an efficient predictor of the Bonny Light (BL) spot price?* Other secondary questions considered are; *is there any need for a BL futures market? Also, at what point is the need tenable?*
3. *What is the nature of different crude oil revenue dependent economies' reaction to changes in the commodity price? Is there any volatility transmission between crude oil prices and global stock market returns? Could gold reserve serve as an alternative to equity markets?*

In addition to this introduction, the chapter is organised in the following sections: research methodology, time series, model specifications, diagnostic tests, data adjustments and conclusion. Overall, the chapter presents the methodological insights pertinent to the empirical investigation reported in the subsequent three chapters 4, 5 and 6 of this thesis.

## 3.2 Time Series

Each of the research questions presented in the above section concerns the behaviour of a commodity, economy or share (indices) over time. For example the analysis of oil price volatility and its impact on the Nigerian economy requires an examination of the behaviour over time of these variables. This thesis therefore applies a set of time series analysis in order to address the research questions. Large amount of preceding empirical studies related to crude oil price volatility where time series models are employed exist (Chaudhuri, 2001; Fong and See, 2002; Yang et al., 2002; Agnolucci, 2009; Chen et al., 2009; Malik and Ewing, 2009).

A time series, formally might be described as a random variables $\{Y_t\}$ known as a stochastic process (Maddala and Kim, 1998: p. 8; Maddala, 2001: p. 514). Thus, the variable $Y_t$ represents time series in which $t = 1, 2, \ldots k$ with prior observations as $Y_{t-1}, Y_{t-2}, \ldots Y_{t-k}$. The prior time observations beginning from $t - 1$ are usually captured as the set of information set available at/up to $\Omega_{t-1}$ which could be used to predict current values of $Y_t$. The failure to predict $Y_t$ future value captures the stochastic behaviour of the time series process usually estimated through white noise captured as an error term $(\varepsilon_t)$. The stochastic process could be defined based on the first and second moments of the $Y_t$ variable in line with the linear regression model assumptions of the $\boldsymbol{\varepsilon_t}$ with:

1. Zero mean, $E(\varepsilon_t) = 0$ for all *t*.
2. Common variance, $\mathrm{var}(\varepsilon_t) = \sigma^2$.
3. Error independence, $\varepsilon_t$ and $\varepsilon_k$ are independent for all $t \neq k$
4. Independence of $x_j$, $\varepsilon_j$ and $x_j$ are independent for all *t* and *k*
5. Normally distributed error, $\varepsilon_t$ are normally distributed for all *t*

All assumptions are summarised as: $\varepsilon_t \sim N(0,\, \sigma^2)$

Therefore, the violation of any of the above assumptions will lead to an inefficient Ordinary Least Square (OLS) estimator. For instance, violation of independent errors in assumption (3) will bring about the problem of serial correlation or autocorrelation. This is a situation where errors are serially correlated, thus rendering variables as not independent. Errors are said to be serially correlated if; $\varepsilon_t$ is not independent of $\varepsilon_k$, in which case $E(\varepsilon_t, \varepsilon_k) \neq 0$, $t \neq k$. The general idea is presented given the common form of autoregressive AR(1) model represented as:

$$Y_t = \mathrm{X}_t\beta + \varepsilon_t \qquad (\mathbf{3.1})$$

$$\varepsilon_t = \rho\varepsilon_{t-1} + u_t$$

Where the error term $\varepsilon_t$ at time t is correlated with error terms $\varepsilon_{t+1}, \varepsilon_{t+2}, \ldots\ \varepsilon_{t+k}$ and $\varepsilon_{t-1}, \varepsilon_{t-2}$ , ... $\varepsilon_{t-k}$ . The correlation between $\varepsilon_t$ and $\varepsilon_{t-1}$ is the first-order serial correlation usually denoted as $\rho_1$ while the correlation between $\varepsilon_t$ and $\varepsilon_{t-2}$ is the second-order serial correlation denoted as $\rho_2$. The correlation between $\varepsilon_t$ and $\varepsilon_{t-k}$ is the serial correlation of order *k*. If the first and second moments of the $Y_t$ variables have mean $\mu(t) = E(Y_t)$ and variance $\sigma^2(t) = \mathrm{var}(Y_t)$, thus the mean and variance change with *t*, thereby making the process non-stationary, but it will become first difference stationary.

## 3.3 The Characteristics of Time Series

The empirical application chapters (4 – 6) of this thesis will require the use of time series techniques, some of which include the analysis of series which depend on their own past values'. One of such techniques is the use of autoregressive processes, which however should be noted as an inexhaustible description of the time series. The example of time series application could be in stock prices, commodities and GDP, as applied in preceding empirical studies (Banerjee and Marcellino, 2006; Marcellino et al., 2006).

### 3.3.1 AR, MA and ARMA Processes

The time series properties effective description and analysis is critical to the effective evaluation of interdependence between crude oil price and each of GDP, foreign account, gold prices, futures prices, and also, stock markets which this research's questions are trying to establish.

#### 3.3.1.1 Autoregressive (AR) Process

Again, $\{Y_t\}$ is a purely random process with $\varepsilon_t \sim N(0, \sigma^2)$, then an autoregressive (AR) process is defined by equation (3.2) below known as an autoregressive process of order r denoted by AR($r$).

$$Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \dots + \alpha_r Y_{t-r} + \varepsilon_t \qquad (\mathbf{3.2})$$

#### 3.3.1.2 Moving Average (MA) Process

Given a purely random process with $\varepsilon_t \sim N(0, \sigma^2)$, a moving average (MA) process $\{Y_t\}$ is defined by equation (3.3) below, known as a moving average process of order *m* denoted by MA($m$):

$$Y_t = \beta_0 \varepsilon_t + \beta_1 \varepsilon_{t-1} + \dots + \beta_m \varepsilon_{t-m} \qquad (\mathbf{3.3})$$

Therefore, if $\beta_0 = 0$ given the *OLS* assumptions for $\varepsilon_t$, hence $E(\varepsilon_t) = 0$

#### 3.3.1.3 Autoregressive Moving Average (ARMA) Process

Following equation (3.1) above, the simplest characterisation of an autoregressive process is given as:

$$Y_t = \beta_1 Y_{t-1} + \varepsilon_t \qquad (\mathbf{3.4})$$

$$\varepsilon_t \sim N(0,\ \sigma^2)$$

Useful in understanding non-stationarity, a description which follows the autoregressive moving average (ARMA) is a combination of the AR and MA models, which leads to a parsimonious higher order AR (*p*) or MA (*q*) process. The ARMA (*p*, *q*) model is defined as:

$$Y_t = \alpha_1 Y_{t-1} + \ldots + \alpha_p Y_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \ldots + \beta_q \varepsilon_{t-q} \qquad (\mathbf{3.5})$$

Where $\{\ \varepsilon_t\}$ is a purely random process with $\varepsilon_i \sim N(0,\ \sigma^2)$.

#### 3.3.1.4 Random Walk Process

A random walk process $\{Y_t\}$ is captured given the model:

$$Y_t = Y_{t-1} + \varepsilon_t, \qquad \varepsilon_i \sim N(0,\ \sigma^2) \qquad (\mathbf{3.6})$$

If $Y_0 = 0$ then $Y_1 = \varepsilon_1$ and $Y_2 = Y_1 + \varepsilon_2 = \varepsilon_1 + \varepsilon_2$

Hence,

$$\sum_{t=1}^{T} \varepsilon_t$$

Hence, $\mu(t) = E(Y_t)$ and $\sigma^2(t) = \text{var}(Y_t)$, thus the process is nonstationary as mean and variance change with $t$, but becomes first difference stationary. The random walk process is often used to capture movements in stock prices.

## 3.4 Unit roots

Time series data will be applied in this research and the use of such data for estimation has its' associated issues of spurious or non-stationarity, thus, testing for data stability will be adopted. The unit root process is usually applied in identifying spurious data series for which different testing approaches are available. Spurious regression in the presence of non-stationary data means that one might inappropriately draw conclusion that two time series are related when this is not the case (Granger and Newbold, 1974; Phillips, 1986; Ferson et al., 2003). It is important therefore to test for the presence of a unit root in the time series to ensure that they are not spurious. In the above random walk process section, it was assumed that $\mu(t) = E(Y_t)$ and $\sigma^2(t) = \text{var}(Y_t)$, but the process becomes nonstationary as mean and variance change with $t$. This leads to $\varepsilon_t$ becoming covariance nonstationary, thereby raising the problem which is commonly referred to in time series literature as the unit root problem. Therefore, given the random walk equation in (3.6), $Y_t$ is integrated of order 1 usually represented as $I(1)$, taking the difference of $Y_t$ in (3.6) will lead to a stationary series integrated of order 0 given as $I(0)$ with $\mu$ being introduced as constant or a drift.

Thus, a time series:

$$Y_t = \mu + \rho Y_{t-1} + \varepsilon_t \qquad \varepsilon_i \sim N(0, \sigma^2) \qquad (\mathbf{3.7})$$

### 3.4. 1 Unit root Tests

The Dickey-Fuller test allows one to draw conclusion on $\rho < 1$. Subtracting $Y_{t-1}$ from both sides of equation (3.7) above, the Dickey-Fuller test:

$$\Delta Y_t = (\rho - 1)Y_{t-1} + \varepsilon_t \qquad (\mathbf{3.8})$$

$$= \gamma Y_{t-1} + \varepsilon_t$$

The test assumes a null hypothesis that the series $Y_t$ has a unit root, against the alternative of no unit root in series $Y_t$. Failure to reject $H_0 : \gamma = 0$, implies there is a unit root and rejection of $H_0$ in favour of $H_1 : \gamma < 0$, implies there is no unit root.

As described in the above section, a series is non-stationary when it is integrated of order 1 represented as $I(1)$ and stationary when integrated of order 0 represented as $I(0)$. Examining for the stationarity or otherwise of time series data is known as the unit root testing process, for which different approaches are in existence, including Dickey-Fuller (DF), Augumented Dickey-Fuller (ADF), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS), Ng and Perron (NP) and Phillips-Perron (PP). The Dickey-Fuller test (Dickey and Fuller, 1979, 1981) based on independent and identically distributed errors is the earliest form of unit roots test that was widely applied in empirical work. The test was later generalised to the ADF test using the Autoregressive-Moving average (ARMA) model in Said and Dickey (1984), making it a parametric approach. The Phillips-Perron test (Phillips and Perron, 1988), provides an alternative nonparametric approach, which is nearly as widely used as the ADF test.

Therefore, as different unit root tests exist, they all try to address specific problem which has not been dealt with by other test. For instance, the ADF test adopts the parametric approach which allows for lag selection, whereas the PP uses the nonparametric approach which takes care of the disadvantages noted with the ADF test. Thus, the parametric approach of ADF requires the selection level of autocorrelation which includes a lag specification of the form:

$$\sum_{i=1}^{p} \Delta Y_{t-i}$$

The choice of $p$ is important as it ensure that there is no residual autocorrelation in the test. However, it comes with a disadvantage of increasing the size of test statistic, which reduces the ADF ability to detect data stationarity. The nonparametric approach of PP takes care of such disadvantage since it does not require level selection of serial correlation, although it depends on asymptotic theory and prefer large sample data series.

Thus, the best approach is to adopt one test while using the other as a confirmatory measure. Therefore, in the empirical application of this thesis, the ADF test will be adopted for the unit roots testing, while for robustness, the PP test will also be applied in selected instances as a confirmatory test. This is given that the ADF test remains the most widely accepted and used form of unit root test, with early empirical applications (Dickey et al., 1986; MacKinnon, 1994; Kwon and Shin, 1999). Also, DeJong et al. (1992) described the process as the most robust procedure for identifying autoregressive errors, which makes it more reliable.

Therefore, with equations (3.7) and (3.8) given as the simple case of residual, a more generalised case of serial correlation as presented by Said and Dickey (1984) becomes the ADF model specification as:

$$\Delta Y_t = \mu + \gamma Y_{t-1} + \sum_{i=1}^{p} \phi_i \Delta Y_{t-i} + \varepsilon_t \qquad \mathbf{(3.9)}$$

Where: $Y_t =$ Log of the variable in time period $t$; $t$ = Time trend, $\Delta Y_{t-1} = Y_{t-1} - Y_{t-2}$; $\varepsilon_t =$ Error term with mean = 0 and variance $\sigma^2, i.e., [\varepsilon_t \sim NI\ (0, \sigma^2)]$. Like the DF test, the ADF test assumes a null hypothesis of a unit root in the $Y_t$ series, against the alternative of no unit root in the $Y_t$ series. Therefore, $H_0 : \gamma = 0$, which implies there is unit root and $H_1 : \gamma < 0$, implying there is no unit root.

## 3.5 Granger Causality

As understanding the direction of crude oil prices' behaviour is important for their eventual proceeds, studying such pattern becomes significant for this research, which is interested in whether crude oil futures prices could explain spot prices and also whether the spot price could impact on the commodity producing economies. Granger (1969) will serve as a complementary econometrics tool in estimating such relationships. The model uses Vector Autoregression (VAR) specification in examining the relationship between variables. This approach has been widely tested empirically (Quan, 1992; Jiménez-Rodríguez and Sánchez, 2005; Rafiq et al., 2009).

A very important point in understanding price discovery (one of the intended empirical investigations in this thesis) is to know whether changes in one variable might be said to affect or cause subsequent changes in another and if so how strong this effect is? In order to strengthen potential prediction/s, one needs to be sure of the direction of variable causation. Therefore, for examining the impact of oil shock Granger causality tests may be used. This is seen in the study of Rafiq et al. (2009) who applied both Granger causality and associated generalised impulse response functions to investigate the impact of crude oil volatility on the Thai economy.

The Granger causality model specification is:

$$Y_t = \sum_{i=1}^{n} \alpha_i M_{t-i} + \sum_{j-1}^{m} \beta_j Y_{t-j} + u_{1,t} \qquad (\mathbf{3.10})$$

$H_0 : \alpha_i = 0$ and $H_1 :$ at least one $\alpha_i \neq 0$ . If reject $H_0$ : conclude that $M_t$ Granger causes $Y_t$.

## 3.6 Vector Autoregression

The vector autoregression (VAR) model is an important time series model that could be useful in this research's estimation processes through its associated models of impulse response functions and variance decompositions. The impact of one time series variable on another could be examined using the two processes, for instance crude oil price shocks against gross domestic product (GDP). Therefore, the VAR will be applied in estimating the interactions between multiple time series variables eminent in this thesis. The necessity of determining the impact of one time series variable with another could be examined using the VAR process, for instance crude oil price shocks against the Nigerian foreign account.

Sims (1980) suggested the VAR approach as a solution to dealing with what he termed as '*scepticism*' in earlier simultaneous equation models dealing with multiple time series, for instance, given the need to make arbitrary decisions as constraints imposition on parameter to attain identification. Sims effort is a response to the issues surrounding the study of more than one time series in a dynamic condition, that is carried out using simultaneous equation modelling. The approach considers the endogenous variables in a lagged system assuming that both variables paths may affect each other. Considering the first order (with one lag in each variable) VAR model below:

$$Y_t = \alpha_{11}Y_{t-1} + \alpha_{12}X_{t-1} + \varepsilon_{1t} \qquad (\mathbf{3.11}\boldsymbol{a})$$

$$X_t = \alpha_{21}Y_{t-1} + \alpha_{22}X_{t-1} + \varepsilon_{2t} \qquad (\mathbf{3.11}\boldsymbol{b})$$

Where the path of $Y_t$ is affected by lagged effects of $X_t$ measured by $\alpha_{12}$ and by its own past values measured by $\alpha_{11}$. Also, the path of $X_t$ is affected by lagged effects of $Y_t$ measured by $\alpha_{21}$ and its own past values measured by $\alpha_{22.}$ The lag coefficients ($\alpha_{11}, \alpha_{12}, \alpha_{21}$ and $\alpha_{22}$) measuring the series' lagged effects are in the same condition as the matrix **A** provided in the appendices section.

### 3.6.1 Impulse Response Functions

As capturing the impact of crude oil prices shocks on the economic variables of oil export dependent countries is crucial to this research, the empirical application of impulse response functions (IRF) will be adopted. Preceding sections explained how one might test for whether there is a statistically significant effect of one variable on another. However, remaining are the questions of; how large such effects are and how quickly they act? This is clearly important and examined by introducing a hypothetical one $k.\delta$ shock to an error $\varepsilon_t$. This is through changes in $\varepsilon_{1t}$ and $\varepsilon_{2t}$ and are referred to as Impulse Response Functions (IRF). The process could be understood through the AR($r$) model defined in equation (3.2), thus the IRF (Sims, 1980) is given as:

$$IRF(k,\delta) = \mathrm{E}[Y_{t+k}|\varepsilon_t = \delta, \varepsilon_{t+1} = \cdots = \varepsilon_{t+k} = 0] - \mathrm{E}[Y_{t+k}|\varepsilon_t = 0, \varepsilon t+1=\ldots=\varepsilon t+k=0 \qquad (\mathbf{3.12})$$

The model measures the effect of shock $\delta$ occurred at time $t$ with the intermediate shocks periods at $t-1, \ldots t-k=0$. Equation (3.12) is usually independent of intermediate shocks $\varepsilon_{t+1}, \ldots, \varepsilon_{t+k}$ and of prior time observations $\Omega_{t-1}$, until the shock of interest occurs.

Lütkepohl (2006) has pointed that the results of the IRF may differ due to the ordering of the associated VAR variables. However, the Generalised Impulse Response Function (GIRF) provides a means of dealing with IRF in nonlinear models (Koop et al., 1996; Pesaran and Shin, 1998). Therefore, the GIRF present a better approach of dealing with the problems identified with the traditional IRF. The GIRF model is defined by introducing the prior time observations $\Omega_{t-1}$ given the shock $\varepsilon_t = \delta$ as;

$$GIRF_y(h, \delta, \Omega_{t-1}) = \mathrm{E}[Y_{t+k}|\varepsilon_t = \delta, \Omega_{t-1}] - \mathrm{E}[Y_{t+k}| \Omega_{t-1}] \qquad (\mathbf{3.13})$$

Where; $= 1, 2, \ldots$ Expectations of $Y_{t+k}$ are only conditioned on the history of the process $\Omega_{t-1}$.

### 3.6.2 Engle-Granger Two-step Method

As explained under the above unit root tests section, if series are *I(1)* then the possibility of a spurious regression exist. A test frequently used in the finance literature is the examination of cointegration for futures and spot prices as a means of evaluating the efficiency of futures markets. The approach could be adopted in this thesis's empirical analysis to examine whether West Texas Intermediate (WT) futures is efficient predictor of Bonny Light (BL) spot price. The Engle-Granger two-step procedure (Engle and Granger, 1987) is a widely accepted econometric technique in the study of linear relationships between variables, in both the short and the long run (Quan, 1992; Kwon and Shin, 1999; Chaudhuri, 2001; Yang et al., 2002). This is especially as the model applies OLS approach, thus making it easily applicable and understandable model. The econometric basis behind the procedure is presented first by considering a general linear regression equation of the form:

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad (\mathbf{3.14})$$

Let $Y_t \sim X_t$ both be $I(1)$

Regressing and estimating the error term $(\boldsymbol{\varepsilon_t})$ as;

$$\hat{\varepsilon}_t = Y_t - \hat{\alpha} + \hat{\beta} X_t \qquad (\mathbf{3.15})$$

$Y_t$ and $X_t$ are cointegrated if the estimated error is stationary $\hat{\varepsilon}_t \sim I(0)$

$$\hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \varepsilon_t \qquad (\mathbf{3.16})$$

Where $\rho$ is the correlation between error terms or residuals $(\varepsilon_t)$ which determines the stationarity of the series ($Y_t$ and$X_t$). Therefore, if $\rho < 1$, then the error $(\hat{\varepsilon}_t)$ is stationary and the series $Y_t$ and $X_t$are cointegrated, implying they have a long run relationship. Reflecting the two-step procedure, step 1 is achieved when in equation (3.14) the cointegrating vector $\varepsilon_t$ is measured by taking residuals from the regression of $Y_t$ on $X_t$ as seen in equation (3.15). Regressing $\Delta Y_t$ on lagged $\Delta X_t$changes and on equilibrium error $(\hat{\varepsilon}_t)$ attaining step 2 will lead to the specification for error correction, leading to the Engle-Granger's Error Correction Model (ECM). This process captures how the adjustment back to the long-run equilibrium takes place.

In the process, Engle and Granger (1987) showed cointegration to imply the existence of an error correction model (ECM) of the form:

$$\Delta Y_t = \Theta + \gamma \Delta X_t + \lambda \varepsilon_{t-1} + u_t \qquad (\mathbf{3.17})$$

Where; $\Theta$ = constant, $\gamma$ = Coefficient of the independent variable

$\Delta Y_t$ and $\Delta X_t$= Changes in dependent and independent variables

$\varepsilon_{t-1}$ = Residual from the first step regression

$\lambda$ =Coeffient of the Residual, $u_t$ = Error in the ECM

Explicitly, the Engle-Granger's two-step method is in practice a four-step procedure that involves determining that all variables series are integrated of the same order, showing that series are cointegrated, attaining $\hat{\varepsilon}_t$ (estimated error in equation 3.15) and finally, entering the lagged residuals, resulting in a cointegrated time series with corrected error. This is as *Granger representation theorem* stipulates that when variables are cointegrated there is an error correction mechanism. Hence, incorporating short-run dynamics with long-run equilibrium is important for robust variables relationships. This therefore explains the process of adjustment back to the long-run equilibrium after the short-run process (cointegration).

### 3.6.3 Johansen Test and Vector Error Correction Model

If there are more than two variables within the proposed model as the case of the research questions in this thesis (looking at interdependence of more than two variables), the Engle-Granger model may not be the most appropriate applicable technique. This is because there are several potential cointegrating vectors where a model includes three or more variables. Such relationship is better estimated with the Johansen's vector error correction model (VECM) that is founded in Johansen (1988, 1991) and Johansen (1990). The application of this type of model is given with a typical VAR*(p)* model which represents a case of more than two exogenous variables as:

$$\boldsymbol{y_t = \delta + A_1 y_{t-1} + \cdots A_p y_{t-p} + u_t} \qquad (\mathbf{3.18})$$

Where; $y_t$ is a *k*-dimension vector of a nonstationary variable as $I(1)$, $\boldsymbol{A_i, i = 1, \dots \dots p}$ and is the coefficient matrix (matrices are defined in the appendices section), $u_t$ is a vector of residuals or innovations. Equation (3.18) could be rewritten by subtracting $\boldsymbol{y_{t-1}}$ from both sides of the equation;

$$\boldsymbol{\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t} \qquad \mathbf{(3.19)}$$

Where;

$$\boldsymbol{\Pi = \sum_{i=1}^{p} A_i - I} \quad \textbf{and} \quad \boldsymbol{\Gamma = \sum_{j=i+1}^{p} A_j}$$

Specifically the notation $\boldsymbol{\Gamma}$ represents a matrix for the short-run relationship, whereas $\boldsymbol{\Pi}$ captures a matrix for long-run relationships. In defining the $I(1)$ of cointegration Johansen (1995, p.70) stated that "*the* $I(1)$ *model* $H(r)$ *is defined as the submodel of the VAR we obtained under the reduced rank condition*" The reduced rank condition here reflects the hypothesis that Johansen presented even in his previously cited studies (as referenced above) in a canonical matrix form (explained in appendix section) as $\boldsymbol{\Pi = \alpha\beta'}$, where $\boldsymbol{\alpha}$ *and* $\boldsymbol{\beta}$ are $\boldsymbol{p * r}$ matrices. This reasoning equally follows *Granger Representation Theorem*. The $\boldsymbol{\alpha}$ *and* $\boldsymbol{\beta}$ are vectors which are *r* ranked in such a way that their combination becomes stationary. Ultimately $\boldsymbol{\alpha}$ is the vector of the adjustment coefficient, seen as the adjustment parameter in Johansen's procedure and $\boldsymbol{\beta}$ is the vector for the cointegrating parameter.

Effectively the above intuition results in the reduced form error correction model:

$$\boldsymbol{\Delta y_t = \delta + \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t} \qquad \mathbf{(3.20)}$$

Where, $\boldsymbol{\delta, \alpha, \beta, \Gamma_1, \ldots, \Gamma_{k-1}}$ are vectors of adjustment parameters and vary freely. Therefore, the VECM estimates the matrix $\boldsymbol{\Pi}$ from an unrestricted VAR and tests to see if the reduced rank restriction could be rejected. Thus, by implication $\boldsymbol{\beta'}$ captures a long-run solution, in which case the left hand side and the element of difference of $\boldsymbol{\Delta y_t}$ is $I(0)$. The last element is the linear combination of $I(1)$ variable and it must be stationary to balance the time series properties of right and left hand sides. This is as the variables' series deviation from the long-run equilibrium is gradually corrected by various partial short-run adjustments. Johansen considered the matrix $\boldsymbol{\Pi}$ in zero, reduced and full ranks, thus giving rise to five (5) models of deterministic trends.

I. $\boldsymbol{y_t}$ have no deterministic trends and the cointegrating vectors do not have intercepts; $\boldsymbol{\Pi y_{t-1} + Bx_t = \alpha\beta' y_{t-1}}$

II. $\boldsymbol{y_t}$ have no deterministic trends and the cointegrating vectors have intercepts; $\boldsymbol{\Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0)}$

III. $\boldsymbol{y_t}$ have deterministic trends and the cointegrating vectors have intercepts; $\boldsymbol{\Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0) + \alpha_1\gamma_0}$

IV. $\boldsymbol{y_t}$ have deterministic trends and in cointegrating vectors; $\boldsymbol{\Pi y_{t-1} + Bx_t} = \propto \boldsymbol{(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_1\gamma_0}$

V. $\boldsymbol{y_t}$ have quadratic trends and the cointegrating vectors have deterministic trends; $\boldsymbol{\Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_1(\gamma_0 + \gamma_1 t)}$

The assumptions of these models translate into specifications for cointegration hypotheses which are formulated and tested. The resulting tests are conducted using maximum eigenvalue and trace statistics with model specifications in equations (3.20a) and (3.21b) respectively:

$$\boldsymbol{\lambda_{\max} = -T\ln(1 - \hat{\lambda}_{r+1})} \qquad \boldsymbol{(3.21a)}$$

$$\boldsymbol{\lambda_{\text{trace}} = -T \sum_{i=r+1}^{k} \ln(1 - \hat{\lambda}_i)} \qquad \boldsymbol{(3.21b)}$$

Where T = number of observations, $\boldsymbol{\hat{\lambda}_r}$ = eigenvalue of matrix $\boldsymbol{\Pi}$ in the VECM equation. The matrices operations used in this section are explained under matrices roots, vectors and ranking in the appendices section.

## 3.7 Time-varying Volatility models

Part of the empirical process in this thesis is interested in the examination of volatility through an autoregressive component and also interdependence between the volatilities of different markets, thus making a multivariate ARCH as a suitable model of application. But, as the ARCH model alone is not sufficient to characterise the time series properties of volatility in commodity and equity markets intended for examination, the GARCH model approach common in preceding literature is considered. For instance, given that the Integrated Generalized Autoregressive Conditional Heteroskedasticity (Engle and Bollerslev, 1986), takes some of its motivation from asset pricing theory, it is a well considered model of application. Also, in pointing at the persistence of unit root in past volatility tests, Bollerslev and Engle (1993) suggested the IGARCH model as more accommodating. Tully and Lucey (2007) adopted the power GARCH model in investigating macroeconomic influences on gold, thus, making the model likely to answer the similar research question of this thesis that is interested in the interdependence between gold and oil spot prices.

Engle (1982) developed the Autoregressive Conditional Heteroskedasticity (ARCH) model, which lead to Engle (1983) argument against the OLS assumption of common variance $\sigma^2$ that assumed homoskedasticity. The model was developed based on time series $Y_t$ that is conditioned on AR*(1)*;

$$Y_t = \mathrm{E}[Y_t |\, \Omega_{t-1}] + \boldsymbol{\varepsilon_t} \qquad (\mathbf{3.22})$$

Where, $\Omega_{t-1}$ is the prior time observations dealing with information set in the immediate past $(t-1)$. By relaxing the homoskedasticity assumption, we have a conditional variance $\varepsilon_t$ that varies over time as; $\mathrm{E}[\sigma_t^2 |\, \Omega_{t-1}] = \boldsymbol{h_t}$.

$\boldsymbol{h_t} = \begin{bmatrix} h_{11t} & h_{12t} \\ h_{21t} & h_{22t} \end{bmatrix}$ are covariance matrix summarised as $\varepsilon_t \sim N(\mathbf{0}, \boldsymbol{h_t})$. Here $\boldsymbol{h_t}$ is a matrix representation of the variance and covariance.

$$\boldsymbol{y_t} = \boldsymbol{\varepsilon_t} \qquad (\mathbf{3.23})$$

Where; $\boldsymbol{y_t}$ = $[y_{1t} \quad y_{2t}]$ and is assumed to have a standard normal distribution, $\boldsymbol{\varepsilon_t}$ = $[\varepsilon_{1t} \quad \varepsilon_{2t}]$ and is conditional on history $\Omega_{t-1}$ is normal with zero mean and conditional variance.

Thus the ARCH (1) model could be specified as:

$$\boldsymbol{h_t} = \alpha + \alpha_1 \varepsilon_{t-1}^2 \qquad (\mathbf{3.24})$$

The conditional variance $\boldsymbol{h_t}$ has to be nonnegative as seen above and the parameters have to meet the conditions $\alpha > 0$ and $\alpha_1 \geq 0$ (see explanation under roots and vectors in appendix 1). Equation (3.24) could be rewritten based on the AR(1) model for $\sigma_t^2$, by adding $\sigma_t^2$ and subtracting $\boldsymbol{h_t}$ from both sides and arriving at:

$$\sigma_t^2 = \alpha + \alpha_1 \varepsilon_{t-1}^2 + u_t \qquad (\mathbf{3.25})$$

Following this development, there has been an increased attempts at modelling conditional mean and variance especially in financial time series (Fong and See, 2002; Yang et al., 2002; Agnolucci, 2009; Kang et al., 2009; Malik and Ewing, 2009).

### 3.7.1 GARCH Models

ARCH models were not always found to provide an adequate representation of the volatility in some series (Pagan and Schwert, 1990; Bauwens et al., 2006; Koopman et al., 2010). As with ARMA, it is possible to estimate a richer model of time-varying volatility. Bollerslev (1986) provided a generalisation of the ARCH model known as generalized autoregressive conditional heteroskedasticity (GARCH). The GARCH model allowed for more flexible lag structure capable of dealing with past conditional variances in the current condition, achieved by allowing the lagged conditional variance to enter into the ARCH model process. Following the above development of the ARCH model, the simple GARCH(1,1) model is specified given the following mean and variance equations:

$$y_t = \varepsilon_t, \qquad \varepsilon_t \sim N(0, \sigma_t^2) \tag{3.26}$$

$$\sigma_t^2 = \alpha + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{3.27}$$

Where equation (3.26) is the mean equation and (3.27) is the variance equation. $\sigma_t^2$ is the conditional variance, given that it is a one period forward forecast (based on past information). $\alpha$ = constant term. $\alpha_1$and $\beta_1$ = vectors of the given parameters. $\varepsilon_{t-1}^2$ = past volatility news or shock, captured as lag of squared residual from equation (3.27) and representing the ARCH term. $\sigma_{t-1}^2$= previous period forecast variance. The usual technical condition of the GARCH(1,1) model is for $\alpha_1 + \beta_1 < 1$. This follows a similar explanation of volatility persistence to that given under the above ARCH model. Later generations of ARCH models evolved in different forms, providing alternative ways of dealing with specific volatility problems. Many of these models bear relevance to estimating volatility issues associated with asset pricing situations and commodity price volatility (Engle and Bollerslev, 1986; Bollerslev and Engle, 1993).

### 3.7.2 Multivariate GARCH Model

In many empirical settings it may be unclear whether the volatility in a series is entirely dependent on its own past values or might be affected by that in another series. This has been examined in a number of settings by Malik and Ewing (2009), Arouri et al. (2012) and Moskowitz et al. (2012). The approach to this question, which is also reflected in research question 3 in the above introduction section, is to estimate an MGARCH. This requires the simultaneous estimation of both the underlying model and volatility components for each of the dependent variables. Therefore, given the problems this research is aiming to address that relates to volatility transmissions and multiple financial markets, the MGARCH model will be a suitable choice, this is in line with the justification in Wang (2009: p.66).

Presentation of a multivariate GARCH model here follows equation (3.23) above, where $\boldsymbol{y_t}$ is assumed to have a standard normal distribution, $\boldsymbol{\varepsilon_t}$ is normal with zero mean and conditional variance $\boldsymbol{h_t}$ summarised as $\varepsilon_t \sim N(\mathbf{0}, \boldsymbol{h_t})$. Thus, the conditional variance $\sigma_t^2$ is substituted here with a multivariate $\boldsymbol{h_t}$.

$$z_t = \varepsilon_t, \qquad \varepsilon_t \sim N(\mathbf{0},\, \boldsymbol{h_t}) \qquad (\mathbf{3.28})$$

$\boldsymbol{z_t}$ = $[\boldsymbol{y_{1t}} \quad \boldsymbol{y_{2t}}]$, $\boldsymbol{\varepsilon_t}$ = $[\boldsymbol{\varepsilon_{1t}} \quad \boldsymbol{\varepsilon_{2t}}]$ and $\boldsymbol{h_t}$= $\begin{bmatrix} h_{11t} & h_{12t} \\ h_{21t} & h_{22t} \end{bmatrix}$ are covariance matrix. The $\boldsymbol{h_t}$ is in matrix condition, with all other parameters as explained in the above section. Application of MGARCH will normally require a parameterisation process which works to restrict $\boldsymbol{h_t}$ to be positive and definite for all values of $\varepsilon_{\boldsymbol{t}}$.

Given that the empirical processes want to see the volatility through an autoregressive component and also examine the interdependence between volatilities of different markets, a multivariate ARCH will be a suitable model. But, since the ARCH model alone is not sufficient to characterise the time series properties of volatility in commodity and equity markets, MGARCH model. Different Multivariate GARCH (MGARCH) models are used in covariance specification among which are; constant conditional correlation (CCC), full parameterisation (VECH), positive definite parameterisation (BEKK), power GARCH, with all being widely applied empirically. As pointed in the introduction section of this chapter, MGARCH models suffer problem of large parameter estimation which tend to be intractable. However, the form of parameter restriction available to the BEKK model as first proposed by Engle and Kroner (1995) is more commonly applied. This is for variety of reasons, the most common being the model's ability to built sufficient generality, it requires fewer parameters and also able to remain positive definite under weak conditions, this enables the model to meet the restriction condition of the parameterisation, where $p = q = 1$. The BEKK specification following Engle and Kroner (1995) is given as:

$$\boldsymbol{H_t} = \boldsymbol{B_0'} \boldsymbol{B_0} + \boldsymbol{B_i'} \boldsymbol{\varepsilon_{t-i}} \boldsymbol{\varepsilon_{t-i}'} \boldsymbol{B_i} + \boldsymbol{C_j'}\, \boldsymbol{H_j'} \boldsymbol{C_j} \qquad (\mathbf{3.29})$$

Where; $\boldsymbol{B_0}$ = $n \ x \ n$ symmetric parameter matrix. $\boldsymbol{B_i}$ and $\boldsymbol{C_j}$ = $n \ x \ n$ unrestricted parameter matrices. To avoid the complications associated with large model parameterisation, the BEKK in the bivariate case is empirically implemented given the diagonal representation as below:

$$\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}} \tag{3.30a}$$

$$\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-i}\varepsilon_{2,t-i} + \beta_{22}h_{12,t-1}} \tag{3.30b}$$

$$\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}} \tag{3.30c}$$

Where; $\boldsymbol{h_{11,t}}$and $\boldsymbol{h_{22,t}}$ = variance equations. $\boldsymbol{h_{12,t}}$ = covariance equation.

## 3. 9 Conclusion

This chapter has described and specified the empirical models to be applied in the next three chapters (4, 5 and 6) of this thesis. The models are identified base on their relevance to answering the research questions in this thesis and also due to their previous applications in related studies. Quantitative methods are deemed suitable here, with time series econometrics identified as the primary procedure for application in the overall empirical analysis of the thesis. This is because the overall set of research questions are built around crude oil price volatility for which time series data will naturally be suitable.

The time series models are specified and presented based on their potential relevance to answering this research's questions. Attempt at linking the different models with relevant empirical chapters will be carried out in the next chapters, according to the research questions addressed in each. For instance, the VAR processes of impulse response functions and variance decomposition analysis will be adopted in answering the set of questions in chapter 4. Cointegration and ECMs will be applied in answering the questions in chapter 5. The Multivariate GARCH Model of diagonal BEKK is applicable in chapter 6. Therefore, as the technical aspects of methodological applications in this research are presented and discussed in this chapter, the focus will now turn to their practical application in the following three chapters of 4, 5 and 6.

# Chapter 4: Price Volatility Impact on Oil Export Dependent Economies

## 4.1 Introduction

Volatility is a common issue with crude oil price as Pindyck (2001) emphasised. Thus, it is essential in dealing with the volatility problem to understand its impact. This is particularly as revenues from the commodity continue to play vital role on the economic stability of the producing countries. For example, according to information from the Central Bank of Nigeria, the country has up to 91% of its foreign reserve account proceeds coming from crude oil (CBN, 2011b). Crude oil therefore, constitutes the largest proportion of the country's total revenue. This makes the issue of crude oil price volatility a threatening circumstance, as it tends to make it difficult for the country to establish a stable revenue regime.

Based on figures from the Energy Information Administration (EIA, 2010b), the Nigerian 'Bonny Light' (BL) sold for $146.15/barrel in July 2008, whereas in December 1998 the same commodity was $9.45/barrel. Oil price volatility of this form is a big problem for oil producing governments' revenue earning, culminating in difficulty in both budgetary and economic planning. Rafiq et al. (2009) analysed the impact of crude oil price volatility on the economy of Thailand and found evidence of impact on the budgets. While the sources of the volatility could be numerous, a large aspect of it is linked to economic shocks or sudden changes in the global economic environment. An increasing number of empirical studies are geared toward understanding crude oil price shock's impact on the economies of both producers and exporters. Jiménez-Rodríguez and Sánchez (2005) found oil price increase to cause larger GDP growth impact in most of the OECD countries studied for oil price volatility impact. Specific to Nigeria, Ayadi (2005) examined whether an increase in oil price leads to an increase in industrial production in the country, results suggested no increase in Nigerian industrial production.

However, despite the highlighted significance of crude oil to Nigeria's foreign export earnings, there is currently no empirical work that examines impacts of price volatility on the country's foreign reserve account. Also, despite the exposure of the country's revenue to crude oil volatility, there is still no research that attempted to directly capture the impact of price shocks oil price volatility. This situation has largely motivated the main research questions in this chapter: *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?* Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect the government's financial position?* In answering these questions, vector autoregression (VAR) is the key empirical model applied, given its associated impulse response functions and variance decompositions analysis. This is as the VAR mainly considers the development and interdependence in multiple time-series, examining exogenous responses. Other essential preliminary investigative tests such as unit roots, Granger causality and Wald are carried out in order to confirm stationarity, understand applied variables' causal effects and also, to determine the variables exogeneity and endogeneity. In addition to these, the diagnostics experiments of lag selection test, LM test, etc, are applied to ensure that the model is fit to answer the questions being asked.

The datasets applied in the analysis are from Bonny Light spots, its standard deviations, Nigerian foreign reserve account, Nigeria's gross domestic product, Nigeria's currency/US dollars exchange rate, Nigeria's inflation rate and US treasury rates. All the data are in quarterly frequencies and are for the period from 1983 quarter 1 to 2010 quarter 4, in order to reflect different points in time characterised by crude oil market shocks. The ultimate data analysis is applied in tranches' of short, medium and long terms, in order to understand the different period's impacts of these applied variables. Whilst the research questions and the applied data reflect Nigeria's position, the approach in this chapter's analysis is framed in such a way that the attainable outcomes are expandable, since good research should be both replicable and expandable. Achieving this objective is simplified by the fact that the crude oil spots prices are generally similar, as was highlighted in the previous chapter, where different selected crude oil spots prices were found to move closely.

In addition to this introduction, the remainder parts of the chapter is organised in main sections which will contain a discussion of the global impacts of crude oil price shocks in relation to Nigeria, applied data, empirical applications, empirical analysis, interpretations of findings and conclusion. The findings of the chapter generate a series of implications and useful contributions that form the basis for the next empirical steps, in chapter 5 and for the empirical development of the thesis as a whole.

## 4.2 Global Impact of Crude Oil Price Shocks

A major crude oil market shock commonly referred to in both academic literature and the press is the one in 1973, which resulted from the Organisation of Petroleum Exporting Countries' (OPEC) oil embargo (Smith, 2009). However, the general problems of oil price volatility resulting from such shocks are extensively researched and severally tested empirically. The vast majority of such tests are specific to the impact of such shocks on different economic aspects, such as; GDP, exchange rates, stock market performance, reaction of other commodities' prices, etc. Chaudhuri (2001), Jiménez-Rodríguez and Sánchez (2005) and Kilian and Park (2009) are among few instances of the studies. Above all, the consequences of oil price and its volatility for economic performance and foreign earnings for the commodity's exporting countries such as Nigeria is particularly relevant to this chapter, as the direct implications of shocks on the export earning capacity of countries dependent on the commodity's exports are largely ignored in the available studies, while the problems examined in recent empirical studies also present interesting extension potential.

The literature review in chapter 2 attempted a clear distinction between the two related issues of crude oil price shocks and crude oil price volatility. Hamilton (2003) sees oil price shocks as being more associated with price increase than decrease, given the tendency of price increases to create more distortionary effects within the economy than decreases in price.  Thus, while shocks are seen as an event or combination of events, price volatility could be a consequence of the shocks or other issues, as seen in chapters 1 and 2. Price booms and slumps also are used to characterise prices shocks in commodities markets, since other commodities, like crude oil, are also exposed to such tendencies of sudden and uncontrolled price movement which characterises volatility.

Several empirical studies have looked at the issue of crude oil price shocks in relation to their impact on the economies of both producers and consumers of the commodity. Many of these efforts tend to focus more on the resulting impacts of such shocks on macroeconomic variables; see, for example; Hamilton (1983), Ferderer (1996), Ayadi (2005) and Jiménez-Rodríguez and Sánchez (2005), Berument et al. (2010).

An increasing volume of academic literature suggests that crude oil price shocks systematically affect the economic wellbeing of both producing and consuming countries. Jiménez-Rodríguez and Sánchez (2005) examined the impact of crude oil shocks on the GDP growth of industrialised countries. The countries include net crude oil exporters such as Norway, a country which the study's result suggests benefits from a situation of crude oil price increase. Again the question; *impact of crude oil price shocks on economic growth* was a prominent driver in Berument et al. (2010). The research examined how some Middle East and North African crude oil producing countries' output growth is affected by shocks. The findings here are mixed as some of the countries exhibited significant results while for others the results were insignificant. Earlier, certain empirical efforts attempted to understand the pattern of the oil price shocks by investigating the directional impacts. Lee et al. (1995) and Hamilton (1996) concentrated in finding out what happens when there is a positive or negative crude oil price shock. This chapter's secondary research questions will address something similar to these notions, by analysing the data in tranches of short, medium and long term coverage, although the chapter's main research questions focus on the generic impacts of crude oil shocks as specific to Nigeria's economic condition.

### 4.2.1 Crude Oil Price Shocks in relation to the Nigerian Economy

The Central Bank of Nigeria (CBN) has pointed at the need to safeguard Nigeria's local currency value as among the reasons for holding a foreign reserve account (CBN, 2011b), as this is a very important aspect of ensuring a stable currency regime. Also, the outflows of the foreign reserve account are mainly for foreign currency intervention, which sees the CBN selling foreign exchange to individuals and other economic agents requiring them for importation of goods and services. This position is well supported by the International Monetary Fund (IMF) which points out that the use of foreign reserve account is more inclined to domestic purposes (IMF, 1993). The same IMF and CBN sources also highlighted the importance of the foreign account for the international trading position, as it plays a role in stabilising balance of payments, international investment, policy adjustments, etc. Given the importance of these issues to foreign revenue, a country relying for up to 91% of its foreign income on crude oil should pay attention to examining the impact of the commodity's price volatility on its foreign account.

In order to fully answer the research questions set out in this chapter, this section will seek to understand the perspective of crude oil as discussed in academic literature, with specific reference to Nigeria's situation. As has been pointed out in the above section, the Nigerian situation is only used here as a basis for understanding a particular scenario, it is hoped can be extended to other similar countries. With 91% of foreign exchange income coming from crude oil, Nigeria is undoubtedly exposed to the risk of volatility in the commodity's price. Therefore, crude oil market shocks are expected to have consequences on the country's foreign revenue. This could be seen statistically as Nigeria's gross reserve peaked at near $65 billion in August 2008 and then fell to about $38 billion during June 2010 (CBN, 2011a). The first period coincided with the time when global crude oil prices were at their peak, the second matched up with the time of global economic meltdown. During the second period, global crude oil prices fell sharply as demand dropped, which may be connected to the recession witnessed by the leading consumers of crude oil. This position may suggest that Nigeria's foreign reserve account responded to the decline in demand and fall in price by dropping, even though the account is used for other withdrawals. This could be typical given the level of significance crude oil has as the main source of the country's foreign reserve account. Figure 4.1 below is a pictorial representation of the situation.

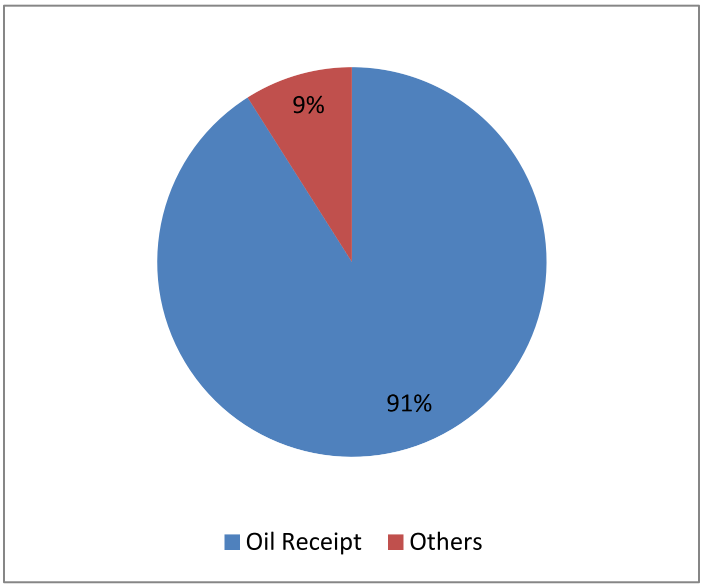



**Figure 4.1: Source of Nigeria's External Reserve**[4]

The above situation makes Nigeria vulnerable to changes in the crude oil market. Theoretically, one might expect that a crude oil price shock resulting in upward movement in the commodity price will be good for the country as it will earn more money from its principal export. However, empirical evidence from Ayadi (2005) suggests otherwise, as the findings reveal that the country's macroeconomic variable of industrial production does not do well in the face of crude oil price increase. Also, the present reality of Nigeria having to import refined crude oil products for its domestic need exposes the country to foreign exchange loss. This situation causes the country to suffer each time there is a crude oil price increase resulting from market shocks. This is in addition to revenue loss each time there is a fall in the commodity price, as is expected of a country that is almost wholly dependent on the proceeds of oil sales.

In particular, Ayadi (2005) has confirmed that changes in oil price affect industrial production in Nigeria. Ayadi's study was focused on crude oil price volatility and the performance of the Nigerian economy, which in a sense is partly similar to the questions being answered in this chapter. Essentially, the oil price data used in the study is from

[4] Figure was reproduced based on original from the Central Bank of Nigeria website (CBN, 2011b)

the Bonny Light (BL) spot. However, despite the investigations in both Ayadi and other cited studies as above, a wide gap still exists, in the area of determining the impact crude oil price shocks and volatility could have on the foreign revenue profile of a crude oil exports dependent economy such as Nigeria. Despite the importance of the foreign account to Nigeria, its response to crude oil price shocks has still not been empirically examined in the context of preceding academic literature. Hence, the approach in Jiménez-Rodríguez and Sánchez could be applied in the case of Nigeria to study a similar case of a large crude oil exporting country with a developing status. A broader picture is aimed at, given the potential for generalization to other countries with similar traits.

### 4.2.2 Research Questions Arising

Sections 4.2 and 4.2.1 identified gaps which largely motivated the research questions in this chapter as:

- *Does crude oil price volatility impact on Nigeria's GDP?*
- *Does oil market shock alter the commodity's price volatility for Nigeria?*
- *Is Nigeria's foreign reserve account sensitive to crude oil price volatility? If yes; how sensitive, in what pattern, over what period and how does it affect the government's financial position?*

### 4.2.3 Hypotheses

In order to obtain answers to the above research questions, hypotheses ***H4A, H4B*** and ***H4C*** as specified below will provide the required medium. In conformity with normal practice, $\boldsymbol{H_0}$ is the null and $\boldsymbol{H_1}$ being the alternative;

Hypothesis ***H4A***-

$\boldsymbol{H_0}$: *Crude oil price volatility has no impact on Nigeria's GDP.*

$\boldsymbol{H_1}$: Crude *oil price volatility has impact on Nigeria's GDP.*

The highlight of ***H4A*** is the null hypothesis of crude oil price volatility having no impact on Nigeria's GDP ***against*** the alternative having impact. If the null hypothesis is rejected, it will imply that crude oil price volatility or change will have impact on Nigeria's *GDP*.

Hypothesis ***H4B***-

$H_0$: *Oil market shocks do not increase oil price volatility for Nigeria*

$H_1$: *Oil market shocks increases oil price volatility for Nigeria*

The highlight of ***H4B*** is that the null hypothesis of oil market shocks does not increase the Nigerian crude oil price (BL) volatility, *against* the alternative of increasing BL spot prices volatility. The rejection of the null will imply that Nigerian crude oil spots prices are affected by crude oil a market shock.

Hypothesis ***H4C***-

$H_0$: *Nigeria's foreign reserve account is not sensitive to oil price volatility*.

$H_1$: *Nigeria's foreign reserve account is sensitive to oil price volatility*.

The highlight of ***H4C*** is to measure a null hypothesis that Nigerian foreign reserve account is not sensitive to changes in crude oil prices *against* the alternative that the account is sensitive to changes in crude oil price. Rejection of the null will imply that the Nigerian foreign reserve account is sensitive to changes in crude oil price.

## 4.3 Empirical Application

In answering this chapter's research questions, the principal model of application is the vector autoregression (VAR) specified in chapter 3. The model's associated applications of impulse response and variance decomposition analysis will also be used. Although Kilian (2009) was critical of such approach for lack of defined direction, the approach still remains widely applied and is consistent with preceding studies that examined interdependences between oil price changes and macroeconomic variables (Ayadi, 2005; Jiménez-Rodríguez and Sánchez, 2005; Rafiq et al., 2009).

### 4.3.1 Vector Autoregression Applied in Preceding Research

The vector autoregression (VAR) is the chosen model of application and is essentially chosen base on its ability to easily and simultaneously study multiple time series variables. As this chapter is attempting to determine concurrently the actions of seven time series variables of $\boldsymbol{BLA_t}$, $\boldsymbol{BLS_t}$, $\boldsymbol{FRA_t}$ $\boldsymbol{GDP_t}$, $\boldsymbol{NDE_t}$, $\boldsymbol{USI_t}$ and $\boldsymbol{NIR_t}$, the VAR is the most suitable model for this purpose. Although this could also be achieved by estimating a simultaneous equations model, such models are rejected because of the criticisms in  Sims (1980), such as the tedious procedures of having to classify the variables into endogenous and exogenous, imposing constraints, etc. With the VAR model variables does not have to be differently identified as endogenous and exogenous. Again, the fact that the VAR model does not have to use any theoretical assumptions makes it an attractive tool of operation and convenient means of estimation. For these reasons the model relatively simple to implement, although it could be criticise for not being easily interpreted. The application of the VAR model here could also be justified on the basis of being applied in virtually all the cited empirical reference so far. Therefore, as this research attempts to replicate and retest some previous studies VAR is the right model.

The associated VAR model of impulse response analysis is being adopted for its ability to present both graphical and numeric positions of variables' reaction to each other at all times, which is suitable to the task of understanding the behaviour of BLS, FRA GDP, NDE, USI and NIR variables in response to changes in the crude oil spot price as represented by the BLA variable. Hence, in answering the research questions in this chapter, especially in dealing with the part measuring the sensitivity of economic variables to oil prices shocks, the empirical application of impulse response functions is targeted. Also, the VAR application of variance decomposition analysis is crucially applied in the direction of capturing the proportion of each variable's contribution to test forecast error, as the process provides information on the basis founded from the VAR estimates.

### 4.3.2 Vector Autoregression

As vector autoregression (VAR) is applied in estimating the necessary equations for determining interactions between the variables of interest, a brief description of the model and its specification following chapter 3 is given here. The VAR mainly considers the development and interdependence in multiple time-series, examining exogenous responses, considering that exogenous and endogenous variables cannot be isolated. Thus, the path of variable $Y_t$ is affected by another variable $X_t$ and the path of $X_t$ is affected by another variable$Y_t$. Also, its application is a necessary step towards the realisation of impulse responses of the variables, which will be useful in describing the reaction of the Nigerian GDP and foreign account to crude oil price shocks. Thus, as we consider the relationship between crude oil price shocks and the Nigerian foreign account balances, we see the two time series as $Y_t$ and $X_t$ respectively. As the VAR model considers endogenous variables in a lagged system assuming that both variables paths affect each other.

Given that there are more than two variables within the proposed model as the case of the research questions in this chapter that are looking at interdependence of more than two variables. Such relationship is better estimated with the model given in a typical VAR*(p)* process which represents a case of more than two exogenous variables as:

$$\boldsymbol{y_t = \delta + A_1 y_{t-1} + \cdots A_p y_{t-p} + u_t} \qquad (\mathbf{4.1})$$

Where; $\boldsymbol{y_t}$ is a *k*-dimension vector of a nonstationary variable as $I(1)$, $\boldsymbol{A_i, i = 1, \ldots \ldots p}$ and is the coefficient matrix (matrices are defined in the appendices section), $u_t$ is a vector of residuals or innovations.

### 4.3.3 Impulse Response Functions

As capturing the impact of crude oil prices shocks on Nigerian foreign revenue is crucial to this research, the empirical application of impulse response functions (IRF) is applied here. Given that Lütkepohl (2006) has pointed that the results of the traditional IRF may differ due to lag ordering of the associated VAR variables. It has already been discussed in chapter 3 that the Generalised Impulse Response Function (GIRF) provides a means of dealing with IRF in nonlinear models (Koop et al., 1996; Pesaran and Shin, 1998). Therefore, the GIRF present a better approach of dealing with the problems identified with the traditional IRF. The GIRF model is defined by introducing the prior time observations $\Omega_{t-1}$ given the shock $\varepsilon_t = \delta$ as;

$$GIRF_y(h, \delta, \Omega_{t-1}) = \mathrm{E}[Y_{t+k} | \varepsilon_t = \delta, \Omega_{t-1}] - \mathrm{E}[Y_{t+k} | \Omega_{t-1}] \qquad \textbf{(4.2)}$$

Where; $= 1, 2, \ldots$ Expectations of $Y_{t+k}$ are only conditioned on the history of the process $\Omega_{t-1}$.

## 4.4 Data

This section explains the data employed in application of the above models. The process is built on preceding empirical research, while paying attention to the much needed adjustments required to answer this chapter's specific questions. Therefore, for early guidance, the data used in this chapter's analysis are: Bonny Light Spot Price (BLA), Bonny Light Standard Deviation (BLS), Nigeria's Foreign Account (FRA), Nigeria's Gross Domestic Product (GDP), Nigeria's Inflation Rate (NIR), Naira/US Dollars Exchange rate (NDE) and US Treasury Rate (USI). A summary of these variables are provided in section 4.4.2 below, with their normal, log and log difference representations.

### 4.4.1 Preceding Research Data

A common feature found in the body of preceding empirical research investigating the impact of crude oil price shocks is the use of a broad spectrum of macroeconomic variables (Ayadi, 2005; Jiménez-Rodríguez and Sánchez, 2005). These variables, in addition to the oil price, are those determining economic performance, such as GDP, government expenditure, inflation, real exchange rate, net export, unemployment, money supply, etc. Some of the variables used are not mentioned here as they were used differently by the authors. The usual justifications given for inclusion of this long list of variables is the common knowledge that VAR's forecasting power is better exploited with many variables included.

Therefore, this chapter attempts to put in place a VAR model following a similar pattern to the above cited references, particularly Jiménez-Rodríguez and Sánchez (2005), given its closeness to the analysis performed here. However, some variations are appropriate here, given some adjustments to the process. For instance, one of the variables used Jiménez-Rodríguez and Sánchez is the wage rate. However, given that the Nigerian economy is a developing one and still relying on government expenditure, with little industrial input, it is not possible to produce a wage rate variable. Again, in this chapter's analysis, standard deviation of the BL spots (BLS) is introduced, in order to capture the potential impact of crude oil price movements on its own volatility measure. Also, the BL spots are applied in moving average form, given the prominence of price volatility with crude oil, especially as the variables frequencies are quarterly. Thus, having the crude oil spots variable applied in moving average could help to smooth the usually unpredictable pricing pattern of the commodity. This approach is unprecedented in the cited preceding references, despite most of them using quarterly observations. Equally, as pointed out in section 4.2, the important variable of FRA is captured, a step not seen in any of the preceding research.

As noticed, Jiménez-Rodríguez and Sánchez followed a mixed approach of converting some of the used variables to log, while some are left in level terms. This approach also will be adopted here, on the basis that some of the variables do not appear to be near to normal distribution for example BLA, FRA and GDP appear to increase and decrease randomly, so having them in log form could have them fairly normalised. However, variables as USI, NIR, BLS and NDE are already expressed in percentages and appear to be somewhat stable; thus, they could be estimated without being transformed to log. Hence, BLA, FRA and GDP are transformed into log form, while the remaining variables, USI, NIR, BLS and NDE, are left in log normal levels. This is consistent with Jiménez-Rodríguez and Sánchez's treatment of similar variables.

Therefore, as pointed out in the above discussion, each included variable has a given justification. Essentially, GDP, FRA and BLS are included as they constitute the main variables whose reactions to oil price changes as captured by BLA interest the researcher. Other variables; NDE, USI and NIR are typically included based on their importance in determining the performance of the oil dependent Nigerian economy. For instance, NDE is included as the exchange rate for the Nigerian currency (Naira) and US dollar (USD), since the BL is sold in USD, the FRA is kept in USD and also, all official foreign exchange activities in Nigeria are transacted in the USD. Also, USI is captured on the bases of its determining the return to the FRA and all other investments activities related to the USD holding of Nigeria. The NIR variable is included as the historical inflation rates in Nigeria are deemed an important component in determining real versus nominal growth of the economy. Thus, the inclusion of the second set of variables is a mechanism for investigating which of them may be affected by oil price shocks and thereby has economic policy effects.

### 4.4.2 Applied Data

Given that crude oil as a commodity is always in the news with the spots prices regularly changing, often on a daily basis and with a very big price swing, and as oil market prices are very volatile, analysing the spots at long interval such as quarterly, without adjustments, may be misleading. Thus, the data applied in this empirical chapter are based on moving averages, to help bridge the eminent volatility especially in BL spots. Technically, the proposed generalised impulse responses from Pesaran and Shin (1998), employed for the empirical analysis is founded on the basis of moving averages. Also, the concern to analyse impacts of oil price shocks from the perspectives of both BL spots and its standard deviation could help in attaining a more robust outcome. The graph in figure 4.2 displays joint movements of BLA and BLS, from which we can see the BLS as the measure of volatility seems to be more stable than the BLA. Essentially, the $\boldsymbol{BLS_t}$ variable is targeted in the analysis to capture the crude oil price volatility, whereas the $\boldsymbol{LBLA_t}$ variable as a proxy of crude oil price is aimed at capturing crude oil price shocks.

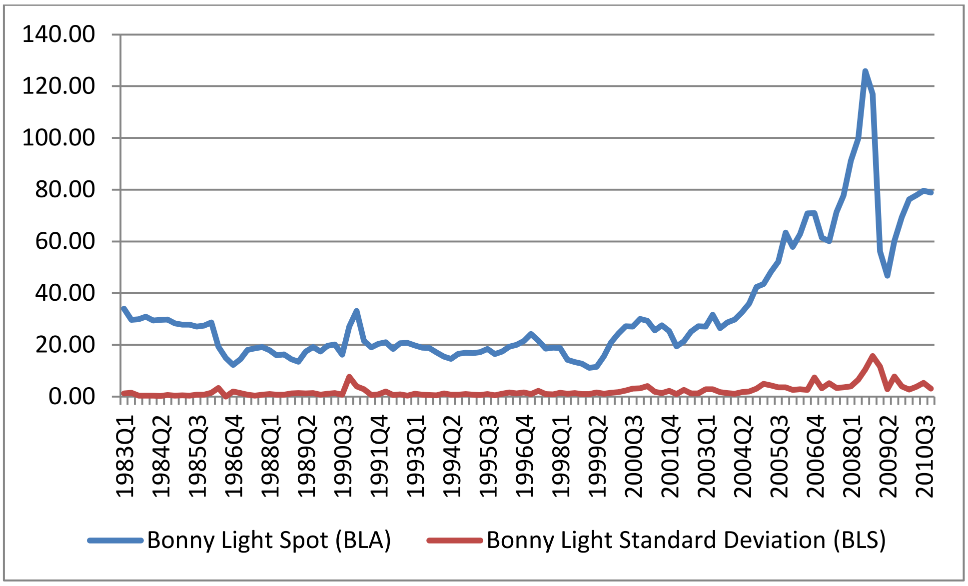



**Figure 4.2: Movements of Bonny Light Spot and Standard Deviation**

As seen in table 4.1 below, this chapter applies datasets from Bonny Light spots (BLA), their standard deviations (BLS), Nigerian foreign account (FRA), Nigerian gross domestic product (GDP), Nigeria's currency (Naira)/US dollars exchange rate (NDE), Nigerian inflation rate (NIR) and US treasury rates (USI). The BL spot is considered in moving averages and standard deviation; they represent the crude oil price and a measure of volatility. All the data are in quarterly frequencies and are for the periods from 1983 quarter 1 to 2010 quarter 4 whose coverage is intended to reflect points in time that characterise crude oil market shocks, which result in price volatility. The data for BLA, BLS, and USI are all sourced from the Thomson Reuters Datastream (TRD) and originally extracted in quarterly frequencies from this source. It is worth noting that data from the TRD originate from other adopted sources. Data for FRA, GDP, NIR and NDE were taken from CBN's statistical bulletin (CBN, 2010). Data for GDP is in quarterly frequency, while FRA, NIR and NDE are all in monthly frequencies and converted into quarterly moving averages, in conformity with other applied variables.

**Table 4.1: Applied variables and their representations**

| Variables | Representation | | | Source |
|---|---|---|---|---|
| | Normal | Log level | Log Diff | |
| Bonny Light Spot Price (moving average) | $BLA$ | $LBLA_t$ | $\Delta LBLA_t$ | TRD |
| Bonny Light Spots Prices Standard Deviation | $BLS$ | $LBLS_t$ | $\Delta LBLS_t$ | TRD |
| Nigeria's Foreign Accounts Balances | $FRA$ | $LFRA_t$ | $\Delta LFRA_t$ | CBN |
| Nigeria's Gross Domestic Product | $GDP$ | $LGDP_t$ | $\Delta LGDP_t$ | CBN |
| Nigeria's Inflation Rates | $NIR$ | $LNIR_t$ | $\Delta LNIR_t$ | CBN |
| Naira/US Dollars Exchange rate | $NDE$ | $LNDE_t$ | $\Delta LNDE_t$ | CBN |
| US Treasury Rate | $USI$ | $LUSI_t$ | $\Delta LUSI_t$ | TRD |

*TRD = Thomson Routers Datastream, CBN = Central Bank of Nigeria.*

The BLA captures Nigeria's crude oil prices, whereas the BLS is its standard deviation and a measure of BL spots price risk. FRA reflects Nigeria's exports earnings account, which contains the country's total exports proceeds, of which 91% are from crude oil sales. Hence, it can be assumed that the commodity's income will have a strong impact on the Nigerian foreign account. GDP is provided on current basis and is intended to capture the productive capacity of the Nigerian economy. Together the four variables of BLA, BLS, FRA and GDP are captured given that they are directly linked with the research questions being asked. The variables of NDE and NIR as expressed in percentage are included as representations of other important aspects of the economy which could be affected by changes in oil prices. The US treasury rates are adopted here since the FRA is held in US dollars, vast majority of which are invested in other governments bonds. Finally, since the chosen empirical method of VAR could easily handle many variables, capturing as much as seven different variables can only help to bolster the analytical outcome.

### 4.4.3 Assumptions and Data Adjustments

This section presents the assumptions made and extrapolations carried out in getting the applied datasets to the desired level for the analysis. Also, some important hints regarding the data are reflected here in order to facilitate a general understanding of how some decisions were reached. The fact that 91% of Nigeria export revenues is from crude oil has already been highlighted. All proceeds from the country's foreign exports earnings are kept in the foreign reserve account (FRA). Given this position, it is easy to assume that the Nigerian foreign reserve account is largely populated with her crude oil revenues. Given its mandate in the country's constitution, the Central Bank of Nigeria (CBN) manages and operates the account on behalf of the government. Therefore, FRA outflows are only due to foreign currency intervention by the CBN, which are foreign exchange sales to individuals and other agents of the economy that require them for economic reasons (importation of goods and services). Thus, while the FRA experiences withdrawals at the end of every month, it only reflects the account's outflows due to foreign currency intervention by the CBN. This may be considered as negligible and ignored for the purpose of this analysis. Although, Nigeria mainly exports two different grades of crude oil known as Bonny Light and Forcados, this chapter's analysis will only focus on Bonny Light (BL), since the BL is of a higher grade and enjoys more patronage than the Forcados, while the price difference between the two is not too great. Hence, the BLA spot adequately captures the crude oil prices from which the Nigerian FRA gets 91% of its income.

Given the above insights, the below assumptions are made regarding data application;

- BL spots are able to represent the crude oil prices.
- BL spots proceeds are able to capture the foreign income earnings of Nigeria.
- Outflow due to foreign exchange sales in the economy is considered to be negligible and is seen as constant in the analysis.

The following adjustments were carried out;

- The BL spots were extracted based on quarterly frequency on the basis of moving average
- BLS is the standard deviation of BLA.
- The FRA was originally provided for in monthly frequency and was adjusted into quarterly moving average format.

- The GDP, denominated in local currency, was converted to US dollars based on the NDE, which as stated above comes from the CBN. The NDE are in monthly format and were converted to quarterly moving average.
- BLA, FRA and GDP were adjusted and estimated in log levels, whereas the remaining variables of BLS, NDE, USI and NIR were estimated in normal levels.

### 4.4.4 Descriptive statistics

This section presents a summary of the data series descriptive statistics as done on the basis of simple correlation matrix and graphical analysis. While the analysis is not expected to provide definitive empirical outcomes, it could offer some insights about relationships among individual, joint and collective variables, of providing a useful preliminary understanding, required for better empirical analysis. Table 4.2 below, therefore, presents the variable correlation matrix required for the initial analysis. From the table, we can see that the correlation between the $\boldsymbol{LBLA_t}$ and $\boldsymbol{BLS_t}$ variables is relatively high at 0.6904. Given that the *BLS* is a measure of *BLA* volatility, this suggests a strong positive relationship between oil price and volatility; thus, the higher the oil price ($\boldsymbol{LBLA_t}$) the higher price volatility ($\boldsymbol{BLS_t}$), the relationship is marked by a positive correlation, depicting that one variable increases with increase in the other.

**Table 4.2: Variables Correlation Matrix**

| | $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
|---|---|---|---|---|---|---|---|
| $LBLA_t$ | 1.0000 | | | | | | |
| $LFRA_t$ | 0.6202* | 1.0000 | | | | | |
| $LGDP_t$ | 0.7229* | 0.4701 | 1.0000 | | | | |
| $NDE_t$ | 0.7152* | 0.7936* | 0.5363* | 1.0000 | | | |
| $NIR_t$ | -0.3815 | -0.3340 | -0.2443 | -0.3878 | 1.0000 | | |
| $USI_t$ | -0.4130 | -0.7187* | -0.3671 | -0.7588* | 0.1832 | 1.0000 | |
| $BLS_t$ | 0.6904* | 0.6157* | 0.4845 | 0.5297* | -0.3322 | -0.4101 | 1.0000 |

**indicates statistical significance*

Also, the relationship between $\boldsymbol{LBLA_t}$ and $\boldsymbol{LFRA_t}$ is significant and positive at 0.6202. This result suggests that the higher the price of crude oil, the higher will be the $\boldsymbol{LFRA_t}$. Thus, by implication the Nigerian foreign account will naturally grow during positive oil shocks. As better stated, with all things being constant, any increase in the global market's crude oil prices, here represented by $\boldsymbol{LBLA_t}$ will naturally increase the $\boldsymbol{LFRA_t}$ and vice versa. This outcome is able to highlight how the BL spot is a price taker, therefore, highlighting that the spot price is decided by outcomes in the global crude oil market, rather than dictated by Nigeria. Given this indication, including the GDP and BLS in the analysis, aiming at their responses to oil price shocks, will help to increase the robustness of the process.

The $\boldsymbol{LFRA_t}$ and $\boldsymbol{LGDP_t}$ variables have an insignificant correlation of 0.4701. This implies the Nigerian foreign account position and the country's productive capacity are not linked to each other. Again, the correlation between $\boldsymbol{LGDP_t}$ and $\boldsymbol{LBLA_t}$ variable is also positive and significant at 0.7229. This position implies that when the oil price is high, the country's production level is increased. In the case of $\boldsymbol{NIR_t}$, the results exhibit negative insignificant correlations with all other variables, except for the $\boldsymbol{USI_t}$ which was positive but insignificant (0.1832). These results suggest no link, as not much information could be readily deduced from the relationships. The $\boldsymbol{USI_t}$ variable also has a negatively insignificant correlation with $\boldsymbol{LBLA_t}$, $\boldsymbol{BLS_t}$ and $\boldsymbol{LGDP_t}$, a significant but negative correlation with $\boldsymbol{LFRA_t}$ and a negative significant correlation with $\boldsymbol{NDE_t}$. The remaining relationships between $\boldsymbol{NDE_t}$ and other variables are all significant. As this analysis is inconclusive, a more detailed examination will be carried out in the section below, where the applied variables will be examined for unit root.

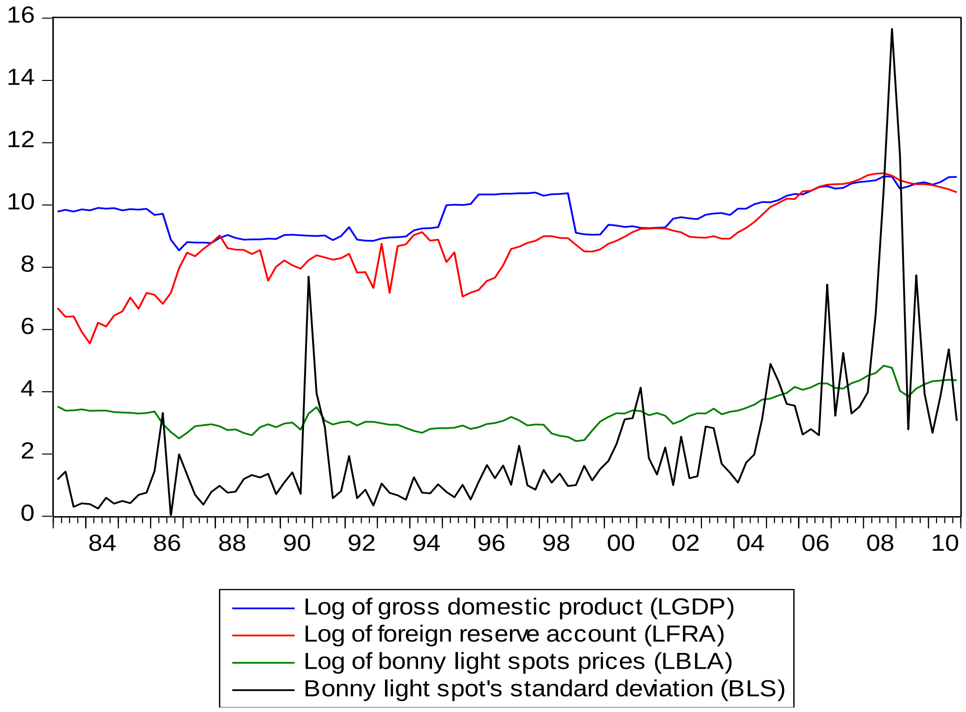



**Figure 4. 3: Movements among variables**

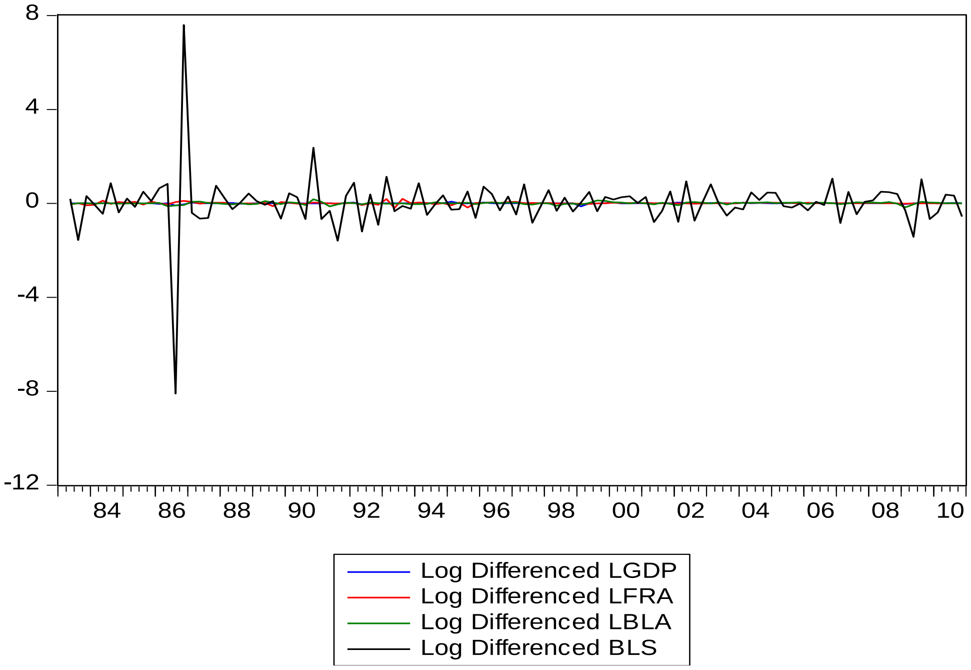



**Figure 4.4: Movements of variables at log difference level**

Figures 4.3 and 4.4 above present the graphical features of the applied variables' joint movements. In figure 4.3, we can see that the four variables ($\boldsymbol{BLA_t}$, $\boldsymbol{BLS_t}$, $\boldsymbol{FRA_t}$ and $\boldsymbol{GDP_t}$) exhibit a similar unstable movement pattern, typical of in log normal level. Thus, being irregular may present a problem of non-stationarity associated with unit root. In contrast, in figure 4.4 the variables display different movement patterns; now at log difference level, they all present a stable data series.

## 4.5 Empirical Analysis and Results

As reflected in the above introduction section, this chapter is interested in answering the questions: *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?* Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect government financial position?* This section will, therefore, present an empirical attempt to answering these questions. In order to attain this objective, the three hypotheses of ***H4A***, ***H4B*** and ***H4C*** as specified in the empirical section will be tested. Again, as pointed out in the same section, vector autoregression (VAR) is the key empirical model of application in this chapter. Also, VAR's associated models of impulse response functions and variance decomposition analysis are examined in order to provide interpretations of the impact of crude oil price shocks on Nigeria's major economic and associated variables of BLS, FRA GDP, NDE, USI and NIR.

Preliminary analyses were carried out and results presented, to guide the main empirical investigation. As part of these preliminary tests, unit root tests conducted to determine if the variables are free from the problems leading to spurious regression. Also, lag selection tests were carried out in determining that only the optimal lag/s are selected, as VAR analysis relies on optimal lag selection for better results. Granger causality tests also is conducted in order to understand which of the variables, GDP, FRA, NDE, USI and NIR, are either affected or caused by the BL spot prices captured here as $\boldsymbol{BLA_t}$ and its volatility represented as $\boldsymbol{BLS_t}$. Hence, the remaining parts of this section will present the empirical analysis results and findings.

### 4.5.1 Augmented Dickey-Fuller Test

The Augmented Dickey-Fuller (ADF) unit root test was carried out here to check the datasets for stationarity, and avoid the danger of spurious regression. Table 4.3 below presents the outcome of the individual variables unit root tests at both normal and log difference levels. In the table, we see the summary of unit root results at level (intercept and trend), in which case all the variables return evidence of unit root existence except for $\boldsymbol{BLS_t}$, which was stable. These results were judged based on the standard decision rule in statistics: *ADF statistics > critical values, we do not reject the null hypothesis of unit root, thus, implying that unit root exists*. Also, when *ADF statistics < critical values, we reject the null hypothesis*, consequently, implying that unit root does not exist. The tests were based on the given null hypotheses assumption of the series with unit root, as against the alternative.

ADF testing of all the variables presented in Table 4.3 clearly depicts that unit root exists at 1% and 5% levels of significance, with the exception of $\boldsymbol{BLS_t}$, which was seen to be stable given an ADF *t-statistic* of -5.5404, which is lower than both the critical values of -4.0428 and -3.4508, at the 1% and 5% level of significance. Also, $\boldsymbol{NIR_t}$ has an ADF *t-statistic* of -3.8858, which is lower than the 5% critical value of -3.4511, this makes it stationary at the 5% level of significance. The $\boldsymbol{BLS_t}$ result could be said to be expected, given that it is the standard deviation variable, which measures the variability of the *BL* spot price that is essentially intended as the $\boldsymbol{BLA_t}$ series smoothening variable. Even thought the $\boldsymbol{USI_t}$ ADF test results in the first half of the table appearing as unstable, US interest rates in a developed economy are expected to be stationary. Thus, the results may be taken at first value, meaning that further investigation could reveal other evidences. Overall, the results are seen as reliable given the *p*-values of just 5% or less in all instances, except in the case of $\boldsymbol{GDP_t}$ which returned 9%.

The second half (right hand side) of Table 4.3 represents a summary of unit root results at log difference (intercept and trend). In all the instances but for $\boldsymbol{BLS_t}$ which was not tested, the ADF statistics are less than the critical values, due to all the series being taken to log difference level. This implies the unit roots test in both instances gave rise to stable data series, with all *p*-values being 0.0000. However, the $\boldsymbol{FRA_t}$ variable is still not stationary at 1% level of significance with *t*- statistic value of -4.0444. All the ADF unit root results were corroborated by undertaking the Phillip-Perron (PP) version of the test both at normal and log levels. Although the PP results are not presented here, they tallied with their ADF counterparts, with very minor variations, insufficient to affect the interpretation noted in some instances.

**Table 4.3: ADF unit root results (intercept and trend)**

| Series | Lag length | ADF *t*-stat | Series | Lag length | ADF *t*-stat |
|---|---|---|---|---|---|
| $BLA_t$ | 2 | -2.1800 | $\Delta BLA_t$ | 0 | -9.8615** |
| $BLS_t$ | 0 | -5.5404** | $\Delta BLS_t$ | NA | NA |
| $FRA_t$ | 2 | -2.4105 | $\Delta FRA_t$ | 0 | -3.7742* |
| $GDP_t$ | 0 | -1.6975 | $\Delta GDP_t$ | 1 | -10.264** |
| $NDE_t$ | 0 | -1. 9874 | $\Delta NDE_t$ | 0 | -9.4565** |
| $NIR_t$ | 1 | -3.8858* | $\Delta NIR_t$ | 0 | -6.0393** |
| $USI_t$ | 1 | -3.3168 | $\Delta USI_t$ | 0 | -5.5975** |

*Tests were conducted using Schwarz information criteria (SIC). * and ** indicates significance at 5% and 1% respectively . Significant results indicate the null of unit root is rejected. NA indicates not applicable.*

### 4.5.2 Optimal Lag Selection Criteria

As optimal lag selection is very important for optimising the VAR analysis, this section presents the results of the lag order selection criteria test. Table 4.4 contained estimates of lag selection order in view of different information criteria, at 1, 4 and 12 lags level (see Appendix 3 for full table). Given that the choice of lag length is determined by reference to information criteria, the Schwarz information criterion (SC) which returned 1 lag as optimal was chosen in order to avoid the problem of over-parameterisation associated with other information criteria. As seen in the table, all other information criteria have lengthy optimal lag order as compared with the SIC, which has an optimal lag order of 1. An investigative VAR test was carried out based on the optimal lags of 12 suggested by Akaike and other information criteria (as seen in Table 4.4); also, using 4 lags given that the data frequency applied is quarterly (see Appendix 2 for results). The outcome of the tests suggests insignificant results for all the lag levels beyond 1 lag selection, except in the case of lag value of some variables. Consequently, all the VAR analyses were carried out using 1 lag selection.

**Table 4.4: VAR lag order selection criteria**

| Lag | Log L | LR | FPE | AIC | SIC | HQ |
|---|---|---|---|---|---|---|
| 1 | -836.1148 | 1294.476 | 0.132596 | 17.84230 | 19.30119* | 18.43274 |
| 4 | -663.5759 | 41.20309 | 0.089484 | 17.33152 | 22.62001 | 19.47187 |
| 12 | 41.34951 | 67.46015* | 0.044780* | 11.07301* | 26.57377 | 17.34645* |

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

### 4.5.3 Analysing and Interpreting Empirical Findings

This sub section ultimately answers the chapter's empirical questions through the hypotheses in section 4.2.3. The research questions are; *does crude oil price volatility impact on Nigeria's GDP? (**H4A**), does oil market shock alter the commodity's price volatility for Nigeria? (**H4B**), is Nigeria's foreign reserve account sensitive to crude oil price volatility? (**H4C**)* Other secondary questions are; - *if yes, how sensitive, in what pattern, over what period and how does it affect government financial position?* Therefore, each of the stated questions will be aligned to an appropriate hypothesis from among ***H4A, H4B*** and ***H4C*** as specified in the section 4.2.3 above in order to reach suitable answers. The results are presented and interpreted in the below subsections.

To meet the requirements of the secondary research questions, the impulse response analysis is being carried out in tranches of different periods: short (0-3 years), medium (5years) and long terms (10 years), in order to understand the persistence of crude oil prices shocks impacts. As already indicated in section 4.5, some of the applied variables were converted to log form, others left in log level terms. Thus, from the first step of the main VAR estimation process $BLA_t$, $FRA_t$, and $GDP_t$ were transformed into log form, while the remaining variables, $NDE_t$, $USI_t$, $NIR_t$ and $BLS_t$ are left in their log normal form. As the VAR model is the foundation of the impulse response and variance decomposition analyses, this trend continue to the end of the analysis.

#### 4.5.3.1 Interpreting Vector Autoregression Results

Table 4.5 below is the VAR estimates which present different equations with their determining variables. These equations were generated following the development of the surrounding equation (4.1) which is the VAR model specification determining interactions between the variables of interest (BLA, BLS, FRA GDP, NDE, USI and NIR). These equations are the necessary step towards achieving the ensuing analyses that will enable the research questions in this chapter to be answered. The equations are generated on the basis of 1 lag period, reflecting the outcome of the optimal lag selection test reported earlier. Therefore, in Table 4.5 the variables are endogenously tested in determining the VAR equations. The figures following each variable are their coefficients, whereas those in parentheses are the *t*-statistics which decide the level of the variables' significance in determining the equation. For instance, in the table we have a situation of seven different VAR equations, with the lag variables in first column. Each of the equations points to the level of significance in determining which of the endogenous variables is relevant in deciding the VAR equations.

Therefore, judging from the equation involving the BLA variable, we can see that only BLA lag value ($\boldsymbol{BLA_{t-1}}$), and the lag values of BLS and NDE ($\boldsymbol{BLS_{t-1}}$ and $\boldsymbol{NDE_{t-1}}$) could relevantly determine the equation, as it is only in their case that the determining *t*-statistics are significant (a value of 2 and above). Expectedly, the lag value of a variable to predict itself is normal, this will naturally happen, given the clear connection. This reasoning follows in all the equations; as seen in the table, lag values of variables were able to strongly predict them due to significant *t*-statistics. The $R^2$ in all the equations are highly significant as the values are more than 90% or thereabouts, except in the case of the BLS equation, where it turns out to be barely relevant with a value of about 60%. This outcome indicates the reliable prediction power of these equations; thus the regression's measure of fit could be seen as good. Hence, the next step of the analyses, employing impulse responses and variance decompositions, are based on a sound footing.

**Table 4. 5: Vector Autoregression Estimates**

| *Lag Variables* | *VAR Equations* $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
|---|---|---|---|---|---|---|---|
| $LBLA_{t-1}$ | 0.9335<br>(18.158)* | 0.0434<br>(0.32414) | 0.1615<br>(2.4975)* | -6.3001<br>(-2.7013)* | 4.6913<br>(1.7454) | -0.0835<br>(-0.4969) | 1.7302<br>(3.1226)* |
| $LFRA_{t-1}$ | 0.0199<br>(1.0151) | 0.8442<br>(16.5102)* | 0.0185<br>(0.7503) | -0.3582<br>(-0.4026) | 0.9626<br>(0.9388) | 0.0545<br>(0.8509) | 0.5112<br>(2.4184)* |
| $LGDP_{t-1}$ | 0.0001<br>(0.0036) | -0.0230<br>(-0.2957) | 0.8956<br>(23.870)* | -0.1212<br>(-0.0896) | -3.9302<br>(-2.5207)* | 0.0443<br>(0.4544) | -0.0700<br>(-0.2176) |
| $NDE_{t-1}$ | 0.0017<br>(3.0910)* | 0.0014<br>(0.9881) | 0.0006<br>(0.7743) | 1.0112<br>(40.605)* | -0.0691<br>(-2.4067)* | 0.0007<br>(0.4150) | -0.0067<br>(-1.1325) |
| $NIR_{t-1}$ | 0.0002<br>(0.3125) | -0.0020<br>(-1.0593) | 0.0025<br>(2.7466)* | -0.0394<br>(-1.1817) | 0.9030<br>(23.513)* | 0.0046<br>(1.9081) | -0.0060<br>(-0.7545) |
| $USI_{t-1}$ | 0.01403<br>(1.4604) | -0.0278<br>(-1.1088) | -0.0026<br>(-0.2181) | -0.3336<br>(-0.7656) | -0.9901<br>(-1.9715) | 0.9904<br>(31.568)* | -0.0119<br>(-0.1146) |
| $BLS_{t-1}$ | -0.0268<br>(-3.0789)* | 0.0044<br>(0.1949) | -0.0266<br>(-2.4249)* | 1.0479<br>(2.6514)* | -0.2817<br>(-0.6185) | -0.0528<br>(-1.8536) | 0.3235<br>(3.4450)* |
| *C* | -0.0578<br>(-0.1969) | 1.5545<br>(2.0322)* | 0.3119<br>(0.8448) | 25.91228<br>(1.9466) | 25.809<br>(1.6823) | -0.6859<br>(-0.7157) | 7.3927<br>(-2.3376)* |
| *Adjusted* $R^2$ | 0.9364 | 0.9159 | 0.9276 | 0.9871 | 0.8705 | 0.9649 | 0.5819 |

*Figures on right hand side of the lag values represents variables coefficients and the figures in parenthesis are the t-statistics values. *indicates statistical significance.*

### 4.5.3.2 Granger Causality Tests and Wald Tests

The tests here are conducted on the basis of Granger causality equation specified in chapter 3, founded on the basis of VAR. Thus, the results were estimated from the body of VAR estimates presented in Table 4.5 above. The application here is done in terms of the null hypothesis in each of the tests that is variable A does not Granger cause B, against the alternative. Thus, the Granger causality and the Wald tests results of individual variables' interaction with each other focusing on the key variables of BLA, BLS, FRA and GDP are presented in Table 4.6. These tests were carried out in order to determine which of the variables causes which, a level of analysis helpful in preliminary understanding of variables' relationships. In addition, a discovery of other directions of causation among the numerous variables considered here could help to shape the overall empirical application. The Wald tests results are equally presented in the same table. This approach is consistent with such preliminary tests being carried out with a few others as a set of diagnostic procedures in preceding literature, particularly in Jiménez-Rodríguez and Sánchez (2005). Also, for robustness, Pairwise Granger Causality tests were conducted (see Appendix 4). In the Pairwise results, since *F*-statistics are the joint Wald statistics results of the causality tests, it could be technically presumed that the results suffice for the Wald test.

From Table 4.6, we can reject the null hypotheses ($H_0$) that log of Bonny Light Spot Price (***LBLA$_t$***) do not cause Bonny Light Standard Deviation (***BLS$_t$***) and Naira/US Dollars Exchange rate (***NDE$_t$***), given that the relationship's *chi-square* ($X^2$) indicators are high enough with the resulting *p*-values lower than the 5% threshold. Also, we can reject the $H_0$, that log of Nigeria's Gross Domestic Product (***LGDP$_t$***) does not cause log of Bonny Light Spot Price (***LBLA$_t$***), Nigeria's Inflation Rate (***NIR$_t$***) and Bonny Light Standard Deviation (***BLS$_t$***), on the same reasoning. We similarly, reject $H_0$, in that Bonny Light Standard Deviation (***BLS$_t$***) does not cause log of Bonny Light Spot Price (***LBLA$_t$***) and log Nigeria's Foreign Account (***LFRA$_t$***). All the null hypotheses involving the remaining variable interactions could be rejected given the low *F*-statistics observations, and the high *p*-values being too high, far higher than the 5% threshold for rejection of the $H_0$. However, given the same yardstick of judgement in all relationships other than those cited above, involving the four key variables, the $H_0$ cannot be rejected, suggesting no causal relationships among the variables. As such, they do not Granger cause each other. Hence, we accept all the $\boldsymbol{H_0}$. The pattern of relationships seen in Table 4.6 could be seen as expected, particularly the level of causal link between **BLS$_t$** and other variables, given the information from the descriptive analysis (section 4.3 above), where the two variables had a very high correlation.

**Table 4. 6: VAR Granger Causality and Wald Tests**

| *Indicators* | $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ | *Total* |
|---|---|---|---|---|---|---|---|---|
| | | | | **Dependent Variable: $LBLA_t$** | | | | |
| $X^2$ | NA | 1.0305 | 1.26E-1 | 9.5544 | 0.0977 | 2.1327 | 9.4796 | 28.873 |
| $P$ | NA | 0.3101 | 0.9972 | 0.0020* | 0.7547 | 0.1442 | 0.0021* | 0.0001* |
| | | | | **Dependent Variable: $LFRA_t$** | | | | |
| $X^2$ | 0.1051 | NA | 0.0874 | 0.9762 | 1.1221 | 1.2293 | 0.0380 | 7.9101 |
| $P$ | 0.7458 | NA | 0.7675 | 0.3231 | 0.2895 | 0.2675 | 0.8455 | 0.2448 |
| | | | | **Dependent Variable: $LGDP_t$** | | | | |
| $X^2$ | 6.2374 | 0.5629 | NA | 0.5995 | 7.5438 | 0.0476 | 5.8802 | 23.148 |
| $P$ | 0.0125* | 0.4531 | NA | 0.4388 | 0.0060* | 0.8273 | 0.0153* | 0.0007* |
| | | | | **Dependent Variable: $BLS_t$** | | | | |
| $X^2$ | 9.7508 | 5.8487 | 0.0474 | 1.2825 | 0.5693 | 0.0131 | NA | 29.551 |
| $P$ | 0.0018* | 0.0156* | 0.8277 | 0.2574 | 0.4506 | 0.9087 | NA | 0.0000* |

*$H_0$ represents null hypothesis. *indicates rejection of $H_0$. Number of lags = 1. Number of observation = 111. NA = Not applicable. Degree of freedom for individual variables = 1. Degree of freedom for total variables = 6. $X^2$ = Chi-Square indicator. P = p-value.*

As for the Wald tests, we rely on the *p*-values of the total *chi-square* outcomes given the degrees of freedom, which in the case of our test is six (6), given that we are using one degree of freedom in all the variables (1 lag value). Thus, from the table, all *p*-values in the case of all other variables suggest an acceptable limit of less than 5%, except in the case of $LFRA_t$ as a dependent variable. Hence, all the variables in the VAR model could be treated as exogenous, except $LFRA_t$.

### 4.5.3.3 Application and Interpretation of Impulse Response Functions

The impulse responses are here applied on the basis of the generalised responses (Pesaran and Shin, 1998), specified in section 4.3.3 as equation (4.2). Thus, the model will reflect up to the entire variable at time t, in the case of this analysis, $BLA_t$, $BLS_t$, $FRA_t$, $GDP_t$, $NDE_t$, $USI_t$ and $NIR_t$. Therefore, the results presented in Table 4.7 were estimated based on equation (4.2) and are on the basis of the need to understand if crude oil price shocks (***$LBLA_t$***) result in any impact on the variables of ***$BLS_t$, $LFRA_t$, $LGDP_t$, $NDE_t$, $USI_t$*** and ***$NIR_t$***. Again as pointed out in section 4.3.3, equation (4.2) is the moving average version of the VAR model (equation 4.1), thus, the outcome of the VAR estimates in the above section gave rise to the impulses responses. In addition to this generalised responses process, the traditional type of impulse response analysis is also estimated. Results from the process which pays attention to testing the response of unit changes due to innovations in a variable by other variables are presented in Table 4.8. This is merely a confirmatory attempt, as the process suffers from criticism that partly has to do with variables ordering. This problem could be overcome by the generalised type of impulse responses.

The overall analysis is carried out over 40 periods of quarterly frequencies (10 years), in tranches of short, medium and long terms. As pointed out above, this is in order to answer the research question concerning the period over which crude oil price shocks last. This approach will thus ensure that the immediate and lasting impact of the innovations on the BL spots are separated and understood individually. This understanding could further stimulate potential policy implications for the government. Hence, in furtherance of this understanding, the analysed tests are based on accumulated responses, which examine continues impacts from innovations of ***$LBLA_t$*** and ***$BLS_t$*** on other variables.

Therefore, Tables 4.7 and 4.8 below are the accumulated results summaries of impulse responses analysed based on the generalised and one unit responses of other variables from innovations in ***$LBLA_t$*** these measure impacts of crude oil prices shocks on other variables. In the same vein, Table 4.9 is the generalised accumulated responses of other variables to innovations in ***$BLS_t$***, which also measure volatility impacts on other variables. Figures 4.6, 4.7 and 4.8 are the graphical versions of the results in tables 4.7, 4.8 and 4.9 respectively, which show their practical movements. The tables are organised to reflect periodic responses on a short-term basis implying periods 1 to 12, which covers 0-3 years, medium term of 20 to 23 at around 5 years and also, long term, periods 37 to 40, around 10 years. The results in-between are not reported, but the accumulated impacts of the responses are seen through from period 1 to 40 (full results are presented in Appendices 5 - 7). Essentially, the interpretation yardstick will be that variables responses from $\boldsymbol{LBLA_t}$ and $\boldsymbol{BLS_t}$ innovations are seen as having increasing effects on percentages when they stay positive and decreasing impacts when they turn negative.

Thus, in Table 4.7, the short term generalised responses of the $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$, $\boldsymbol{LGDP_t}$, $\boldsymbol{NDE_t}$, $\boldsymbol{USI_t}$ and $\boldsymbol{NIR_t}$ variables are seen to return diverse effects. While $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$, $\boldsymbol{LGDP_t}$, and $\boldsymbol{USI_t}$ are seen to have increasing responses to innovations in $\boldsymbol{LBLA_t}$ throughout that period, $\boldsymbol{NIR_t}$ and $\boldsymbol{NDE_t}$ are noted for mixed outcomes of both positive and negative responses. $\boldsymbol{NDE_t}$ responded with an increase of 1.17% during the first period, but went on declining to an accumulated level of -20.22% during the 12$^{th}$ quarter (end of the 3$^{rd}$ year). As for $\boldsymbol{NIR_t}$, it responded with a decline of -36.86% during the first quarter and started climbing in rapidly to 716.44% in the 12$^{th}$ period. In the case of variables with upward increasing responses, $\boldsymbol{BLS_t}$ responded with an increase of 38.83% in the first period and peaked at 265.36% during the 12$^{th}$ period. While the $\boldsymbol{USI_t}$ variable was 11.09% in the first quarter and fell to 8.23% in the 12$^{th}$ quarter, there were increased responses for, $\boldsymbol{LFRA_t}$, are from 3.66% in the 1$^{st}$ period to 20.59% in the 12$^{th}$ period and for $\boldsymbol{LGDP_t}$, from 3.86% to 59.76% in the 1$^{st}$ and 12$^{th}$ periods respectively.

In the medium term, the trend is almost similar to the short term, as the variables responses are mixed. The $\boldsymbol{USI_t}$ responses, noted to be declining in short term analysis, continued in that manner getting into a negative trend in the 23$^{rd}$ quarter at -10.35%. The positive and increasing responses of $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$ and $\boldsymbol{LGDP_t}$ variables have started waning during this period, with 23$^{rd}$ period responses being 222.43%, -4.71% and 75.57% respectively, thus seeing the foreign account variable ($\boldsymbol{LFRA_t}$) already falling to a negative level. The inflation variable ($\boldsymbol{NIR_t}$) continues increasing to 1356.40% in the 23$^{rd}$ period. The pattern of variables long term responses to crude oil price shocks ($\boldsymbol{LBLA_t}$) more or less continued from where it stopped during the medium term. The $\boldsymbol{USI_t}$ variable gets back to responding in a positive way 54.94% in the 40$^{th}$ period, its highest response point of the entire analysis. The declining responses of $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$ and $\boldsymbol{LGDP_t}$ variables continued in this period, with the negative trend of the foreign account variable ($\boldsymbol{LFRA_t}$) continuing to the highest level of -57.51% in the 40$^{th}$ period, whereas $\boldsymbol{BLS_t}$ and $\boldsymbol{LGDP_t}$ were 103.37% and 45.69% respectively. Again, the inflation variable (***NIR$_t$***) continued to increase, to its highest level of the analysis period, 1844.70% in the 40th quarter. Continuing from the short term analysis, the ***NDE$_t$*** variable went on with same trend of negatively increasing responses, peaking at -7249%.

**Table 4. 7: Accumulated responses of variables to generalised changes in *LBLA$_t$***

| *Period* | *LFRA$_t$* | *LGDP$_t$* | *NDE$_t$* | *NIR$_t$* | *USI$_t$* | *BLS$_t$* |
|---|---|---|---|---|---|---|
| | | | **Short Term Response** | | | |
| 1 | 0.0366 | 0.0386 | 0.0117 | -0.3686 | 0.1109 | 0.3883 |
| 2 | 0.0721 | 0.0855 | -0.5107 | -0.3673 | 0.1903 | 0.7780 |
| 3 | 0.1053 | 0.1375 | -1.4648 | -0.0806 | 0.2416 | 1.1384 |
| 4 | 0.1350 | 0.1925 | -2.7755 | 0.4236 | 0.2691 | 1.4582 |
| 12 | 0.2059 | 0.5976 | -20.224 | 7.1644 | 0.0823 | 2.6536 |
| | | | **Medium Term Response** | | | |
| 20 | 0.0420 | 0.7596 | -39.658 | 12.310 | -0.1067 | 2.4381 |
| 21 | 0.0132 | 0.7615 | -41.849 | 12.759 | -0.1104 | 2.3705 |
| 22 | -0.0166 | 0.7601 | -43.971 | 13.176 | -0.1093 | 2.2989 |
| 23 | -0.0471 | 0.7557 | -46.024 | 13.564 | -0.1035 | 2.2243 |
| | | | **Long Term Response** | | | |
| 37 | -0.4855 | 0.5195 | -68.604 | 17.675 | 0.3790 | 1.2093 |
| 38 | -0.5156 | 0.4984 | -69.918 | 17.935 | 0.4341 | 1.1498 |
| 39 | -0.5455 | 0.4775 | -71.212 | 18.192 | 0.4909 | 1.0925 |
| 40 | -0.5751 | 0.4569 | -72.490 | 18.447 | 0.5494 | 1.0370 |

*Responses are based on generalised innovations.*

The analysis for the one unit responses to crude oil prices shocks (***LBLA$_t$***) here as seen in Table 4.8 below depicts a situation not dissimilar from the generalised responses in Table 4.7. For instances, the pattern of increasing responses in the ***BLS$_t$*, *LFRA$_t$*** and ***LGDP$_t$***, noted in the short term generalised responses, remains the same here, except that the ***LFRA$_t$*** has effectively become negative during the 12th quarter. This situation is not too much of an anomaly, if we consider that in the former analysis too, the $\boldsymbol{LGDP_t}$ started waning in the 12th period. Similar patterns to the generalised analysis are seen in the medium and long term analyses. The $\boldsymbol{NIR_t}$ variable, responded throughout in a positive and an increasing manner. The $\boldsymbol{USI_t}$ variable responded with a negative trend throughout the analysis period, starting at -8.35% in the 2nd quarter, peaking in the 21st quarter with -759.80% before dropping to -38.45% during the 40th period of the analysis. This is a little bit different from the generalised analysis outcome, which saw the variable responding with an increase in the short term, before falling to negative in the medium and returning to positive responses in the long term analysis. Finally, the $\boldsymbol{NDE_t}$ variable here, too, responded with a negative and declining pattern throughout the analysis period.

**Table 4. 8: One unit Accumulated responses of variables to changes in $\boldsymbol{LBLA_t}$**

| *Period* | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
|---|---|---|---|---|---|---|
| | | | **Short Term Response** | | | |
| 1 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | 0.0434 | 0.1615 | -6.3001 | 4.6913 | -0.0835 | 1.7302 |
| 3 | 0.1085 | 0.4206 | -16.931 | 12.744 | -0.3089 | 3.9310 |
| 4 | 0.1775 | 0.7423 | -30.806 | 23.223 | -0.6724 | 6.0941 |
| 12 | -0.1352 | 3.7760 | -200.53 | 130.56 | -5.3229 | 13.713 |
| | | | **Medium Term Response** | | | |
| 20 | -2.2064 | 5.3033 | -387.40 | 202.02 | -7.5876 | 10.181 |
| 21 | -2.5314 | 5.3394 | -408.80 | 207.59 | -7.5979 | 9.4400 |
| 22 | -2.8630 | 5.3444 | -429.62 | 212.59 | -7.5530 | 8.6730 |
| 23 | -3.1992 | 5.3202 | -449.84 | 217.09 | -7.4555 | 7.8889 |
| | | | **Long Term Response** | | | |
| 37 | -7.8117 | 3.1438 | -677.66 | 255.82 | -2.1317 | -2.2869 |
| 38 | -8.1189 | 2.9345 | -691.10 | 258.10 | -1.5638 | -2.8779 |
| 39 | -8.4230 | 2.7254 | -704.33 | 260.38 | -0.9810 | -3.4494 |
| 40 | -8.7244 | 2.5173 | -717.38 | 262.67 | -0.3845 | -4.0023 |

*Responses are based on one unit innovations.*

The results in Table 4.9 are the accumulated responses of the $\boldsymbol{LBLA_t}$, $\boldsymbol{LFRA_t}$ $\boldsymbol{LGDP_t}$, $\boldsymbol{NDE_t}$, $\boldsymbol{NIR_t}$ and $\boldsymbol{USI_t}$ variables to generalised innovations in the $\boldsymbol{BLS_t}$ variables. This analysis is aimed at testing the level of other variables' responses to crude oil price volatility, essentially the impact of crude oil prices volatility on the other variables. The results suggest that $\boldsymbol{NIR_t}$ and $\boldsymbol{USI_t}$ respond negatively to innovations in $\boldsymbol{BLS_t}$, whereas $\boldsymbol{LFRA_t}$ returned positive responses in all the measured periods. The $\boldsymbol{NDE_t}$ followed similar pattern of responses to $\boldsymbol{LFRA_t}$, except in the first period, where it responded negatively to the innovations. The $\boldsymbol{LBLA_t}$ and $\boldsymbol{LGDP_t}$ responses to innovations here are in diverse proportions, as their reactions are a mixture of positive and negative during the periods. Both the variables started with a positive reaction during the first period, which lasted up to the third period for $\boldsymbol{LBLA_t}$ before it changed to a negative reaction. In the medium term, the two variables reacted differently, with $\boldsymbol{LBLA_t}$ being positive from period 20 to 23, while $\boldsymbol{LGDP_t}$ stayed negative during the same period. In the long run, both variables exhibited positive and increasing reactions as seen throughout periods 37 to 40. These results indicate that the different sets of variables responded differently to the issue of crude oil price volatility. While volatility in crude oil prices impacted negatively on $\boldsymbol{NIR_t}$ and $\boldsymbol{USI_t}$, it impacted positively $\boldsymbol{LFRA_t}$ and to a very large extent on $\boldsymbol{NDE_t}$, throughout all the examined periods. As for $\boldsymbol{LBLA_t}$ and $\boldsymbol{LGDP_t}$, the impact of volatility on them was also positive in the immediate short and the longer term perspectives. The overall picture of the results suggests that $\boldsymbol{BLS_t}$ impacts differently on other tested variables, with some of the variables reacting to innovations in $\boldsymbol{BLS_t}$ positively, whereas others have negative or mixed responses.

**Table 4. 9: Accumulated responses of variables to generalised changes in $BLS_t$**

| *Period* | $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ |
|---|---|---|---|---|---|---|
| | | | **Short Term Response** | | | |
| 1 | 0.0360 | 0.0363 | 0.0048 | -0.2766 | -0.4734 | -0.0022 |
| 2 | 0.0284 | 0.0758 | -0.0265 | 0.8376 | -1.1287 | -0.0889 |
| 3 | 0.0070 | 0.1175 | -0.0718 | 2.6687 | -1.7497 | -0.20634 |
| 4 | -0.0161 | 0.1607 | -0.1204 | 4.9137 | -2.2591 | -0.3324 |
| 12 | -0.0362 | 0.5367 | -0.3596 | 28.165 | -2.7373 | -1.2035 |
| | | | **Medium Term Response** | | | |
| 20 | 0.1554 | 0.9218 | -0.2686 | 51.670 | -2.2481 | -1.8648 |
| 21 | 0.1847 | 0.9692 | -0.2418 | 54.364 | -2.3492 | -1.9444 |
| 22 | 0.2143 | 1.0165 | -0.2129 | 56.998 | -2.4927 | -2.0246 |
| 23 | 0.2440 | 1.0637 | -0.1822 | 59.573 | -2.6775 | -2.1057 |
| | | | **Long Term Response** | | | |
| 37 | 0.6113 | 1.7191 | 0.2856 | 91.419 | -7.9157 | -3.4078 |
| 38 | 0.6331 | 1.7661 | 0.3166 | 93.542 | -8.3526 | -3.5130 |
| 39 | 0.6544 | 1.8132 | 0.3471 | 95.662 | -8.7850 | -3.6194 |
| 40 | 0.6753 | 1.8603 | 0.3771 | 97.779 | -9.2118 | -3.7269 |

*Responses are based on generalised innovations.*

Figures 4.5 and 4.6 give a pictorial representation of the variables responses in Tables 4.7 and 4.8 described above. Figure 4.5 is the generalised responses movements which show how each of the $BLS_t$, $LFRA_t$, $LGDP_t$, $NDE_t$, $USI_t$ and $NIR_t$ responded to innovations in $LBLA_t$. Again the periods seen on the horizontal axes of the graphs span from $1^{st}$ to $40^{th}$, each representing a given quarter, while the vertical axes contain the percentages changes, depicting either an increase or a decrease. One important point to be highlighted here is that since we are considering accumulated responses, the occurrences are based on accumulative patterns. Hence, each subsequent period is formed on the basis of both the present and previous occurrences in cumulative order.

This point in graphical terms will imply a persistent curve as against the individual point observations, that would ordinarily portray an individual point based scenario.

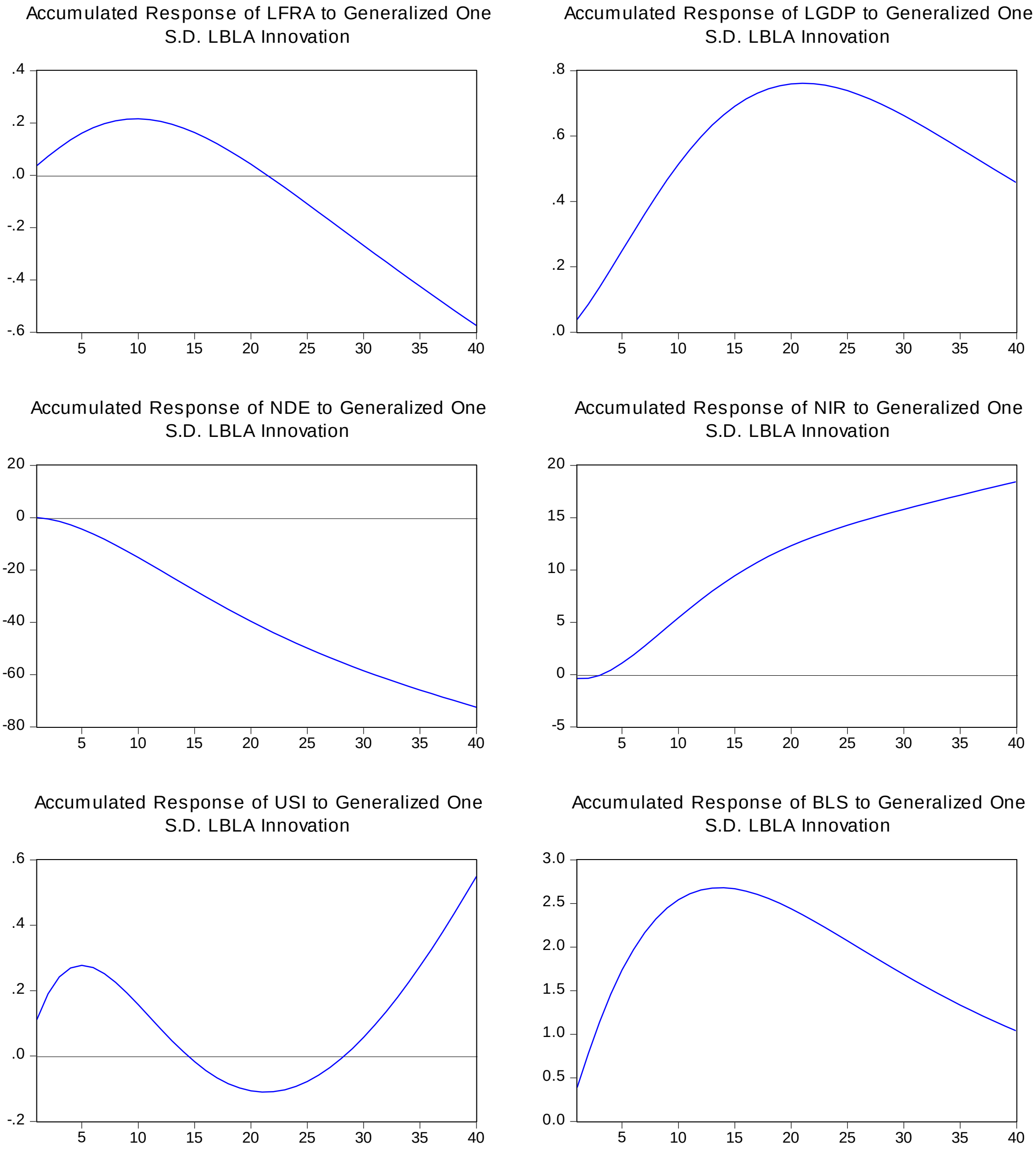



**Figure 4. 5: Generalised accumulated responses graphs of changes in $LBLA_t$**

As the results are for the tabulated versions, the graphs in figures 4.5 and 4.6 look generically the same, as the shapes are not distant from each other. For instance, the $LGDP_t$ graphical responses to innovations in $LBLA_t$ have a nearly the same shape in both figures 4.5 and 4.6. This is largely the same for all the comparisons, except for some slight variations in percentage changes, which have more or less minimal impact.

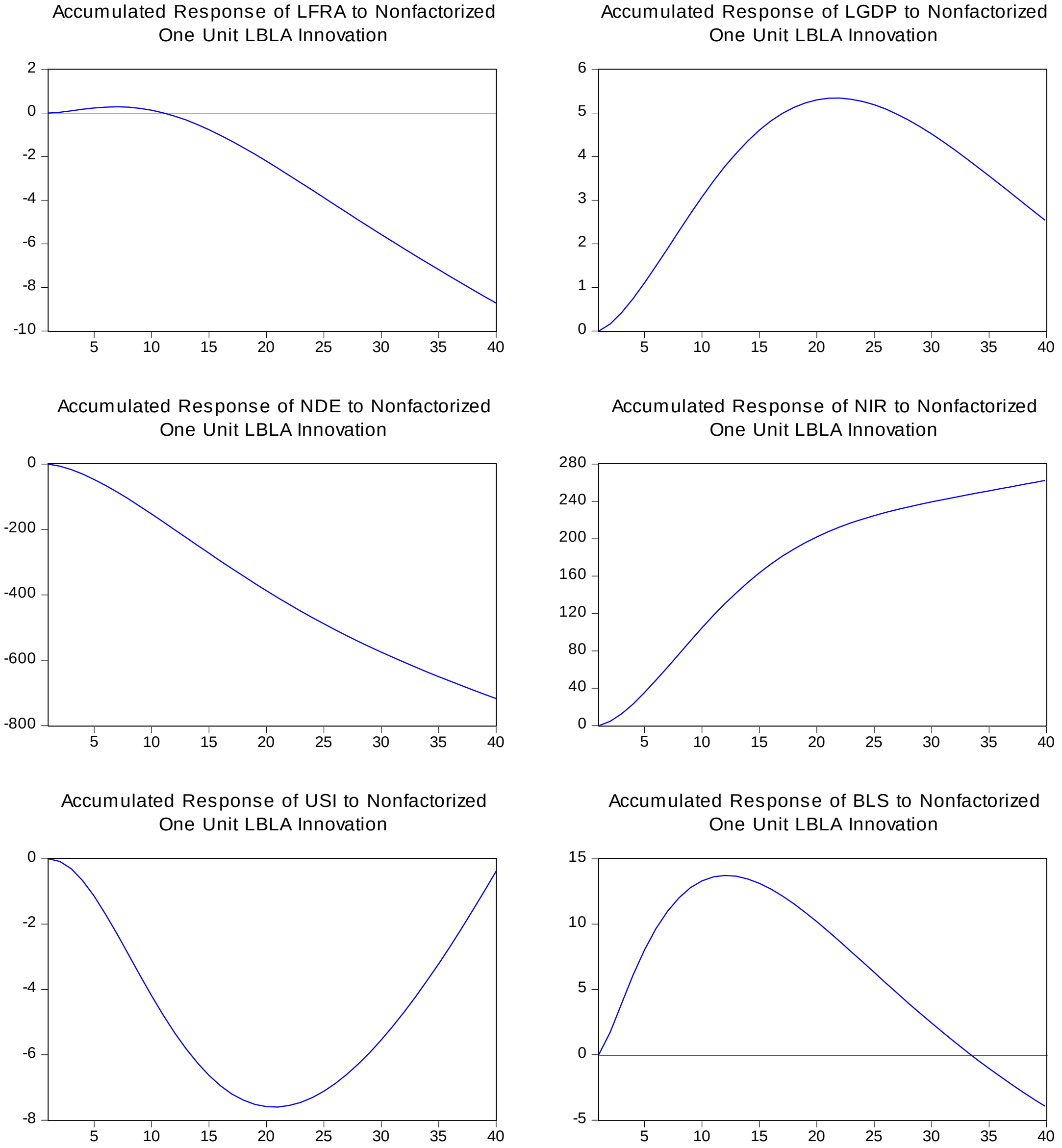



**Figure 4. 6: One unit's accumulated responses graphs of changes in $LBLA_t$**

Figure 4.7 below is the graphical presentation of the generalised accumulated responses of other variables to innovations in $BLS_t$. In similar manner to figures 4.5 and 4.6, the figure shows graphically variables responses to innovations in $BLS_t$ given the results in Table 4.9.

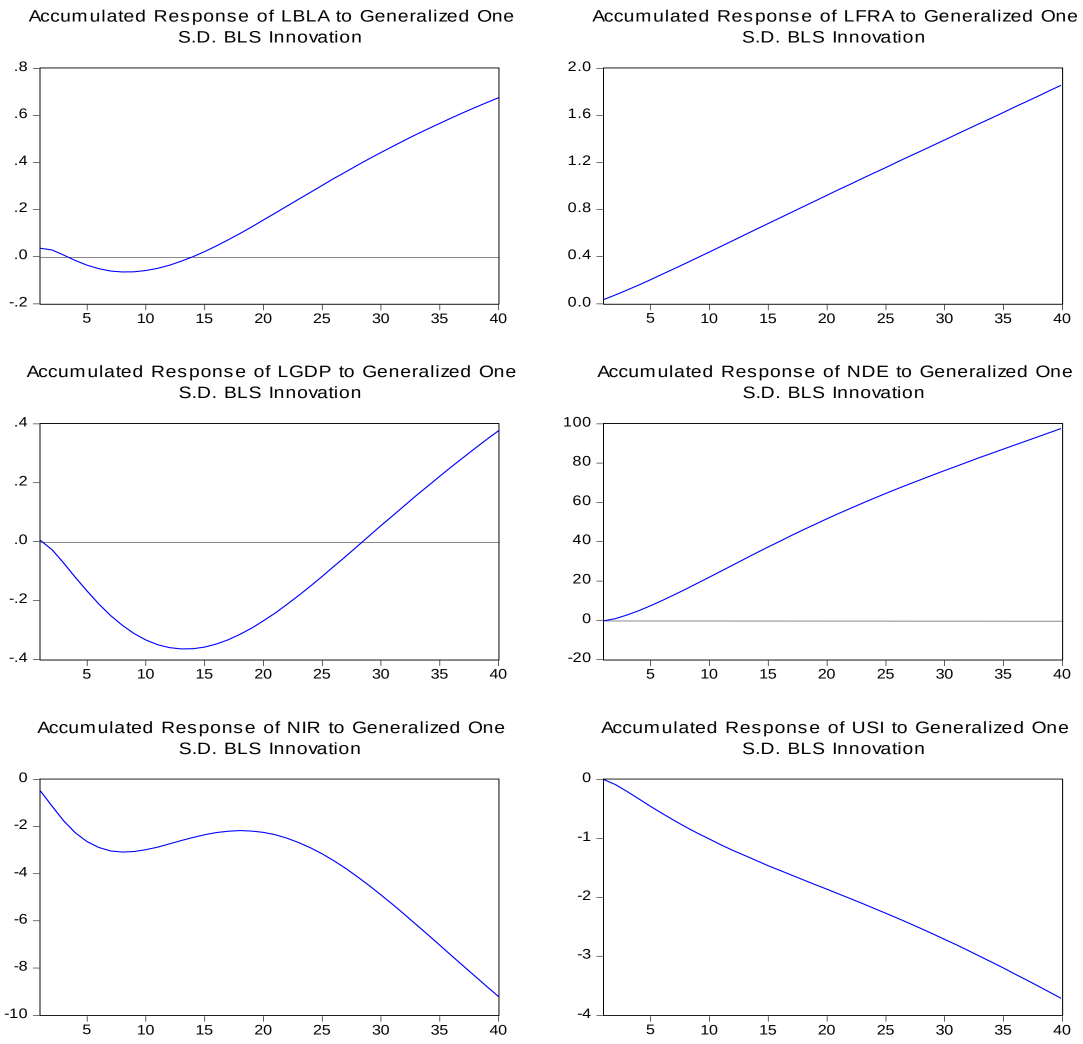



**Figure 4. 7: Generalised accumulated responses graphs of changes in $BLS_t$**

### 4.5.3.4 Application and Interpretation of Variance Decomposition

Variance decomposition analysis captures the proportion of each variable's contribution to the test's forecast error (standard error). Technically, the variance decomposition analysis is based on the VAR estimates and the process provides information on that basis. The application process here presents each variable's composition of forecast error in percentage during a given forecast period. Therefore, Table 4.10 represents a summary of the variance decomposition analyses reflecting the short, medium and long term patterns as the above impulse responses analyses was carried out. The table contains 1$^{st}$, 12$^{th}$, 20$^{th}$ and 40$^{th}$ period ahead forecast error/variances decompositions of each variable, thereby capturing 1, 3, 5 and 10 years in advance error forecasts.

From the table we can see 1, 12, 20 and 40 periods ahead forecasts for all the variables containing the distribution of the standard error (*SE*). Each variable's variance decomposition shows how in the first period ahead's forecast its given error is stronger and slips down in the ensuing periods; this essentially measures the level of variations. We can see that the *SE* increases as the forecast period increases. This is logically expected given that error expectation becomes wider with a longer period forecast. In the variance decomposition of $\boldsymbol{LBLA_t}$, it can be seen that crude oil price shocks was the dominant source of price volatility in the first period, as it accounted for 100% of the *SE*, but as the forecast period increases, that position changes, with the $40^{th}$ period forecast suggesting the $\boldsymbol{LBLA_t}$ accounts foronly 31.72%, while $\boldsymbol{NDE_t}$ accounts for the largest source of volatility, at 38.27%. The standard deviation ($\boldsymbol{BLS_t}$) and inflation ($\boldsymbol{NIR_t}$) variables also show some influence at 14.51% and 9.49% respectively. The SE share of exchange rate ($\boldsymbol{NDE_t}$) and inflation ($\boldsymbol{NIR_t}$) are seen to increase with increased forecast periods, similar to their outcomes in the above impulse responses analysis.

In the case $\boldsymbol{LFRA_t}$, in the first forecast period it accounted for 99% of the error, to with the reminder due to $\boldsymbol{LBLA_t}$. Again during the $40^{th}$ period the $\boldsymbol{NDE_t}$ variable increased to 20.26% of the forecast error, while $\boldsymbol{LFRA_t}$ influence dropped to 42.62%. With $\boldsymbol{LGDP_t}$, $\boldsymbol{LBLA_t}$ accounted for about 5% of the SE in the first period and rose to about 14% in the $12^{th}$ and $20^{th}$ period before dropping to 10% in the $40^{th}$ period. In the case of $\boldsymbol{USI_t}$ decomposition, the crude oil price variable started strongly in the first period with a 5.64% share of the *SE*, but dropped to 1.20% during the $40^{th}$ forecast period. One thing that has become clear throughout the table, especially in the first period forecast, is the ability of crude oil price to exert some level of influence on all the variables' decompositions, particularly $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$ and $\boldsymbol{LGDP_t}$. Also the standard deviation variable ($\boldsymbol{BLS_t}$) features prominently in determining all the levels of variances in *SE* forecasts. This points to how crude oil price shocks influence all variables in the model. These results, thus, coincide with the outcomes for $\boldsymbol{LBLA_t}$ on the variables $\boldsymbol{BLS_t}$, $\boldsymbol{LFRA_t}$, $\boldsymbol{LGDP_t}$, $\boldsymbol{NDE_t}$, $\boldsymbol{USI_t}$ and $\boldsymbol{NIR_t}$, as revealed by the above impulse responses analysis. Appendices 8 to 11 give a graphical representation of the *SE* tests shown in Table 4.10, which depict variables' *SE* movements.

**Table 4. 10: Variance Decomposition Results Table**

| *Period* | *SE* | *LBLA$_t$* | *LFRA$_t$* | *LGDP$_t$* | *NDE$_t$* | *NIR$_t$* | *USI$_t$* | *BLS$_t$* |
|---|---|---|---|---|---|---|---|---|
| | | | | **Variance Decomposition of *LBLA$_t$*** | | | | |
| 1 | 0.1430 | 100.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 0.3399 | 60.282 | 0.1286 | 0.2426 | 27.635 | 0.7354 | 3.278485 | 7.6978 |
| 20 | 0.4015 | 44.980 | 0.1877 | 0.2754 | 39.797 | 1.6769 | 2.570396 | 10.513 |
| 40 | 0.5143 | 31.723 | 0.4077 | 1.8068 | 38.265 | 9.4931 | 3.794772 | 14.510 |
| | | | | **Variance Decomposition of *LFRA$_t$*** | | | | |
| 1 | 0.3728 | 0.9613 | 99.039 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 0.7706 | 1.0358 | 82.361 | 0.1535 | 4.0984 | 8.0449 | 2.5524 | 1.7544 |
| 20 | 0.8715 | 1.2838 | 65.568 | 1.2343 | 10.415 | 13.515 | 3.8290 | 4.1552 |
| 40 | 1.0821 | 2.4605 | 42.621 | 3.6018 | 20.258 | 16.930 | 6.1966 | 7.9328 |
| | | | | **Variance Decomposition of *LGDP$_t$*** | | | | |
| 1 | 0.1799 | 4.6131 | 1.35E-1 | 95.387 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 0.4680 | 13.787 | 0.5104 | 55.598 | 4.3337 | 15.147 | 0.7424 | 9.8814 |
| 20 | 0.5049 | 13.441 | 0.4776 | 48.058 | 10.345 | 14.791 | 3.8592 | 9.0281 |
| 40 | 0.6357 | 9.8610 | 0.4185 | 31.221 | 18.694 | 19.449 | 8.3952 | 11.962 |
| | | | | **Variance Decomposition of *NDE$_t$*** | | | | |
| 1 | 6.4871 | 0.0003 | 1.1596 | 0.3109 | 98.529 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 25.649 | 6.3376 | 0.3582 | 0.3692 | 62.973 | 8.9484 | 2.7295 | 18.284 |
| 20 | 33.942 | 7.7225 | 0.4304 | 1.4453 | 50.534 | 15.624 | 4.9224 | 19.322 |
| 40 | 46.004 | 6.8288 | 0.3074 | 4.2717 | 42.415 | 20.178 | 8.3891 | 17.611 |
| | | | | **Variance Decomposition of *NIR$_t$*** | | | | |
| 1 | 7.4763 | 0.2431 | 5.3757 | 0.1307 | 0.0072 | 94.243 | 0.0000 | 0.0000 |
| 12 | 18.126 | 1.8873 | 1.7577 | 20.427 | 7.5654 | 61.514 | 6.0906 | 0.7582 |
| 20 | 19.665 | 2.4831 | 1.5961 | 23.691 | 11.511 | 52.695 | 7.1999 | 0.8247 |
| 40 | 20.339 | 2.7917 | 1.5653 | 22.616 | 13.865 | 50.062 | 7.3363 | 1.7642 |
| | | | | **Variance Decomposition of *USI$_t$*** | | | | |
| 1 | 0.4671 | 5.6353 | 0.0075 | 1.8719 | 0.2670 | 2.3242 | 89.894 | 0.0000 |
| 12 | 1.5446 | 1.1856 | 0.0237 | 1.4096 | 0.4047 | 19.438 | 74.356 | 3.1834 |
| 20 | 1.8125 | 1.0173 | 0.1244 | 1.7928 | 2.5947 | 25.172 | 65.948 | 3.3508 |
| 40 | 2.2804 | 1.1976 | 0.1507 | 3.8505 | 14.961 | 25.089 | 48.575 | 6.1757 |
| | | | | **Variance Decomposition of *BLS$_t$*** | | | | |
| 1 | 1.5412 | 6.3461 | 0.5327 | 0.0794 | 0.1150 | 0.1278 | 0.3263 | 92.473 |
| 12 | 1.9311 | 20.394 | 7.9677 | 0.2267 | 3.9284 | 0.7171 | 0.5998 | 66.166 |
| 20 | 2.0313 | 18.724 | 7.3603 | 0.4917 | 10.608 | 1.2319 | 0.6295 | 60.955 |
| 40 | 2.2758 | 16.832 | 6.0095 | 1.3411 | 16.855 | 4.8395 | 1.5793 | 52.543 |

*SE = Standard Error. All figures are in percentages except the SE which are expressed in absolute terms*

#### 4.5.3.5 Answering the Research Questions: An analysis of the tests findings

This section will ultimately answer all of this chapter's questions by using mainly the empirical results from the impulse response analysis in section 4.5.3.3 above. However, the earlier results from the descriptive statistics, preliminary as well as the variance decomposition analysis will be used as complementary inputs. The results will be explained in relation to the research hypotheses ***H4A, H4B*** and ***H4C***. The results from impulses responses revealed that $\boldsymbol{LBLA_t}$ has positive and long lasting impacts on $\boldsymbol{BLS_t}$ and $\boldsymbol{LGDP_t}$, and a positive and medium lasting effect on $\boldsymbol{LFRA_t}$. However, responses to $\boldsymbol{BLS_t}$ vary, with a mixture of both negative and positive responses, highlighting the volatile nature of the Bonny Light (BL) crude oil spot, a major finding.

Whilst Nigeria's situation is in the focus of this analysis, this interpretation section is carried out in such a way that useful extensions to other countries and situations is possible, especially as we have seen that different crude oil grade prices move together closely. Therefore, interpreting the empirical results from the above sections will enable us to explicitly describe the impacts of crude oil price shocks on the tested variables, achievement of which will ultimately answer the entire research questions. However, given that the variables of BLA, BLS, GDP and FRA constitute the main variables of interest, as they provide the basis for the research questions, the core of this discussion will reflect more on their impacts. Essentially, all variables' responses together with their preliminary results outcomes are factored in this section's analysis.

Answering the question: *Does crude oil price volatility impact on Nigeria's GDP?* The answer here is yes, judging by the positive, increasing, and lasting responses of $\boldsymbol{LGDP_t}$ to changes in the $\boldsymbol{LBLA_t}$ as seen in table 4.7. This result is reflected in to the significance of the correlation between the variables (0.8182) and variance decomposition outcomes. This situation essentially implies that with every round of crude oil price shocks, particularly relating to Nigeria's BL spots, the resulting impact will increase the country's GDP with increasing effect lasting for more than 10 years. Again with oil accounting for 91% of the country's foreign income and also, since Nigeria as a developing economy has a strong government presence, it should be expected that the government's main revenue earner will strongly influence GDP.

Therefore, the result here has essentially answered the research hypothesis ***H4A***. Given the outcome, we, reject the null hypothesis (***$H_0$***) and accept the alternative hypothesis (***$H_1$***). Hence, Crude *oil price volatility has impact on Nigeria's GDP.*

Given the question; *does oil market shock alter the commodity's price volatility for Nigeria?* The answer here too is yes, given the increasing, positive and lasting responses of ***$BLS_t$*** to changes in ***$LBLA_t$***. Since ***$BLS_t$*** is the standard deviation of BL spots, it ultimately measures the volatility of crude oil prices. Therefore, a positive increasing response of the ***$BLS_t$*** due to innovations in ***$LBLA_t$***, portrays a positive impact, implying that with every round of crude oil price shocks relating to the Nigerian BL spots, the situation will essentially increase the volatility prospects of crude oil spots. The increase as seen in table 4.7 above will initially be to the tune of 38.83% in the first period and the effect will remain and increase to 265.36% during the 12$^{th}$ period and finally reach 103.70% in the 40$^{th}$ period. This pattern depicts volatility of lasting effect. Turning to research hypothesis ***H4B***, as being related to the question answered here, we therefore reject the null hypothesis (***$H_0$***) and accept the alternative hypothesis (***$H_1$***). Thus, *crude oil market shocks increase oil price volatility for Nigeria.*

On the question*; is Nigeria's foreign reserve account sensitive to crude oil price volatility?* the answer again is yes, judged by the positive and medium lasting responses of ***$LFRA_t$*** to changes in ***$LBLA_t$*** variables as seen in table 4.7. This result could be seen as anticipated, due to the very strong correlation (0.9214) of the Nigerian foreign account (***$FRA_t$***) with the ***$BLA_t$*** variable. Also, the preliminary causality test had confirmed this position by suggesting the two variables cause each other. Therefore, the suggestion from on the descriptive statistics in section 4.4.4, that the higher the price of crude oil, the higher will be the Nigerian foreign account, is supported here. Effectively, the outcome means the Nigerian foreign account position will naturally grow with increasing crude oil price and vice versa. Reflecting on the related research hypothesis of ***H4C***, we could reject the null hypothesis (***$H_0$***) and accept the alternative hypothesis (***$H_1$***). Hence, *Nigeria's foreign reserve account is sensitive to crude oil price volatility*.

As for the other examined variables of ***$NIR_t$***, ***$NDE_t$*** and ***$USI_t$***, the outlook of their results portrays mixed outcomes of increasing and decreasing responses to innovations in the

$\boldsymbol{LBLA_t}$. This is also the same case with the outcomes of their descriptive statistics and other preliminary tests, particularly the Granger causality. These understandings will essentially shape the course of the interpretations here, together with related information from the literature, already described. Beginning with the inflation variable ($\boldsymbol{NIR_t}$), it is seen to display a positive upward response to innovations in $\boldsymbol{LBLA_t}$, peaking at 1844.70% during the $40^{th}$ period in the generalised analysis. This implies that the impact of crude oil shocks on Nigerian inflation is to increase it by that percentage during the indicated period. This situation is expected, largely due to the increased government expenditure following improved oil revenues and also, due to the currency devaluation regime that prevailed during the period under analysis.

The US treasury rates ($\boldsymbol{USI_t}$) in the generalised analysis responded with mixed outcomes of an increase in the short term, falling to negative in the medium term and getting back to positive responses in the long term. This situation suggests fluctuating responses of $\boldsymbol{USI_t}$ to crude oil prices shocks (***LBLA***). The natural explanation of this situation logically reflects the periodic adjustments made to the $\boldsymbol{USI_t}$ variable by the US treasury, purely on policy position. This explanation is strongly supported by a negative insignificant correlation of -0.4342 and a one sided causation between $\boldsymbol{USI_t}$ and $\boldsymbol{LBLA_t}$ as seen in Tables 4.2 and 4.5 respectively, thereby suggesting the possibility they are connected or explain by each other. The impact of crude oil price shocks impact on the $\boldsymbol{NDE_t}$ variable is explained through its responses to innovations in the $\boldsymbol{LBLA_t}$ variables also seen in tables 4.7 and 4.8 above. The situation commonly exhibits a negatively increasing responses pattern, thereby implying an increasing trend of weakening of the Nigerian currency given its US counterpart. Again as explained above, this may largely be due to the currency devaluation regime that has seen the Nigerian currency decline tremendously in its value from the late 1980’s.

Essentially, the above findings have provided the basis for addressing the chapter’s secondary questions: - *if yes, how sensitive, in what pattern, over what period and how does it affect government financial position?* Therefore, the outcome arrived at regarding the responses of the main variables $\boldsymbol{BLA_t}$, $\boldsymbol{LGDP_t}$ and $\boldsymbol{LFRA_t}$ to the innovations in $\boldsymbol{LBLA_t}$ has provided the obvious yardstick for dealing with the secondary questions; Hence, as the answers to the main questions involving the three variables’ responses were to yes in all cases, we will thus, say *yes* to the first secondary question. As for *how sensitive and in what pattern*, the answers to these questions are jointly provided by the above explanation of variables' positive and negative response and speed of increase and decrease. The question on the pattern of responses was provided by examining responses to innovations in the short, medium and long term, ably capturing the pattern of their sensitivity. Finally, the question of the government's financial position is dealt with, given the tendencies of price shocks to impact on the foreign account ($\boldsymbol{FRA_t}$). As we found out, the Nigerian foreign account increases with increasing crude oil price. This question is, thus, answered.

Comparing the above empirical results with reviewed preceding empirical studies specific to the impact of crude oil price shocks on Nigeria's economic variables, we see agreement with some and a disagreement with others. However, like the results here, what was evident in most of the past research is the agreement that crude oil price shocks are a source of volatility in the oil market. The results of the variance decomposition analysis confirm this view, as crude oil price shocks was the dominant source of price volatility in almost all the variables. This situation is similar to the findings of Jiménez-Rodríguez and Sánchez (2005), where the contribution of oil price to variability in the GDP of all countries tested was very high. It also supports a similar analysis in Sadorsky (1999), who found oil price movements accounted for the larger proportion of the forecast error in the sample tested. Ultimately, the finding given the GDP of some Organisation for Economic Co-operation and Development (OECD) countries in Jiménez-Rodríguez and Sánchez (2005) is that oil price increase rather than the price decrease causes larger GDP growth impact in most countries. For oil importing countries there is an adverse effect of oil price increase (except in Japan). More interestingly to this study, the findings revealed that the GDP of a net oil exporting country such as Norway grows with oil price increases. This particular finding is very consistent with the Nigerian case examined in this chapter.

## 4.6 Conclusion

This chapter addresses whether crude oil price volatility has any impact on the commodity's export dependent economies such as Nigeria. The task was addressed through answering the chapter's research questions: *Does crude oil price volatility impact on Nigeria's GDP? Does oil market shock alter the commodity's price volatility for Nigeria? Is Nigeria's foreign reserve account sensitive to crude oil price volatility?* Secondary questions were; - *if yes, how sensitive, in what pattern, over what period and how does it affect government financial position?* The results found evidence of crude oil price volatility impact on the Bonny Light (BL) crude oil spot price, GDP and also, the foreign reserve account. Thus, the essential concern of whether crude oil price volatility has any impact on Nigeria's foreign income earnings and economic variables such as GDP was answered in this chapter. Although some preceding empirical studies attempted to find different aspects of crude oil volatility impact, one area not previously covered, which was addressed in this research, is the impact of volatility on crude oil price as measured through standard deviation. Also, the impact on the foreign reserve account of major crude oil export dependent country was crucially covered.

The empirical process adopted Vector Autoregression (VAR) and other elements of its applications, Bonny Light spot prices and their standard deviation represented oil price shocks and volatility. Preliminary outcomes highlighted how the BL spot is more like a price taker, reflecting on the fact that price is decided by outcomes in the global crude oil market, rather than dictated by Nigeria. The main empirical finding is crude oil price shocks impact positively on the Nigerian GDP, BL spot's standard deviation (BLS) and foreign account (FRA), but negatively on inflation rate (NIR) and exchange rates (NDE). Therefore, based on these empirical outcomes, certain implications could be far reaching for the Nigerian economy, as well as for potential extension to other similar situations.

The implications of this chapter's findings constitute either policy or academic dimensions. For instance, the increased volatility of crude oil prices ($\boldsymbol{BLS_t}$) due to price shocks ($\boldsymbol{LBLA_t}$), uncovered in the empirical test, suggest Nigeria is exposed to crude oil prices risk. With increase in price, the country is bound to gain more revenue, and hence have better budgets, especially as the country's budgets are pegged on crude oil prices.

Again, protecting the country's local currency value (Naira) very much relies on the size of the country's foreign reserve. The likely implication in this area that will affect the country's economic policy is in determining the country's currency value against the US dollar, which is the international currency used in pegging the value of the Naira. On the academic side, useful extensions could be made from the empirical outcomes here, given that the price of different crude oil grades behave similarly to each other. This point of potential implication to other areas was highlighted in the main body of this chapter and will be further discussed in the concluding chapter of this research.

Finally, given that this chapter has found that crude oil price shocks have a general impact on Nigeria's foreign earnings and major economic variables, as well as additional volatility sources, the next level of this research's empirical analysis will focus on the need to tackle the adverse effects of these impacts, by identifying measures capable of reducing or even avoiding the impacts of price volatility. Essentially, a means of predicting the Nigerian BL spots price behaviour in the futures market could provide the yardstick for such a judgement. Also, given the discovered impacts of oil price shocks on the BL spot's standard deviation, hedging both in the short, medium and long term could be a useful strategy. Therefore, chapter five will focus on identifying a useful hedge for the Nigerian crude oil price volatility, which could be through a proxy for prediction of the BL spots or by other available means.

# Chapter 5: Exploring Price Discovery for Bonny Light Spot

## 5.1 Introduction

The issue of crude oil price volatility presents a worrying circumstance for both producers and consumers of the commodity. Chapter 4 of this thesis found evidence of crude oil price volatility impact on GDP, foreign reserve account, and 'Bonny Light' (BL) spot prices in Nigeria, a typical oil revenue dependent country. Also, empirical studies looking into the impact of crude oil price shock have confirmed the commodity's price volatility as a source of problems for major macroeconomic variables of both net producing and consuming countries (Jiménez-Rodríguez and Sánchez, 2005; Malik and Ewing, 2009). The problem of crude oil price volatility is particularly worrisome for the producing countries, especially as the problem is associated with an irregular revenue pattern, which manifest into distorted budgetary and economic planning for the producing countries.

According to the Energy Information Administration (EIA), Nigeria is Africa's largest and world number 7$^{th}$ exporter of crude oil, with approximately two (2) million barrels of production/day (EIA, 2012). As the commodity provides the country with over 91% of its foreign exchange, the Central Bank of Nigeria (CBN) pointed to volatility as the main challenge managing the country's foreign reserves (CBN, 2011b). Yet, the BL spot market largely remains empirically unexamined within the academic literature, especially with regard to understanding price movements in relation to any futures prices. Also, the BL as a grade of crude oil is still without its own futures market. A body of empirical research looking into crude oil price movement currently exists (Quan, 1992; Schwarz and Szakmary, 1994; Hammoudeh et al., 2003; Maslyuk and Smyth, 2009). Quan (1992) specifically, tried to determine if a stable long run relationship exist between crude oil spots and futures prices.

Against the above background, this chapter is interested in answering the fundamental question of: *Are West Texas Intermediate (WT) futures price efficient predictor of Bonny Light (BL) spots price?* Other secondary questions considered are; *is there any need for a BL futures market? Also, at what point is the need tenable?* Answering these questions requires uncovering whether an efficient hedging tool for BL spots prices is present in WT futures prices or otherwise. Also, it will aid our understanding of any need for setting up a BL futures market. Existence of a futures market will provide the free flow of market information required, as the relevant futures contract prices existing in it may explain BL spot prices.

The empirical analysis mainly employs cointegration tests, for which both Engle-Granger two-step method and Johansen test are used in relation to their respective error correction models (ECMs). Additional empirical procedures applied are generalised impulse responses, Granger causality and other diagnostic tests aimed at increasing the robustness of the analysis. Bonny Light (BL) spot prices, West Texas Intermediate (WT) spot prices and four successive months' futures contracts written on the basis of WT spot prices are the major data of application. The West Texas Intermediate or Texas light sweet crude oil has characteristics of high gravity and low sulphur content according to the American Petroleum Institute (API) classification; the same light sweet categorization is enjoyed by the BL, indicating a high quality, low sulphur grade of crude oil usually in high demand for refining petrol. In terms of spots pricing both grades enjoy similar pricing in the market with slight variations over time. Therefore, as we do not presently have any recognised futures market for the BL, we may be able to use the futures market contracts from New York Mercantile Exchange (NYMEX) which is written on the basis of WT futures contracts. The applied data is in weekly frequency, from the week beginning January 03, 1997 to March 18, 2011. The remainder of the chapter is organised into major sections dealing with controlling the impact of crude oil price, empirical application, data, empirical analysis and results.

## 5.2 Controlling the Impact of Crude Oil Price Volatility

As we try to confirm whether WT futures prices are efficient predictors of BL spots prices, it is important to understand the nature of crude oil price volatility. As already confirmed in chapter 4, crude oil price volatility is real and the impacts on the economies of both the exporting and importing countries are enormous, see Jiménez-Rodríguez and Sánchez (2005). Figure 5.1 below depicts a volatile pattern of movements in the spot prices of both BL and WT over the whole time observed. Again as highlighted in chapter 2 of this thesis, several factors may be jointly or separately responsible for the volatile pattern, among which could be sudden shocks that may not have been foreseen or explained, as asserted by Pindyck (2001). Thus, prices changes due to shocks are important component in understanding crude oil price volatility pattern. As such, incidences of major economic shocks like the recent global economic meltdown of 2007 are reflected in the datasets.

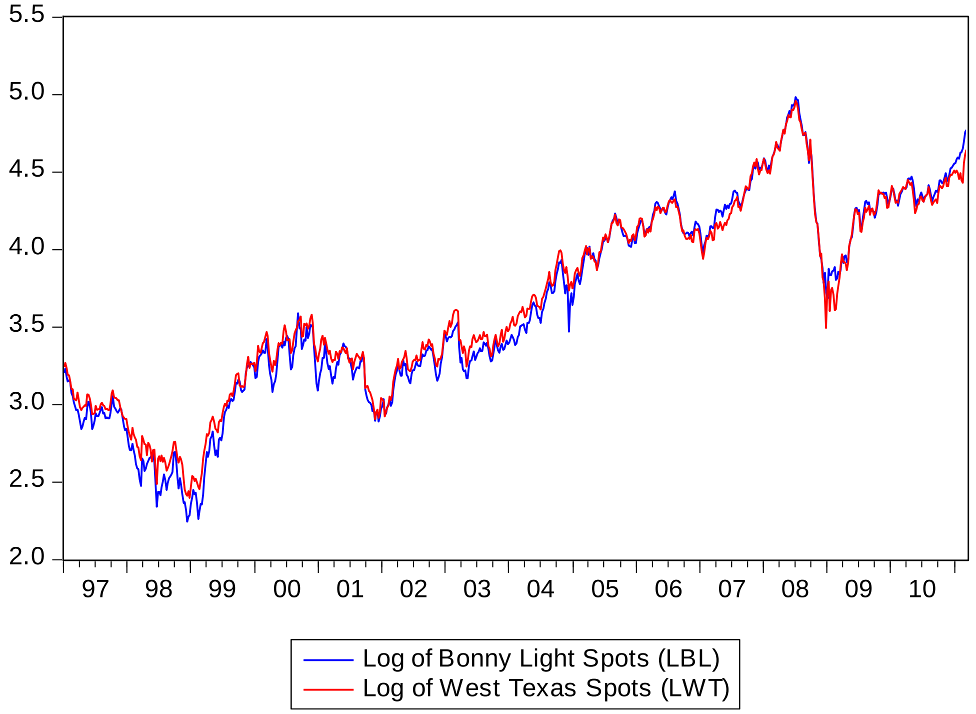



**Figure 5.1: Price movements of Bonny Light and West Texas Intermediate spots**

Empirical research over the years has concentrated more on the attempt to predict the impact rather than controlling the negative effects of such volatility (see for example Chaudhuri, 2001; Chen et al., 2009). In relation to this chapter's research question, price discovery is the reference within which many empirical studies examined the issue of crude oil spot price determination relative to the futures market, and indeed in the study of other commodities price movements. The guiding principle has been the use of futures prices as a mechanism for commodity price discovery, as widely adopted in empirical finance. In the context of crude oil price this approach has numerous empirical precedents (Antoniou and Foster, 1992; Quan, 1992; Schwarz and Szakmary, 1994; Sequeira and McAleer, 2000; Moosa, 2002; Lin and Tamvakis, 2005). Some of these empirical efforts are specific to co-movements between crude oil spots and futures prices, thus signalling attempts at price discovery in crude oil. Quan (1992) and also, Schwarz and Szakmary (1994) are among the earliest examples of such studies which tested the existence of price discovery in crude oil, utilising information from the futures market to understand the spot market.

Quan (1992) made an empirical examination using crude oil spot markets and futures contracts to determine if the latter could predict the former. One problem area addressed was the power of successive information exhibited by futures prices in determining spots market. Instead of accepting past procedures, Quan proposed a two-step process that involved testing for cointegration and causality among the variables. A surprising revelation from the finding suggests inability of the futures market to make any impact on price discovery. This challenges the fundamental assumption that futures contracts will largely provide information about the spots market. This seeming aberration will be empirically reviewed here, as we know from the literature that the overwhelming position is tilted towards crude oil futures contracts being able to determine spots.

Certainly if market information were to be available in perfect order, we may not be talking about crude oil price volatility as a problem. The existence of a futures market works as a bridge between future information and the current situation. The Efficient Market Hypothesis (EMH) is the theoretical basis closely linked with the existence of futures markets, as the EMH assumes that financial markets are up to date with information. Understanding future price behaviour (market information) is relevant in answering the fundamental question of WT futures as an efficient predictor of BL spots. As such, the theoretical underpinning of EMH is relevant. In relation to the empirical approach and for the purposes of this chapter, the EMH will be assumed to hold. This assumption will allow us to infer a determining relationship between the variables of interest (BL spots and WT futures prices). However, as Quan (1992) pointed out, "*to be of value to hedgers, the futures price must respond quickly and accurately to relevant new information"*, Thus, we have to be sure whether the futures prices are powerful elements. By implication, without the existence of balanced information in the market, it will be somewhat difficult to guarantee smooth transactions and attainment of the efficient market criterion. Cointegration is often applied empirically in testing the theoretical strength of the EMH; thus, linking the chosen empirical models here with the theoretical stance in the EMH is important. Crowder and Hamed (1993) used cointegration analysis to analyse the oil futures market as linked to market efficiency.

However, in relying on the futures market as mechanism of attaining price discovery, it is important to indicate here that significant amount of existing literature (Bessembinder et al., 1995; Schwartz, 1997; Sarno and Valente, 2000; Schwartz and Smith, 2000; Roll et al., 2007) points to the relevance of cost of carry model in determining commodities futures prices. The model assumes the existence of zero arbitrage opportunity between spot and futures market, such that a market participant is indifferent between physical hedging and yields of the financial instrument. Therefore, if the model applies, then the spot and futures basis are stationary, where a stationary test of the basis could be used in determining market efficiency in the spot and the futures markets. In their analysis of the mean reversion in commodities futures markets, Bessembinder et al. (1995) made assumption of the cost of carry. The study argued that oil like other physical commodities will have a convenience yield, thus, it could be argued further that with oil being the examined commodity in this chapter, the arbitrage argument in the cost of carry model may not efficiently hold. Hence, the empirical process in this chapter would follow the approach in Crowder and Hamed (1993) among others. This is given that Schwartz and Smith (2000) also developed a model of investigating mean reversion process in short and long terms futures which bears semblance to the application of cointegration/error correction model in price discovery process in some of the earlier cited references (among which is Crowder and Hamed, 1993). Therefore, by making use of information pool from the four months' successive futures contracts of West Texas Intermediate, this chapter will attempt to determine the BL spot prices.

### 5.2.1 Research Questions Arising

Following the literature review and the identification of gaps, this chapter is interested in answering the fundamental questions:

- *Are West Texas Intermediate (WT) futures prices efficient predictor of the Bonny Light (BL) spot price?*
- *Is there any need for a BL futures market?*
- Also, *at what point is the need tenable?*

### 5.2.2 Hypotheses

The above research questions will be channelled through the hypotheses below;

Hypothesis ***H5A***-

$\boldsymbol{H_0}$: *West Texas Intermediate futures are not an efficient means of managing price risk in Bonny Light spots.*

$\boldsymbol{H_1}$: West Texas Intermediate futures are an efficient means of managing price risk in Bonny Light spots.

The highlight of ***H5A*** is the null hypothesis that Bonny Light spots are not cointegrated with CF1, CF2, CF3 and CF4 futures prices *against* the alternative that they are cointegrated. The rejection of the null will imply that one could conclude that futures prices or a futures market can be used to hedge market risk.

Hypothesis ***H5B***-

$\boldsymbol{H_0}$: There is no short-run adjustment back to long-run equilibrium in the variables' relationships from ***H5A***.

$\boldsymbol{H_1}$: There is short-run adjustment back to long-run equilibrium in the variables relationships from ***H5A***.

The essence of ***H5B*** is to explore a null hypothesis of no short-run adjustments among the variables relationships preceding the cointegration processes in all the variables relations tested *against* the alternative of existing short-run adjustments. The rejection of the null will imply that one could conclude that variables are able to regain any lost information due to the cointegration process and thus, have the ability to get back to equilibrium, see Granger (1981) and also, Engle and Granger (1987).

## 5.3 Empirical Application

The fundamental basis for the empirical procedures in this section will be from the models specifications in the methodology chapter (chapter 3). Thus, what is done below with each model is an attempt to specify the tools, pointing out how they could be relevant in each case, before using them in analysing the chosen data. This is because precise applications of the used variables are employed which is achieved by substituting them in the specified equations.

### 5.3.1 Rationale for Choosing Empirical Models

In answering the research question; *is the WT futures prices an efficient predictor of BL spots price*, this empirical application section mainly employs the cointegration approaches of Engle-Granger two-step method and Johansen test in relation to their respective error ECMs. These are in addition to other procedures for Granger causality and a host of other diagnostic tests aimed at increasing the robustness of the examination. However, the choice here is made in a way that makes the tools in the system of analysis mutually complementary rather than exclusive. Furthermore, this goes a long way in making the approach more robust and acceptable. As referenced in section 5.2 above, determining crude oil spots prices using futures prices by applying cointegration, error correction models supported by related models as proposed here has precedents in other empirical studies. This is because cointegration testing methods have the power of determining the existence of long-run relationships between variables, here BL spots and WT futures. In technical terms, $\boldsymbol{LBL_t}$ and $\boldsymbol{LWT_t}$ are cointegrated if the estimated error $\hat{\varepsilon}_t \sim I(0)$ is stationary, as already indicated in chapter 3.

The unit root test is first applied to be sure of the data stationarity, in order not run into the danger of spurious regression. Cointegration testing methods are adopted to determine if long-run relationships exist between the variables of BL spots and WT futures, to decide if WT futures price is capable of determining BL spots price. The Engle-Granger two-step procedure will usually determine this relationship, but not to the extent of confirming how many cointegrating vectors are present. Determining the number of cointegrating vectors will further confirm the strength of the cointegrating relationships and is the simple reason why the Johansen test procedure is adopted. A technique based on restricted vector autoregression (VAR) which applies maximum likelihood estimators is adopted in studying cointegrated non-stationary series. This approach is more widely accepted than the ordinary least square estimation procedure associated with the Engle-Granger two-step method. Finally, error correction models are utilised in order to test if the variables are able to return to equilibrium after the cointegration process and at what speed. Generalised impulses, Granger causality and other diagnostic measures are employed for increased robustness and data checks.

### 5.3.2 Engle-Granger Two-step Method and Error Correction Model

As this process has already been described in chapter 3, only the model specifications are recalled below, for the purpose of practical application.

$$Y_t = \alpha + \beta X_t + \varepsilon_t \tag{5.1}$$

Let $Y_t \sim X_t$ both be $I(1)$

Estimating the error term $(\varepsilon_t)$ as;

$$\hat{\varepsilon}_t = Y_t - \hat{\alpha} + \hat{\beta} X_t \tag{5.2}$$

$Y_t$ and $X_t$ are cointegrated if the estimated error is stationary $\hat{\varepsilon}_t \sim I(0)$

$$\hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \varepsilon_t \tag{5.3}$$

If $\boldsymbol{\rho} < 1$, then the error is stationary and $Y_t$ and $X_t$are cointegrated, implying they have a long run relationship. Practically, the two-step procedure is applied here to test the long run relationship between the variables of $\boldsymbol{LBL_t}$ and $\boldsymbol{LCF1_t}$ – $\boldsymbol{LCF4_t}$ also**,** $\boldsymbol{LWT_t}$ and $\boldsymbol{LCF1_t}$ – $\boldsymbol{LCF4_t}$. Step 1 is achieved when in equation (5.1) the cointegrating vector $\varepsilon_t$ is measured by taking residuals from the regression of $Y_t$ on $X_t$ as seen in equation (5.3). Estimating the $\Delta Y_t$ on lagged $\Delta X_t$ changes and on equilibrium error $(\hat{\varepsilon}_t)$ attained step 2. This ultimately leads to the specification for Engle-Granger error correction seen in equation (5.4) below, which will test the ability to correct for disequilibrium.

Engle and Granger (1987) showed cointegration to imply the existence of an error correction model (ECM) of the form in equation (5.4) which relates the change in $Y_t$ to change in $X_t$ based on past disequilibrium. In answering the research questions posed above, $\boldsymbol{LBL_t}$ takes the form of $\boldsymbol{Y_t}$ and $\boldsymbol{LCF1_t}$ – $\boldsymbol{LCF4_t}$ individually takes the form of $X_t$.

$$\Delta Y_t = \Theta + \gamma \Delta X_t + \lambda \varepsilon_{t-1} + u_t \tag{5.4}$$

Where; $\Theta$ = constant, $\gamma$ = Coefficient of the independent variable

$\Delta Y_t$ and $\Delta X_t$ = Changes in dependent and independent variables

$\varepsilon_{t-1}$ = Residual from the first step regression

$\lambda$ =Coeffient of the Residual, $u_t$ = Error in the ECM

### 5.3.3 Johansen Test and Vector Error Correction Model (VECM)

The Johansen procedure introduces the approach of measuring the number of cointegrating vectors present in variables' long run relationships. As pointed out in chapter 3, the technique with its vector error correction model (VECM) are based on restricted vector autoregression (VAR) which applies maximum likelihood estimators. The model specification takes the form in equation (5.5) below;

$$\boldsymbol{\Delta y_t = \delta + \alpha \beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t} \tag{5.5}$$

Where, $\boldsymbol{\delta, \alpha, \beta, \Gamma_1, \ldots.., \Gamma_{k-1}}$ are adjustment parameters and vary freely. Therefore, the VECM estimates the matrix $\boldsymbol{\Pi}$ from an unrestricted VAR and tests to see if the reduced rank restriction could be rejected. Thus, by implication $\boldsymbol{\beta}'$ captures the long run solution, in which case the left hand side and the element of difference of $\boldsymbol{\Delta y_t}$ are $\boldsymbol{I(0)}$. The last element is the linear combination of $\boldsymbol{I(1)}$ variable and it must be stationary to balance the time series properties of right and left hand sides. This is as the variable series deviation from the long-run equilibrium is gradually corrected by various partial short-run adjustments. Johansen considered the matrix $\boldsymbol{\Pi}$ in zero, reduced and full ranks, thus giving rise to five (5) models of deterministic trends:

I. $\boldsymbol{y_t}$ have no deterministic trends and the cointegrating vectors do not have intercepts; $\boldsymbol{\Pi y_{t-1} + B x_t = \alpha \beta' y_{t-1}}$

II. $\boldsymbol{y_t}$ have no deterministic trends and the cointegrating vectors have intercepts; $\boldsymbol{\Pi y_{t-1} + B x_t = \alpha(\beta' y_{t-1} + \rho_0)}$

III. $\boldsymbol{y_t}$ have deterministic trends and the cointegrating vectors have intercepts; $\boldsymbol{\Pi y_{t-1} + B x_t = \alpha(\beta' y_{t-1} + \rho_0) + \alpha_1 \gamma_0}$

IV. $\boldsymbol{y_t}$ have deterministic trends and in cointegrating vectors; $\boldsymbol{\Pi y_{t-1} + B x_t} = \propto (\boldsymbol{\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_1 \gamma_0}$

V. $\boldsymbol{y_t}$ have quadratic trends and the cointegrating vectors have deterministic trends; $\boldsymbol{\Pi y_{t-1} + B x_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_1(\gamma_0 + \gamma_1 t)}$

These models assumptions translate into specifications for which hypotheses for cointegrations are formulated and tested. The tests are conducted using maximum eigenvalue and trace statistics in equations (5.6) and (5.7) respectively.

$$\boldsymbol{\lambda_{\mathrm{max}} = -T\ln(1 - \hat{\lambda}_{r+1})} \qquad (5.6)$$

$$\boldsymbol{\lambda_{\mathrm{trace}} = -T \sum_{i=r+1}^{k} \ln(1 - \hat{\lambda}_i)} \qquad (5.7)$$

Where $\boldsymbol{T}$ = number of observations, $\boldsymbol{\hat{\lambda}_r}$= eigenvalue of matrix $\boldsymbol{\Pi}$ in the VECM equation.

## 5.4 Data

Table 5.1 below presents a summary of the variables used in this chapter’s data analysis. Essentially, the table captures the variables in their different levels of classification of normal, log and difference level.

**Table 5. 1: Variables representation**

| Variable Full Name | Variable Representation | | |
|---|---|---|---|
| | Normal | Log level | Log Difference |
| Bonny Light Spots Price | $BL$ | $LBL_t$ | $\Delta LBL_t$ |
| West Texas Intermediate Spots Price | $WT$ | $LWT_t$ | $\Delta LWT_t$ |
| First Month Futures Contract Price | $CF1$ | $LCF1_t$ | $\Delta LCF1_t$ |
| Second Month Futures Contract Price | $CF2$ | $LCF2_t$ | $\Delta LCF2_t$ |
| Third Month Futures Contract Price | $CF3$ | $LCF3_t$ | $\Delta LCF3_t$ |
| Fourth Month Futures Contract Price | $CF4$ | $LCF4_t$ | $\Delta LCF4_t$ |

*The pattern of contracts timing, maturity and delivery are defined in appendix 12.*

### 5.4.1 Data Presentation

The data to be applied in the empirical analysis of this chapter are weekly Bonny Light (BL) and West Texas Intermediate (WT) spots prices in conjunction with the weekly crude oil future contracts prices (CF1-CF4) written on the basis of light sweet crude oil delivered to Cushing, Oklahoma. Appendix 12 contains explanation of these variables and the assumptions behind them from the original sources. Where the patterns of contracts based on timing, maturity and delivery periods are well specified. The appendices section contains a detailed explanation and assumptions of the applied datasets. This covers a 14 year period, from the week beginning January 03, 1997 to March 18, 2011 and translating into 742 observations. BL spot is the Nigerian crude oil spot price index as recognised in the global crude oil market. The crude oil future contract prices are the contracts from New York Mercantile Exchange (NYMEX), the choice of which was made on the basis that BL is in the class of '*light sweet crude oil*'[5] on which the contract is based. These data are obtained from the Energy Information Administration (EIA) website. Data for BL spots during the weeks beginning December 17, 1999 and September 01, 2000 were missing from the database. To correct for these, the corresponding data for the WT was adopted, as the WT is the underlying commodity for which NYMEX futures contracts prices are written. Also, a closer look at the BL

[5] High quality crude oil with low sulphur content commonly used in refining petrol

and WT spots prices movements in figure 5.1 above reveals a close approximation over a long period of time.

The choice of analysis period is based on the turbulent pattern seen in the crude oil market, which was characterised by systemic volatility during that time. Typical of this is BL spot being sold for $146.15/barrel during July 2008, representing a major shock in the price and the highest price at which the commodity was ever sold. Incidentally, the period coincided with the peak of the global economic crisis. Given the same data range, we equally, have a point when the same commodity was only $9.60/barrel in February 1999, which was some 10 years earlier and the amount represents one of the lowest prices for the commodity in recent times. Between those points is a very unstable and unpredictable period when the commodity price kept oscillating. Other details that characterised this volatility are seen in figure 5.1 and in the descriptive statistics section. The use of such a period selection pattern could be seen in Maslyuk and Smyth (2009), where structural breaks were reflected in the study of the long-run relationship between different grades of crude oil.

WT spot price is mainly being analysed here to provide a comparative basis for the BL spot price as the main variable of interest. As suggested in section 5.5 above, WT spots have been widely adopted in cointegration and ECM analyses of different nature, usually resulting in consistent conclusions. Therefore, bringing WT spots into comparative analysis with BL spots will not only help to confirm the test process and results, but will equally increase the robustness, since the futures prices used in the main BL spot test is written on the basis of WT spots. Therefore, the data series for the WT spots will be equated into the same period as the BL spots and the futures prices. Characteristically, all the occurrences due to periodic disturbances or volatility noted in the case of BL spots are present in the WT spots. This is seen in the manner with which the commodities' prices move together. For example, the price shocks recorded for BL spots during the peak of the global economic crisis in 2008 also gave rise to the same manner of price change in WT spots, implying that the commodities' prices depict common trends, which is typical and expected.

A series of four (4) succeeding months' contracts were used in the analysis for a variety of reasons. In addition to availability, the most important reason was that we wanted to analyse and capture the speed of market information across the four successive months.

This problem was captured in the past (see Quan, 1992) however the outcome defied traditional expectations. To address the issues that arose, this chapter pays attention to the pattern of information flow through the ECMs, particularly as we assume EMH as a theoretical foundation. Also, use of all four available futures contracts (1, 2, 3 and 4) as adopted will increase the robustness of the tests.

### 5.4.2 Basis for Choosing Crude oil Futures

West Texas Intermediate spot alternate name is Texas light sweet derived from its characteristic of high API[6] gravity and low sulphur content. This same classification is enjoyed by the BL spots. In terms of spots pricing both grades enjoy similar pricing in the market with small variations over time. Again, a closer look at figure 5.1 will superficially confirm this claim as the Granger causality tests section will unveil a step further analysing the linkage between the two spots. Therefore, as we do not presently have any recognised futures market for the BL, hopefully we can use the futures market contracts from NYMEX, which represents the WT futures. Above all, a practical look at the two commodities spots' prices will reveal close approximation and figure 5.1 also suggests a close movement of the two spots prices.

### 5.4.3 Descriptive statistics

Although the usual checks applied to data do not normally constitute a source of concern for time series data, descriptive statistics for the data being used in log form are provided in table 5.2. Also in the same manner, the correlation matrix is tabulated in table 5.3, for easy understanding of data series behaviour. The respective results for the series Mean, Standard Deviation, Kurtosis, Jarque-Bera are all as expected, except that they are slightly skewed. With all variables presented in log form, the direction movements for the two main variables of LBL and LWT are very much similar. Also, the independent variables of $\boldsymbol{LCF1_t}$, $\boldsymbol{LCF2_t}$, $\boldsymbol{LCF3_t}$ and $\boldsymbol{LCF4}_t$ are not too far from each other. The correlation matrix in each co-relationship exhibits a very high possibility of a near perfect match as the coefficients are in all cases very high, nearly 1. This essentially signifies the closeness of the variables with each other, which to an extent could imply that the variables may explain or mirror each other.

[6] API is the American Petroleum Institute

**Table 5.2: Descriptive statistics of Log *BL* and the contract prices (Logs CF1-4)**

| Series | Mean | Std Dev | Skeweness | Kurtosis | Jarque-Bera | Probability |
|---|---|---|---|---|---|---|
| $LBL_t$ | 3.6362 | 0.6515 | -0.0347 | 1.9714 | 32.858 | 0.0000 |
| $LWT_t$ | 3.6681 | 0.6052 | -0.0159 | 1.9745 | 32.548 | 0.0000 |
| $LCF1_t$ | 3.6684 | 0.6062 | -0.0159 | 1.9690 | 32.892 | 0.0000 |
| $LCF2_t$ | 3.6722 | 0.6083 | 0.0074 | 1.8984 | 37.527 | 0.0000 |
| $LCF3_t$ | 3.6732 | 0.6111 | 0.0320 | 1.8372 | 41.932 | 0.0000 |
| $LCF4_t$ | 3.6721 | 0.6141 | 0.0558 | 1.7847 | 46.045 | 0.0000 |

**Table 5.3: Variables Correlation Matrix**

| | $LBL_t$ | $LWT_t$ | $LCF1_t$ | $LCF2_t$ | $LCF3_t$ | $LCF4_t$ |
|---|---|---|---|---|---|---|
| $LBL_t$ | 1.0000 | | | | | |
| $LWT_t$ | 0.9968* | 1.0000 | | | | |
| $LCF1_t$ | 0.9971* | 0.9999* | 1.0000 | | | |
| $LCF2_t$ | 0.9978* | 0.9991* | 0.9993* | 1.0000 | | |
| $LCF3_t$ | 0.9973* | 0.9977* | 0.9980* | 0.9996* | 1.0000 | |
| $LCF4_t$ | 0.9963* | 0.9960* | 0.9964* | 0.9988* | 0.9998* | 1.0000 |

**indicates statistical significance*

The respective graphs in figures 5.2 and 5.3 convey the different variables' common movements. Figure 5.2 presents common movements of BL, WT and CF1 at log normal level, which portrays their price movement over time. The positions show a nonstationary trend with highly unpredictable price pattern over time. However, all the variable can be seen to move together closely, which suggests a close link in the spots prices of BL and WT, together with the first months' futures contract. This preliminary level of information about the relationships between variables, suggests potential long term equilibrium, which further empirical testing could confirm. Figure 5.3 portrays a stable graphical position of the joint variables given log differenced level, against outcome in figure 5.2. Again as achieved in chapter 4, a more detailed examination will be carried out in section 5.5.2 below, where the applied variables will be examined for unit root.

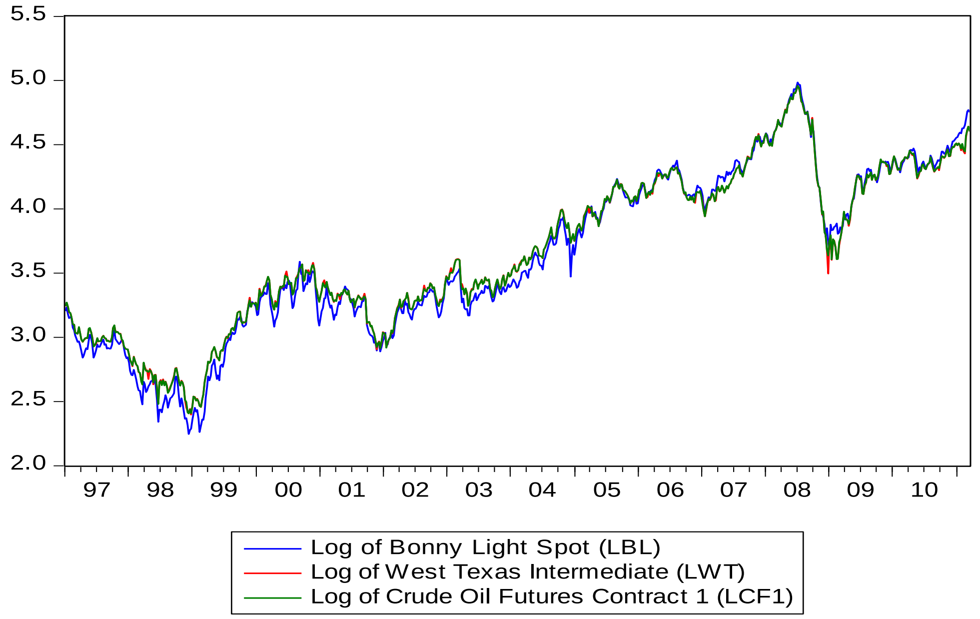



**Figure 5. 2: Common movements of variables graphs at log normal level**

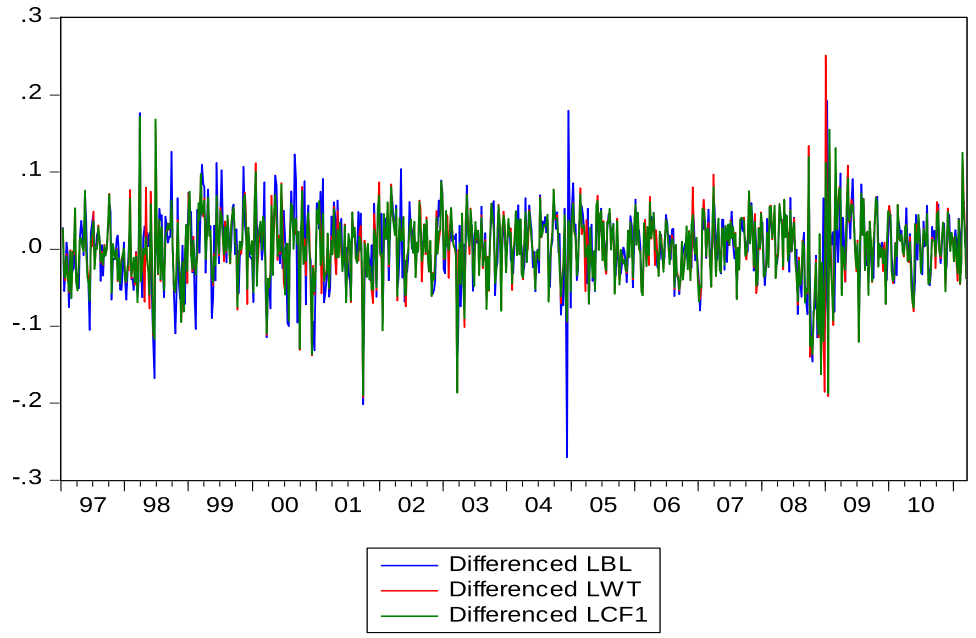



**Figure 5.3: Common movements of variables graphs at log differenced level**

## 5.5 Empirical Analysis and Results

This empirical section aims to fulfil the overall objective of the chapter that targets the institution of price discovery mechanism for BL and WT spots and by extension the crude oil *SWFs*. Achieving this aim is essentially base on testing two hypotheses ***H5A*** and ***H5B***, The data shall be analysed by applying the unit roots procedures of ADF and PP to confirm if the data is stable or otherwise. Granger causality is employed to determine the direction of causation. However since Granger has suggested that cointegration is not causation, Engle-Granger ECM and Johansen VECM will be applied to understand if any long-run equilibrium relationship exists among the variables. Equally, dynamic relationships will be examined using the error correction procedures of Engle-Granger ECM and Johansen VECM. The existence of such long-run equilibrium and short-term dynamic relationships could help to establish a price discovery mechanism and thus lead to acceptance or rejection of the research hypotheses.

### 5.5.1 Tested Series Pairs

Specific variable relationships were estimated in series pairs and also given general series. For clarity and ease of understanding, this section will explain the tested series, both in pairs and in general form. These series will be tested in log forms and are based on the variables of observation which emanate from the crude oil spots of Bonny Light ($LBL_t$), the West Texas Intermediate ($LWL_t$) and their four (4) successive months' futures contracts ($LCF1_t$ $LCF2_t$ $LCF3_t$ $LCF4_t$). Tables 5.4 - 5.7 below present and explain the tested series, with the general series comprising a relationship that includes all the applied variables, specified as; $LBL_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$ and $LWT_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$. These general series which reflects the estimation of the two spots of Bonny Light and West Texas Intermediate will be largely tested as an alternative series in trying to improve results from tested series pairs. Technically, all the variables related to cointegration procedures are presented in log form, whereas the ones analysing ECMs are seen in log difference level form, due to the different needs in analysing each situation, as reflected in the empirical application section with both cointegration and ECMs specifications and also clearly presented in Table 5.1.

**Table 5.4: Description of tested series for *BL* and futures contracts at log levels**

| Series Pair | Specification | Series Pair | Specification |
|---|---|---|---|
| Series Pair 4A11 | $LBL_t = LCF1_t$ | Series Pair 4A21 | $LCF1_t = LBL_t$ |
| Series Pair 4A12 | $LBL_t = LCF2_t$ | Series Pair 4A22 | $LCF2_t = LBL_t$ |
| Series Pair 4A13 | $LBL_t = LCF3_t$ | Series Pair 4A23 | $LCF3_t = LBL_t$ |
| Series Pair 4A14 | $LBL_t = LCF4_t$ | Series Pair 4A24 | $LCF3_t = LBL_t$ |

**Table 5.5: Description of tested series for *WT* and futures contracts at log levels**

| Series Pair | Specification | Series Pair | Specification |
|---|---|---|---|
| Series Pair 4B11 | $LWT_t = LCF1_t$ | Series Pair 4B21 | $LCF1_t = LWT_t$ |
| Series Pair 4B12 | $LWT_t = LCF2_t$ | Series Pair 4B22 | $LCF2_t = LWT_t$ |
| Series Pair 4B13 | $LWT_t = LCF3_t$ | Series Pair 4B23 | $LCF3_t = LWT_t$ |
| Series Pair 4B14 | $LWT_t = LCF4_t$ | Series Pair 4B24 | $LCF4_t = LWT_t$ |

The series pairs in Tables 5.4 and 5.5 above were specifically tested in the case of determining long-run relationships among the variables of Bonny Light and West Texas spots against the chosen futures contracts for four (4) successive months. The series pairs in tables 5.6 and 5.7 below were used in determining the short-run dynamics among variables; the difference is highlighted by change ($\Delta$) notation in the variables.

**Table 5.6: Description of tested series for *BL* and futures contracts (difference)**

| Series Pair | Specification | Series Pair | Specification |
|---|---|---|---|
| Series Pair 4C11 | $\Delta \boldsymbol{LBL_t} = \Delta \boldsymbol{LCF1_t}$ | Series Pair 4C21 | $\Delta \boldsymbol{LCF1_t} = \Delta \boldsymbol{LBL_t}$ |
| Series Pair 4C12 | $\Delta \boldsymbol{LBL_t} = \Delta \boldsymbol{LCF2_t}$ | Series Pair 4C22 | $\Delta \boldsymbol{LCF2_t} = \Delta \boldsymbol{LBL_t}$ |
| Series Pair 4C13 | $\Delta \boldsymbol{LBL_t} = \Delta \boldsymbol{LCF3_t}$ | Series Pair 4C23 | $\Delta \boldsymbol{LCF3_t} = \Delta \boldsymbol{LBL_t}$ |
| Series Pair 4C14 | $\Delta \boldsymbol{LBL_t} = \Delta \boldsymbol{LCF4_t}$ | Series Pair 4C24 | $\Delta \boldsymbol{LCF4_t} = \Delta \boldsymbol{LBL_t}$ |

**Table 5.7: Description of tested series for *WT* and futures contracts (difference)**

| Series Pair | Specification | Series Pair | Specification |
|---|---|---|---|
| Series Pair 4D11 | $\Delta \boldsymbol{LWT_t} = \Delta \boldsymbol{LCF1_t}$ | Series Pair 4D21 | $\Delta \boldsymbol{LCF1_t} = \Delta \boldsymbol{LWT_t}$ |
| Series Pair 4D12 | $\Delta \boldsymbol{LWT_t} = \Delta \boldsymbol{LCF2_t}$ | Series Pair 4D22 | $\Delta \boldsymbol{LCF2_t} = \Delta \boldsymbol{LWT_t}$ |
| Series Pair 4D13 | $\Delta \boldsymbol{LWT_t} = \Delta \boldsymbol{LCF3_t}$ | Series Pair 4D23 | $\Delta \boldsymbol{LCF3_t} = \Delta \boldsymbol{LWT_t}$ |
| Series Pair 4D14 | $\Delta \boldsymbol{LWT_t} = \Delta \boldsymbol{LCF4_t}$ | Series Pair 4D24 | $\Delta \boldsymbol{LCF4_t} = \Delta \boldsymbol{LWT_t}$ |

The Granger causality tests with results seen in Tables 5.12, 5.13 and 5.14 below are carried out in a manner which confirms how both variables in the modelled relationships could potentially cause each other. Thus, the above tested series pairs are equally fashioned in similar manner, but among them, the representations of series pair ***4A11*** – series pair ***4A14*** in Table 5.4, series pair ***4B11*** – series pair ***4B14*** in Table 5.5, series pair ***4C11*** – series pair ***4C14*** in Table 5.6 and also series pair ***4D11*** – series pair ***4D14*** in Table 5.7 are of more interest to this research, since these series pairs sought to confirm if the applied crude oil futures contracts are able to explain the chosen spots. With the other series pairs being tested more as a confirmatory process, more attention will be given to the highlighted series pairs.

### 5.5.2 Preliminary Analysis

This section will present preliminary analyses that will open the way to the main empirical analyses in this chapter. Unit roots tests of both Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) are analysed to check that variables from the datasets applied are free from the problems associated with unit root, and hence that the regressions estimated are not spurious. Also, an attempt is made at preliminarily testing the variables using the Engle-Granger two-step procedure for robustness.

#### 5.5.2.1 Augmented Dickey-Fuller and Phillips-Perron Unit root Tests

Tables 5.8 – 5.9 below present the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root results for all applied data as analysed both at level and level difference. The assumption of constant and trend is made based on the ADF model specification in equation (5.1). Adoption of lag length is based on the Schwarz Information Criteria (SIC) decision of *t*-statistic absolute value of greater than 1.6 from Ng and Perron (1995). Table 5.8 has the ADF unit root tests results summary of data series at log and log differenced levels, which includes constant and trends. For the hypotheses assumption, the null is that the series has a unit root, against the alternative that the series has no unit root. The given decision rule is that when ADF statistics > critical values, we do not reject the null hypothesis, which implies that unit-root exists. Also, when critical values > *ADF* statistics, we reject the null hypothesis, implying that unit root does not exist. Thus in this case, unit root clearly exists in all the test outcomes, given the 1% and 5% levels of significance. However, the $\boldsymbol{LBL_t}$ variable is stationary at 5% level of significance with *t*-statistic value of -3.4159, which is greater than the ADF's *t*-statistic of -3.4836. The full results are presented in the first half of Table 5.8.

As suggested above, the tests were conducted based on PP and ADF, with respective results not being far from each other, as evident in the two tables. This is quite expected, given that the fundamentals of the tests are similar. The PP tests here are acting as a confirmatory process, thereby increasing the robustness of the ADF process. The column for lag length depicts a changing pattern for the length selections. This is consistent with the suggestions of numerous simulations findings, such as Ng and Perron (1995), and as explained above. Taking the difference of time series usually results in making non-stationary datasets stationary. The summary of outcomes seen in the second halves of tables 5.8 and 5.9 represents the situation when the series are at log difference. Unit roots test in both instances gave rise to stable data series as indicated by the results' level of significance.

**Table 5.8: ADF unit root results summary (constant and trend)**

| Series | Lag length | ADF *t*-stat | Series | Lag length | ADF *t*-stat |
|---|---|---|---|---|---|
| $LBL_t$ | 1 | -3.4836* | $\Delta LBL_t$ | 0 | -22.112** |
| $LWT_t$ | 3 | -3.2502 | $\Delta LWT_t$ | 2 | -13.999** |
| $LCF1_t$ | 1 | -3.2006 | $\Delta LCF1_t$ | 0 | -23.540** |
| $LCF2_t$ | 1 | -3.1256 | $\Delta LCF2_t$ | 0 | -23.014** |
| $LCF3_t$ | 1 | -3.0395 | $\Delta LCF3_t$ | 0 | -22.906** |
| $LCF4_t$ | 1 | -2.9454 | $\Delta LCF4_t$ | 0 | -22.841** |

*Tests were conducted using Schwarz information criteria. * and ** indicates significance at 5% and 1% respectively . Significant results indicate the null of unit root is rejected.*

**Table 5. 9: PP unit root results summary (constant and trend)**

| Series | Lag length | PP *t*-stat | Series | Lag length | ADF *t*-stat |
|---|---|---|---|---|---|
| $LBL_t$ | 1 | -2.9484 | $\Delta LBL_t$ | 0 | -22.112** |
| $LWT_t$ | 1 | -2.9030 | $\Delta LWT_t$ | 0 | -23.86** |
| $LCF1_t$ | 1 | -2.8339 | $\Delta LCF1_t$ | 0 | -23.540** |
| $LCF2_t$ | 1 | -2.7296 | $\Delta LCF2_t$ | 0 | -22.014** |
| $LCF3_t$ | 1 | -2.6473 | $\Delta LCF3_t$ | 0 | -22.906** |
| $LCF4_t$ | 1 | -2.5638 | $\Delta LCF4_t$ | 0 | -22.841** |

*Tests were conducted using Schwarz information criteria. ** indicates significance at 1%. Significant results indicate the null of unit root is rejected.*

#### 5.5.2.2 Granger Causality Results

The approach here is based on the Granger causality model specified in chapter 3. Testing for causality with time series data could certify if any reasonable link exists between the variables. This will ensure a preliminary basis is founded for the application of cointegration and ECMs, while the Granger causality tests for variables (say A against B) do not indicated if the variables directly cause each other, the test gives some level of information about the variables' relationships. Tables 5.10 and 5.11 below present the Granger causality results for log of Bonny Light spots price (***LBL****$_t$*) against log of futures contract prices (***LCF1****$_t$* **-** ***LCF4****$_t$*) and log of West Texas Intermediate spots price (***LWT****$_t$*) against the stated futures contracts. Twelve lags were employed in the tests since what is being sought is information flow from the past, and using many lags will guarantee that most past information is intact. The *F*-statistics is mainly used for deciding which of the variables Granger cause which as supported with the null hypothesis that variable A does not Granger cause B.

In Tables 5.10 and 5.11, judging from the relatively high *F*-statistics, we can reject the null hypotheses in all tested cases. Therefore, all the variables Granger cause each other. These claims are backed by probability values of zero throughout. A salient point to note here is the size of the *F*-statistics in all cases involving the futures contracts causing the spots, which is bigger than the converse, again this is more prominent in the case of BL than the WT spots. This finding could be seen as very important as it tallies with the expectation, at least with concerning the direction of information flow in the relationships. Also Table 5.12 presents the results of Granger causality for variables ***BL****$_t$* and ***WT****$_t$*. In this regard also, the *F*-statistics revealed that both variables Granger cause each other; again, the *p*-values are zeros, revealing acceptable results.

**Table 5.10: Pairwise Granger Causality Results for *LBL$_t$* against *LCF1t* – *LCF4$_t$***

| Variables interaction ($H_0$) | *F*-Statistic | Probability |
|---|---|---|
| ***LCF1****$_t$* does not Granger Cause ***LBL****$_t$* | 9.8208 | 0.0000 |
| ***LBL****$_t$* does not Granger Cause ***LCF1****$_t$* | 3.6729 | 0.0000 |
| ***LCF2****$_t$* does not Granger Cause ***LBL****$_t$* | 12.682 | 0.0000 |
| ***LBL****$_t$* does not Granger Cause ***LCF2****$_t$* | 3.3736 | 0.0000 |
| ***LCF3****$_t$* does not Granger Cause ***LBL****$_t$* | 12.890 | 0.0000 |
| ***LBL****$_t$* does not Granger Cause ***LCF3****$_t$* | 3.5616 | 0.0000 |
| ***LCF4****$_t$* does not Granger Cause ***LBL****$_t$* | 12.374 | 0.0000 |
| ***LBL****$_t$* does not Granger Cause ***LCF4****$_t$* | 3.6475 | 0.0000 |

*$H_0$ represents null hypothesis. Number of lags = 12.*

**Table 5.11: Pairwise Granger Causality Results for $LWT_t$ against $LCF1_t$ – $LCF4_t$**

| Variables interaction ($H_0$) | $F$-Statistic | Probability |
|---|---|---|
| $LCF1_t$ does not Granger Cause $LWT_t$ | 8.7883 | 0.0000 |
| $LWT_t$ does not Granger Cause $LCF1_t$ | 5.8349 | 0.0000 |
| $LCF2_t$ does not Granger Cause $LWT_t$ | 5.5387 | 0.0000 |
| $LWT_t$ does not Granger Cause $LCF2_t$ | 4.0493 | 0.0000 |
| $LCF3_t$ does not Granger Cause $LWT_t$ | 3.9595 | 0.0000 |
| $LWT_t$ does not Granger Cause $LCF3_t$ | 3.4479 | 0.0000 |
| $LCF4_t$ does not Granger Cause $LWT_t$ | 3.3177 | 0.0001 |
| $LWT_t$ does not Granger Cause $LCF4_t$ | 3.3242 | 0.0001 |

*$H_0$ represents null hypothesis. Number of lags = 12.*

**Table 5.12: Pairwise Granger Causality Results for $LWT_t$ against $LBL_t$**

| Variables interaction ($H_0$) | $F$-Statistic | Probability |
|---|---|---|
| $LWT_t$ does not Granger Cause $LBL_t$ | 10.898 | 0.0000 |
| $LBL_t$ does not Granger Cause $LWT_t$ | 4.5686 | 0.0000 |

*$H_0$ represents null hypothesis. Number of lags = 12.*

### 5.5.2.3 A Preliminary Analysis of Engle-Granger two-step Method

As presented under the unit root tests results above, both the information criteria of AIC and SIC are applied in testing the cointegration relationship here for the purpose of reaching a compromise in the chosen criteria. Tables 5.13, 5.14 and 5.15 below present the results of the Engle-Granger two-step method within which both information criteria of AIC and SIC are adopted. As we can see, the cointegration results in Table 5.18 are the same as the results under the SIC of Table 5.13, either the same as or very close to those under the AIC criterion. Even where the results are different from each other, it tends to be as a consequence of the different number of lags selected which is necessitated by the lag selection process adopted (this claim is supported by Table 5.15, which has the same number of lags selected throughout). Also, Tables 5.14 and 5.15 reveal a similar pattern of results as both AIC and the SIC outcomes precisely equate to each other. As a confirmation of the lag selection claim, from the Table 5.13, we can see that all the numbers of lags selected under each criterion are the same as each other. Hence, the similarity of the results from the information criteria of AIC and SIC is an indication of compromise between the two.

Again, an attempt was made to reach a compromise with type of regression method utilised in attaining the first-step outcome of the Engle-Granger approach. This is given that we could exploit the step with any of the three (3) separate regression estimation processes of Fully Modified OLS (FMOLS) associated with Hansen and Phillips (1990) which uses a semi-parametric correctional method to take care of problems associated with long-run correlation. Alternatively, there are the Canonical Cointegrating Regression (CCR) from Park (1992) and Dynamic OLS (DOLS) of Saikkonen (1992), whose methods employ stationary transformations of regressors data in attaining the least squares estimates and construct an asymptotically efficient estimator which eliminates feedback in the cointegrating system respectively. As in the case of the information criteria results, all the three different regression processes are tested here and they all returned the same results, as seen in Tables 5.14 and 5.15. Both this and the attempt to confirm the information criteria are in order to attain a compromise among the different possible choices and also to increase the robustness of the process.

**Table 5.13: Engle-Granger Two-step Results for $LBL_t$ against $LCF1_t$ – $LCF4_t$**

| Series | Lag length | Information Criteria | Engle-Granger *t*-statistics | Engle-Granger *z*-statistics | *P*-value |
|---|---|---|---|---|---|
| | | | **AIC** | | |
| $LBL_t$ and $LCF1_t$ | 2 | -4.1460 | -6.3890 | -90.578 | 0.0000 |
| $LBL_t$ and $LCF2_t$ | 2 | -4.3750 | -6.9632 | -108.53 | 0.0000 |
| $LBL_t$ and $LCF3_t$ | 2 | -4.3714 | -6.5368 | -93.496 | 0.0000 |
| $LBL_t$ and $LCF4_t$ | 2 | -4.3251 | -5.9115 | -74.576 | 0.0000 |
| ***General series*** | 2 | -4.3612 | -7.2504 | -119.18 | 0.0000 |
| | | | **SIC** | | |
| $LBL_t$ and $LCF1_t$ | 2 | 2 | -6.3890 | -90.578 | 0.0000 |
| $LBL_t$ and $LCF2_t$ | 2 | 2 | -6.9632 | -108.53 | 0.0000 |
| $LBL_t$ and $LCF3_t$ | 0 | 2 | -8.4384 | -131.35 | 0.0000 |
| $LBL_t$ and $LCF4_t$ | 0 | 2 | -7.2013 | -97.229 | 0.0000 |
| ***General series*** | 1 | 2 | -8.4272 | -146.80 | 0.0000 |

*The tests are for general series; $LBL_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$ given different regressions estimates. The results are based on the both AIC and SIC with automated lag selection level at 1% and 5% level of significance as -3.971 and -3.416 given the MacKinnon (1996) critical values table.*

Whilst a general series of four months' futures prices was used here in the cointegration tests, it is just for increased robustness, as the best method for capturing multivariate cointegration is the Johansen procedure tested below.

**Table 5.14: Engle-Granger Two-step Results in different regressions estimates**

| Series | Lag length | Information Criteria | Engle-Granger *t*-statistics | Engle-Granger *z*-statistics | ***P***-value |
|---|---|---|---|---|---|
| | | | **AIC** | | |
| **CCR** | 2 | -4.1460 | -7.2504 | -119.18 | 0.0000 |
| **DOLS** | 2 | -4.3750 | -7.2504 | -119.18 | 0.0000 |
| ***FMOLS*** | 2 | -4.3714 | -7.2504 | -119.18 | 0.0000 |
| | | | **SIC** | | |
| **CCR** | 1 | -4.3444 | -8.4272 | -146.80 | 0.0000 |
| **DOLS** | 1 | -4.3444 | -8.4272 | -146.80 | 0.0000 |
| ***FMOLS*** | 1 | -4.3444 | -8.4272 | -146.80 | 0.0000 |

*The tests are for general series; $LBL_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$ given different regressions estimates. The results are based on the both AIC and SIC with automated lag selection level at 1% and 5% level of significance as -3.971 and -3.416 given the MacKinnon (1996) critical values table.*

**Table 5.15: Engle-Granger Two-step Results in different regressions estimates**

| Series | Lag length | Information Criteria | Engle-Granger *t*-statistics | Engle-Granger *z*-statistics | ***P***-value |
|---|---|---|---|---|---|
| | | | **AIC** | | |
| **CCR** | 2 | -4.1460 | -6.3890 | -90.578 | 0.0000 |
| **DOLS** | 2 | -4.1460 | -6.3890 | -90.578 | 0.0000 |
| ***FMOLS*** | 2 | -4.1460 | -6.3890 | -90.578 | 0.0000 |
| | | | **SIC** | | |
| **CCR** | 1 | -4.1273 | -6.3890 | -90.578 | 0.0000 |
| **DOLS** | 1 | -4.1273 | -6.3890 | -90.578 | 0.0000 |
| ***FMOLS*** | 1 | -4.1273 | -6.3890 | -90.578 | 0.0000 |

*The tests are for general series; $LWT_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$ given different regressions estimates. The results are based on the both AIC and SIC with automated lag selection level at 1% and 5% level of significance as -3.971 and -3.416 given the MacKinnon (1996) critical values table.*

### 5.5.3 Interpreting Empirical Findings

As already noted within the context of the literature review chapter and section 5.2 above, some relevant past empirical contributions will be specifically tied to the empirical analysis in this section, because of their closeness to the processes adopted here. For instance, one problem Quan (1992) and also, Hammoudeh et al. (2003) attempted to address is the power of successive information exhibited by futures prices in determining spots prices. This is the same as measuring the speed of correction, which this section will seek to corroborate in relation to applied variables. This section will take the task of interpreting the results for both the Engle-Granger two-step method and the Johansen test with their respective ECMs. Essentially, hypotheses ***H5A*** with the null of; *West Texas Intermediate futures are not an efficient means of managing price risk in Bonny Light spots* and ***H5B*** with the null of; *there is no short-run adjustment back to long-run equilibrium in the variables' relationships* are respectively tested here. The tests were carried out with specified series pairs in tables 5.6 and 5.7, but as the main interest here is to confirm if the WT futures contracts could help to determine the BL spots, more attention is given to this aspect.

#### 5.5.3.1 Interpreting Engle-Granger two-steps Procedure Results

This section will interpret the results of the tests carried out using the Engle-Granger two-step procedure. The procedure is a very important component of this chapter's empirical work, it is the means of empirically answering the main research question of whether WT futures are efficient predictors of BL spots. Therefore, the application will ultimately test hypothesis ***H5A*** set above. From the results presented in Tables 5.16 and 5.17, the main indicators of concern are the adjusted R-squared ($\widehat{R^2}$) and the DW statistics. An R-squared of nearly one (1) is normally a good indicator of explained relationship. On the basis of the results from the two tables, we may be tempted to say the regressions obtained are spurious. However since we are not establishing cointegration relationship on the strength of the first-step regression, we accept whatever outcome, at least as a necessary step to moving forward. Therefore, for the two variables of crude oil spots and futures prices to cointegrate in each case, it does not matter if the residual is white noise, that is, with a DW indicator of less than 2.

**Table 5.16: Engle-Granger First Step Regression for $LBL_t$ *against* $LCF1_t$-$LCF4_t$**

| Regression Models | $\alpha$ | $\beta$ | $\widehat{R^2}$ | DW-Stat |
|---|---|---|---|---|
| $LBL_t = \alpha + \beta LCF1_t + \varepsilon_t$ | -0.3127<br>(-8.8616) | 1.0766<br>(113.47) | 0.9942 | 0.4319 |
| $LBL_t = \alpha + \beta LCF2_t + \varepsilon_t$ | -0.2901<br>(-9.3995) | 1.0691<br>(128.97) | 0.9956 | 0.4484 |
| $LBL_t = \alpha + \beta LCF3_t + \varepsilon_t$ | -0.2621<br>(-6.6176) | 1.0610<br>(99.767) | 0.9946 | 0.3547 |
| $LBL_t = \alpha + \beta LCF4_t + \varepsilon_t$ | -0.2288<br>(-4.2585) | 1.0519<br>(72.910) | 0.9925 | 0.2601 |

*Figures parenthesis are t-statistics, the tests are based on model specification;* $(Y_t = \alpha + \beta X_t + \varepsilon_t)$ given in equation (5.1)

**Table 5.17: Engle-Granger First Step Regression for $LWT_t$ *against* $LCF1_t$ - $LCF4_t$**

| Regression Models | $\alpha$ | $\beta$ | $\widehat{R^2}$ | DW-Stat |
|---|---|---|---|---|
| $LWT_t = \alpha + \beta LCF1_t + \varepsilon_t$ | 0.0061<br>(3.0638) | 0.9983<br>(1869.9) | 0.9998 | 1.9574 |
| $LWT_t = \alpha + \beta LCF2_t + \varepsilon_t$ | 0.0326<br>(1.4687) | 0.9898<br>(166.24) | 0.9981 | 0.3513 |
| $LWT_t = \alpha + \beta LCF3_t + \varepsilon_t$ | 0.0712<br>(1.6897) | 0.9785<br>(86.459) | 0.9952 | 0.1955 |
| $LWT_t = \alpha + \beta LCF4_t + \varepsilon_t$ | 0.1108<br>(1.8508) | 0.9675<br>(60.200) | 0.9918 | 0.1414 |

*Figures parentheses are t-statistics, the tests are based on model specification;* $(Y_t = \alpha + \beta X_t + \varepsilon_t)$ *given in equation (5.1).*

The model specification in equation (5.3) estimates residuals which essentially measure the long-run position in a presumed relationship; this characteristically, is the second-step of the Engle-Granger two-steps procedure. The graphs below in figure 5.4 indicate the estimated residuals of the applied variables of $\boldsymbol{LBL_t}$, $\boldsymbol{LWT_t}$, $\boldsymbol{LCF1_t}$, $\boldsymbol{LCF2_t}$, $\boldsymbol{LCF3_t}$ and $\boldsymbol{LCF4_t}$ and since the residuals are taken from the cointegrated variables situation, they all appear to be stable. In Engle-Granger's reasoning, adopting the model in equation (5.3) will mean having passed through equation (5.2), since it ultimately uses the generated simple regression equation based on equation (5.1) that the adopted variables passed through to get cointegrated.

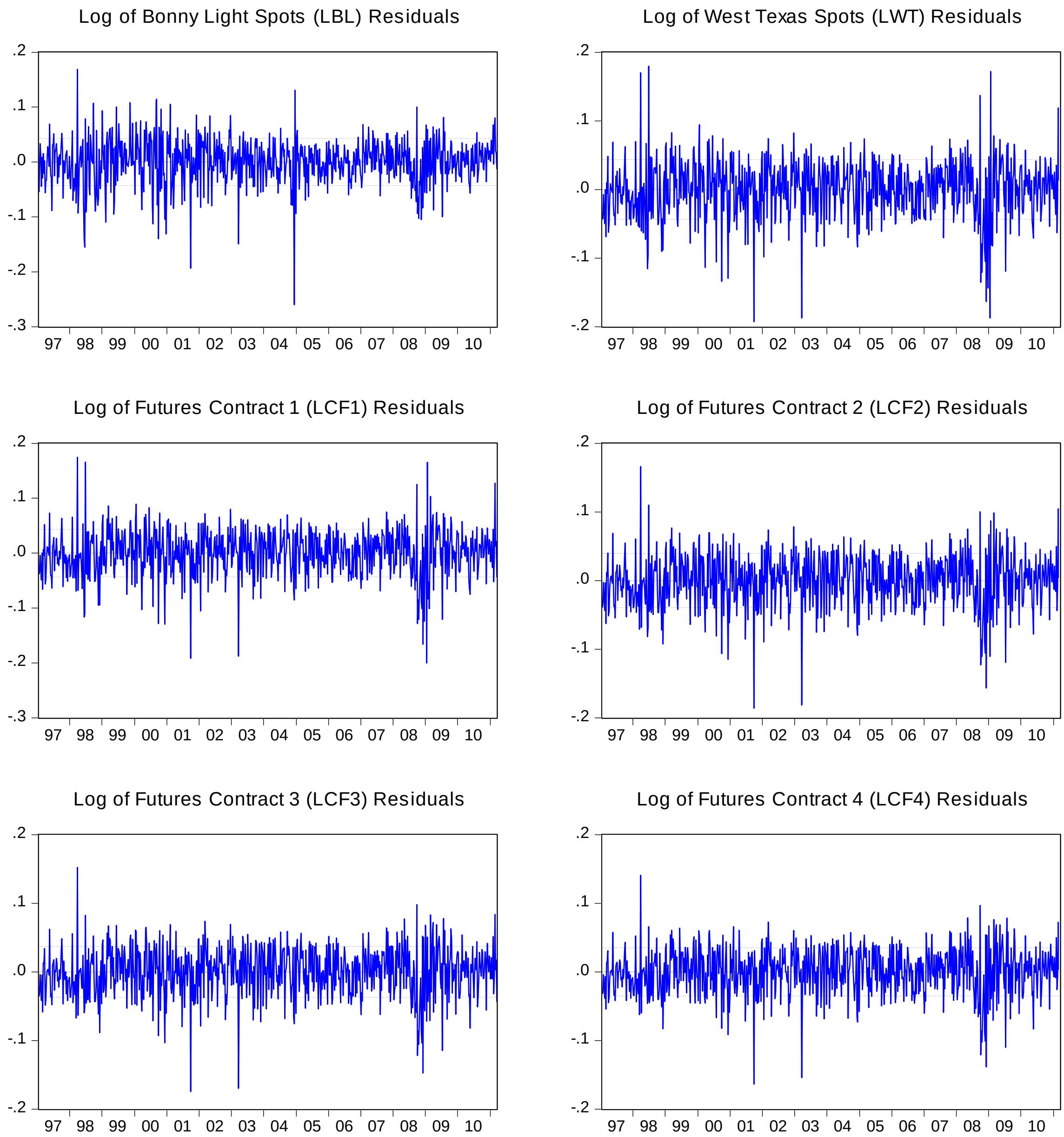



**Figure 5.4: Log of variables residuals**

A careful look at the results in Tables 5.18 and 5.19 will reveal Engle-Granger's indicators of tau-statistics (*t*- statistics) and the normalised auto-correlation coefficient (*z*-statistics) utilised alongside other measures of lag length, information criteria and probability (*p*) values. In determining the existence or nonexistence of cointegration between the chosen variables, the yardstick for decision is judging between both the indicators of *t*-statistic and *z*-statistic with/and the 1% and 5% levels of significance (as chosen here) given the MacKinnon simulation table (Mackinnon, 1991). Thus, if the *t*-statistic > the level of significance (1% and 5% in our instance), we reject the null hypothesis of no cointegration and hence conclude that a long-run relationship exists.

The *z*-statistic, being a very important indicator, is also compared in the same manner given their critical values (Said and Dickey, 1984). Given the said rule and as applied in other research all the results here return overwhelming evidence of cointegration in all the variables' relationships, as seen in Tables 5.18 and 5.19.

Also, since the Engle-Granger procedure is more or less a test of unit root, *t*-statistics in the tables are all lower than the 1% and 5% level of significance, that is, -3.9706 and -3.4159 respectively given the ADF table (Said and Dickey, 1984), this indicates stationarity, suggesting that the linear combination of the joint variables are stable, that is *I(0)*. This is against the individual variables that are non-stationary as seen in the unit root test for individual variables in tables 5.8 and 5.9 that is *I(1)*. This is in line with the proposition of Granger's representation theorem which suggests that the linear combination of joint variables is stable that is *I(0)*. Ultimately, with a low *p*-value level of 0.000, all the results are reliable. The test reflects the above hypothesis ***H5A*** that crude oil spots and futures are not cointegrated. As suggested above, the constant deterministic assumption was applied in each case whereby both the AIC and SIC information criteria were separately examined with lags selected as indicated in the above lag selection section. These tests were conducted given a bivariate stand of testing the crude oil spots against the distinct monthly periods ($LCF1_t$, $LCF2_t$, $LCF3_t$ and $LCF4_t$). However a multivariate general series comprising of the spots against the four different futures was equally tested in both cases for a contrasting outlook (results in Tables 5.14 and 5.15 above).

**Table 5.18: Engle-Granger Two-step for $LBL_t$ against $LCF1_t$ – $LCF4_t$**

| Series | Lag length | Engle-Granger *t*-statistics | Engle-Granger *z*-statistics | *P*-value |
|---|---|---|---|---|
| $LBL_t$ and $LCF1_t$ | 2 | -6.3890 | -90.578 | 0.0000 |
| $LBL_t$ and $LCF2_t$ | 2 | -6.9632 | -108.53 | 0.0000 |
| $LBL_t$ and $LCF3_t$ | 0 | -8.4384 | -131.35 | 0.0000 |
| $LBL_t$ and $LCF4_t$ | 0 | -7.2013 | -97.229 | 0.0000 |
| ***General series*** | 1 | -8.4272 | -146.80 | 0.0000 |

*The tests were carried using the SIC information criteria. General series represents LBL = LCF1 LCF2 LCF3 LCF4. All results are Significant at both 1% and 5% level.*

**Table 5.19: Engle-Granger Two-step Results for $LWT_t$ against $LCF1_t$ – $LCF4_t$**

| Series | Lag length | Engle-Granger *t*-statistics | Engle-Granger *z*-statistics | *P*-value |
|---|---|---|---|---|
| $LWT_t$ and $LCF1_t$ | 8 | -6.4160 | -143.58 | 0.0000 |
| $LWT_t$ and $LCF2_t$ | 2 | -5.3264 | -58.547 | 0.0000 |
| $LWT_t$ and $LCF3_t$ | 2 | -4.4438 | -39.872 | 0.0016/0.0007 |
| $LWT_t$ and $LCF4_t$ | 2 | -4.0441 | -32.611 | 0.0065/0.00035 |
| ***General series*** | 1 | -22.079 | -976.62 | 0.0000/0.0001 |

*The tests were carried out using the SIC information criteria. General series represents LWT = LCF1 LCF2 LCF3 LCF4. All results are Significant at both 1% and 5% level.*

### 5.5.3.2 Findings

In all the instances tested, the results returned strong evidence of cointegration among tested variables, as decided by the interaction between the test indicators of *t* and *z*-statistics at the 1%, 5% and 10% levels of significance, and supported by the *p*-values of less than 5% recorded in virtually all instances. Thus, hypothesis ***H5A*** we reject the null ($H_0$) in favour of the alternative ($H_1$). By implication, the results indicate that both the Bonny Light (BL) and West Texas Intermediate (WT) spots are cointegrated or have long run relationships with CF1, CF2, CF3 and CF4 (futures prices). This conclusion essentially answers the main research question of; *are the WT futures prices able to predict the BL spots price?* This is in addition to the associated questions; *is there any need for a BL futures market?* Also, *at what point is the need tenable?* For the main question the answer is ***yes***, WT futures are efficient predictors of the BL spots prices, whereas, the answer to the secondary question is ***no.*** Therefore, the Nigerian government should not bother to invest in the very expensive process of creating a futures market for its BL, since West Texas Intermediate (WT) futures can act as a predictor or proxy for the missing BL futures market, thus effectively filling that void at no cost. Broadly speaking, the results imply that WT futures prices or futures market can be used to hedge price risk for BL spots. Therefore, WT futures are efficient means of managing price risk in BL spots.

#### 5.5.3.3 Interpreting Johansen Test Results

This section will interpret the results of tests carried out using the Johansen procedure. Here too, the purpose of the tests is to empirically answer the main research question of whether the WT futures are efficient predictors of BL spots. The reason for implementing these tests is mainly to move the previous Engle-Granger procedure to the next level of determining the number of cointegrating ranks the test has, a technique which the Engle-Granger lacks. This will increase the robustness of the entire process and again, confirm hypothesis ***H5A*** in a different process. As specified under the empirical application section earlier, the method here uses cointegration as a hypothesis of reduced long-run impact ($\boldsymbol{\Pi = \alpha\beta'}$). This same assumption is adopted here as an empirical tool for measuring cointegration, but with refined hypotheses to fit the purpose. We have seen that equations (5.6) and (5.7) respectively represent maximum eigenvalues and trace statistics models based on Johansen and Juselius (1990). The two specifications represent sets of tests statistics usually examined as indicators of cointegration presence in the Johansen test. The tests here will thus reflect the modelled hypothesis in Johansen and Juselius (1990) tests conducted using Danish and Finnish data. The tests were conducted using the hypothesis ($\boldsymbol{r \leq 1}$) against the alternative ($\boldsymbol{H_1}$). Using the same approach, the results in tables 5.20 – 5.23 were obtained.

Tables 5.20 and 5.21 reflect the two general tests' series pairs results which sought to confirm if LBL and LCF1 LCF2 LCF3 LCF4, and LWT and LCF1 LCF2 LCF3 LCF4 are collectively cointegrated. Tables 5.22 and 5.23 sought to confirm if the logs of separate monthly futures contracts are individually cointegrated with LBL and LWT spots. In order to facilitate these tests, as done in Johansen and Juselius, the trace and the maximum eigenvalue statistics indicators which constitute the tests statistics are the decision yardsticks. Therefore, in determining the cointegrating relationship we employ the hypothesis $\boldsymbol{r = 0}$ going to $\boldsymbol{r = k - 1}$ as far as we could fail to reject the hypothesis of cointegration. The decision point for determining the existence of cointegration lies in the trace or maximum eigenvalue being greater than the critical values at the chosen level and as usual the *p*-value provides confirmation. For instance, in both tables 5.20 and 5.21 all the trace and the maximum eigenvalues are greater than the critical values, thus resulting in four cointegrating equations at both 1% and 5% levels of significance.

**Table 5.20: Johansen Test Results for General Series *($LBL_t$ and $LCF1_t$-$4_t$)***

| Variables Relationship | $H_0$ | $\lambda_{trace}$ Stat | Critical Value 1% | 5% | $\lambda_{max}$ Stat | Critical Value 1% | 5% | P-Values |
|---|---|---|---|---|---|---|---|---|
| Gen series | r = 0 | 333.92 | 77.82 | 69.82 | 182.82 | 39.37 | 33.88 | 0.0001 |
| | r ≤ 1 | 151.11 | 54.68 | 47.86 | 80.53 | 32.72 | 27.58 | 0.0000 |
| | r ≤ 2 | 70.58 | 35.49 | 29.80 | 49.45 | 25.86 | 21.13 | 0.0000 |
| | r ≤ 3 | 21.12 | 19.94 | 15.50 | 20.95 | 18.52 | 14.27 | 0.006/ 0.004 |

*General series estimated based on:* $LBL_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$

**Table 5.21: Johansen Test Results for General Series *($LWT_t$ and $LCF1_t$-$4_t$)***

| Variables Relationship | $H_0$ | $\lambda_{trace}$ Stat | Critical Value 1% | 5% | $\lambda_{max}$ Stat | Critical Value 1% | 5% | P-Values |
|---|---|---|---|---|---|---|---|---|
| Gen series | r = 0 | 607.32 | 77.819 | 69.819 | 97.110 | 39.370 | 33.877 | 0.0001 |
| | r ≤ 1 | 277.17 | 54.682 | 47.856 | 25.792 | 32.715 | 27.584 | 0.0001 |
| | r ≤ 2 | 94.946 | 35.458 | 29.797 | 20.675 | 25.861 | 21.132 | 0.0000 |
| | r ≤ 3 | 21.449 | 19.937 | 15.495 | 18.844 | 18.520 | 14.265 | 0.006/0.003 |

*General series estimated based on:* $LWT_t = LCF1_t\ LCF2_t\ LCF3_t\ LCF4_t$

**Table 5.22: Johansen Test Results for General Series $LWT_t$ against $LCF1_t$ - $LCF4_t$**

| Variables Relationship | $H_0$ | $\lambda_{trace}$ Stat | Critical Value 1% | 5% | $\lambda_{max}$ Stat | Critical Value 1% | 5% | P-Values |
|---|---|---|---|---|---|---|---|---|
| $LWT_t$ and $LCF1_t$ | r = 0 | 97.656 | 19.937 | 15.495 | 97.110 | 18.520 | 14.265 | 0.000 |
| $LWT_t$ and $LCF2_t$ | r = 0 | 26.199 | 19.937 | 15.495 | 25.792 | 18.520 | 14.265 | 0.001/0.000 |
| $LWT_t$ and $LCF3_t$ | r = 0 | 20.989 | 19.937 | 15.495 | 20.675 | 18.520 | 14.265 | 0.007/0.004 |
| $LWT_t$ and $LCF4_t$ | r = 0 | 19.033 | 19.937 | 15.495 | 18.844 | 18.520 | 14.265 | 0.006/0.004 |

**Table 5.23: Johansen Test Results for General Series $LBL_t$ against $LCF1_t$ - $LCF4_t$**

| Variables Relationship | $H_0$ | $\lambda_{trace}$ Stat | Critical Value 1% | 5% | $\lambda_{max}$ Stat | Critical Value 1% | 5% | P-Values |
|---|---|---|---|---|---|---|---|---|
| $LBL_t$ and $LCF1_t$ | r = 0 | 41.26 | 19.94 | 15.50 | 40.75 | 18.52 | 14.27 | 0.0000 |
| $LBL_t$ and $LCF2_t$ | r = 0 | 49.34 | 19.94 | 15.50 | 48.90 | 18.52 | 14.27 | 0.0000 |
| $LBL_t$ and $LCF3_t$ | r = 0 | 44.59 | 19.94 | 15.50 | 44.26 | 18.52 | 14.27 | 0.0000 |
| $LBL_t$ and $LCF4_t$ | r = 0 | 37.62 | 19.94 | 15.50 | 37.37 | 18.52 | 14.27 | 0.0000 |

#### 5.5.3.4 Findings

An issue of technical importance here is the number of cointegrating ranks (4) found in the relationships under the general test (Tables 5.20 and 5.21). This level of finding was not possible with the Engle-Granger process for the reason of technical superiority. Essentially, the results reject null hypothesis ($\boldsymbol{H_0}$) in favour of the alternative ($\boldsymbol{H_1}$). Therefore, *WT* futures are an efficient means of managing price risk in BL spots. Equally, the results in Tables 5.22 and 5.23 indicate one (1) cointegrating equation in each individual case at both 1% and 5% levels of significance. Again the results also reject the hypotheses of no cointegration in all the individual equations. Interestingly, the results here too have confirmed the position indicated by the Engle-Granger two-step test of huge long run relationships between the tested variables. This suggests that, as we did under the Engle-Granger two-step, here too we should reject the null hypothesis ($\boldsymbol{H_0}$) ***H5A*** in favour of the alternative ($\boldsymbol{H_1}$). Therefore, WT futures are efficient means of managing price risk in BL spots. Also, this conclusion essentially answers the main research question, *are the WT futures prices able to predict the BL spots price?*, as well as the associated questions; *is there any need for BL futures market?* Also, *at what point is the need tenable?* Finally, we arrive at the same broad meaning, that WT futures prices or futures market can be used to hedge price risk for *BL* spots.

#### 5.5.3.5 Engle-Granger Error Correction Model Results

Given the above Engle-Granger Two-step results, model specification in equation (5.4) is applied on variables of Bonny Light (BL) and West Texas Intermediate (WT) spots against the four successive months' crude oil futures contracts. This process resulted to the Engle-Granger error corrections results seen in Tables 5.24 and 5.25 below. The notation λ already defined as the coefficient of the residual in section 5.3.3, is represented in one of the columns and it constitutes the main index of interest here. As with other coefficient, the size will range between 0 and 1, with results nearer to 1 indicating a better correction process. Other important measures included in the tables are the constant term (Θ) and the *t*-statistics which capture if the tests results are significant or not. As known from principles of statistical inference, for any result to be significant, the *t*-statistic has to be up to or above +/-2. Given the results in Table 5.24, only the first test between $\boldsymbol{\Delta LBL_t}$ and $\boldsymbol{\Delta LCF1_t}$ returned a significant outcome, as can be seen by the *t*-statistic value of -21.345 couple with an error recovery of -0.361, indicating a speed of 36%. All other results due to the Engle-Granger ECM for variable interactions $\boldsymbol{\Delta LBL_t}$ and $\boldsymbol{\Delta LCF2_t - \Delta LCF4_t}$ returned non significant outcomes, as represented by RNS in the table. In the relationships for $\boldsymbol{\Delta LWT_t}$ and $\boldsymbol{\Delta LCF1_t - \Delta LCF4_t}$ at least four results are significant.

**Table 5.24: Engle-Granger's ECMs results for $\boldsymbol{\Delta LBL_t}$ against $\boldsymbol{\Delta LCF1_t - \Delta LCF4_t}$**

| Error Correction Model/Representation | Θ | λ | *t*-Stat |
|---|---|---|---|
| $\boldsymbol{\Delta LBL_t} = 0.0001 + 0.7783\boldsymbol{\Delta LCF1_t} - 0.0361\boldsymbol{\varepsilon_{t-1}} + \boldsymbol{u_t}$ | 0.0001<br>(0.3937) | -0.0361<br>(-4.8016) | -21.345<br>(0.0000) |
| $\boldsymbol{\Delta LCF1_t = \Theta + \gamma \Delta LBL_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LBL_t = \Theta + \gamma \Delta LCF2_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta CF2_t = \Theta + \gamma \Delta LBL_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LBL_t = \Theta + \gamma \Delta LCF3_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LCF3_t = \Theta + \gamma \Delta LBL_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LBL_t = \Theta + \gamma \Delta LCF4_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LCF4_t = \Theta + \gamma \Delta LBL_t - \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |

*Results in this table are for interactions between $\boldsymbol{\Delta LBL_t}$ against individuals $\boldsymbol{\Delta LCF1_t - \Delta LCF4_t}$ and vice versa. RNS implies results not Significant. The tests were based on model specification: $\boldsymbol{\Delta Y_t = \Theta + \gamma \Delta X_t + \lambda \varepsilon_{t-1} + u_t}$ in equation (5.4)*

Similarly table 5.25 below portrays the same yardstick for measurement, although the outcome differs greatly from the one in Table 5.24. To begin with only a few relationships here returned non significant outcomes. Where the results are significant, the error mechanism is not constant, as there is no definite pattern. Most importantly and of some concern is the relationship of interest that is, the ability of crude oil futures contracts to determine the chosen spots, was only significant in the first month's futures contract. That is under the relationship $\boldsymbol{\Delta LWT_t}$ and $\boldsymbol{\Delta LCF1_t}$ as seen in Table 5.25. Again, as explained above, given the outcome of Table 5.24, this position will not be too worrying, at least for now, until we are able to confirm the outcome of the Johansen VECM, which is a better error correction testing procedure.

**Table 5.25: Engle-Granger's ECMs results for $\Delta LWT_t$ against $\Delta LCF1_t - \Delta LCF4_t$**

| Error Correction Model/Representation | Θ | λ | *t*-Stat |
|---|---|---|---|
| $\boldsymbol{\Delta LWT_t} = 8.51\text{E}-06 + 0.9874\boldsymbol{\Delta LCF1_t} - 0.1415\boldsymbol{\varepsilon_{t-1}} + \boldsymbol{u_t}$ | 8.51E-06 (0.083) | -0.1415 (-2.878) | -11.308 (0.000) |
| $\Delta LCF1_t = 2.78\text{E}-05 + 0.9533\Delta LWT_t - 0.2527\varepsilon_{t-1} + u_t$ | 2.78E-05 (0.268) | -0.2527 (-20.83) | -11.084 (0.000) |
| $\boldsymbol{\Delta LWT_t = \Theta + \gamma \Delta LCF2_t - \lambda \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LCF2_t} = 0.0004 - 3.9869\boldsymbol{\Delta LWT_t} - 0.5885\boldsymbol{\varepsilon_{t-1}} + \boldsymbol{u_t}$ | 0.0004 (0.122) | -0.5885 (-3.507) | -7.7283 (0.000) |
| $\boldsymbol{\Delta LWT_t = \Theta + \gamma \Delta LCF3_t - \lambda \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LCF3_t} = -3.84\text{E}-05 - 0.0116\boldsymbol{\Delta LWT_t} - \boldsymbol{\lambda \varepsilon_{t-1}} + \boldsymbol{u_t}$ | -3.84E-05 (-0.176) | -0.0116 (-2.102) | -14.610 (0.000) |
| $\boldsymbol{\Delta LWT_t = \Theta + \gamma \Delta LCF4_t - \lambda \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |
| $\boldsymbol{\Delta LCF4_t = \Theta + \gamma \Delta LWT_t - \lambda \varepsilon_{t-1} + u_t}$ | RNS | RNS | RNS |

*Results in this table are for interactions between $\boldsymbol{\Delta LWT_t}$ against individuals $\boldsymbol{\Delta LCF1_t - 4_t}$ and vice versa. RNS implies results not Significant. The tests were based on model specification: $\boldsymbol{\Delta Y_t = \Theta + \gamma \Delta X_t + \lambda \varepsilon_{t-1} + u_t}$ in equation (5.4)*

### 5.5.3.6 Findings

The outcome here suggests that 36% of error due to differencing in the cointegration analysis is corrected every week, given that we applied weekly data. This result confirms hypothesis ***H5B***, which sought to confirm the existence of long run equilibrium in the variables relationship tested for cointegration. The outcome of the results suggests that we reject the null hypothesis ($\boldsymbol{H_0}$) of no short run adjustment back to long run equilibrium in the variables relationships in favour of the alternative hypothesis ($\boldsymbol{H_1}$). Although the condition warranting this conclusion in the relationships BL against CF1 – CF4 is only true for the relationship between $\boldsymbol{\Delta LBL_t}$ and $\boldsymbol{\Delta LCF1_t}$, the situation should not be of great concern, as we are more interested in just that relationship between BL and the first months' contract of CF1. Also, since the same analysis is pursued with the Johansen's procedure, we need only be concerned if the Johansen method equally returns a similar outcome of non significance. Therefore, the focus here is on agreeing that the variables are able to come back to equilibrium after the long run relationships are exploited, significantly with good speed (36% per week).

#### 5.5.3.7 Johansen Vector Error Correction Model Results

The results in Table 5.26 represent the VECM finding for relationships under series pairs ***4A11*** - ***4A14*** and ***4C11*** – ***4C14***. These results ultimately test for both cointegrating relationships and error correction speed for the *BL* spots against the WT futures contracts in four successive months. Table 5.27 is the similar results tested under series pairs ***4B11*** – ***4B14*** and ***4D11*** – ***4D14***, which are based on the possible cointegrating relationships and error correction speed for WT spots with their respective four successive months' futures contracts. The two parameters of interest here are the $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ notations described to represent respective adjustment speed and cointegrating vectors under section 5.3.4. All the results under cointegrating vectors relationships in both Tables 5.26 and 5.27 returned very significant outcomes. Also, their respective error adjustment parameters equally have largely significant. For instance the adjustment coefficient for cointegrating equation 1 under series pair ***4C11*** is negative as expected and it shows that up to 20% of the errors are corrected every week for *BL* spots. Again the futures contract in month 1 is positive as expected, by far a non-significant results (with *t*-statistics a much lot lower than the threshold of 2). This trend of negative and significant results follows throughout for the BL spots, whereas in the case of futures contracts for the second, third and fourth months, the situation is not the same, as results are non-significant.

**Table 5.26: VECM for BL spots and future contracts (*CF1-4*) at level and differenced**

| **Series pair** | **Series pair 4A11** | | **Series pair 4A12** | | **Series pair 4A13** | | **Series pairs 4A14** | |
|---|---|---|---|---|---|---|---|---|
| Cointegration Vectors ($\boldsymbol{\beta}$) (t-stat) | $\boldsymbol{LBL_t}$ | $\boldsymbol{LCF1_t}$ | $\boldsymbol{LBL_t}$ | $\boldsymbol{LCF2_t}$ | $\boldsymbol{LBL_t}$ | $\boldsymbol{LCF3_t}$ | $\boldsymbol{LBL_t}$ | $\boldsymbol{LCF4_t}$ |
| | 1.0000 | -1.0779 (130.38) | 1.0000 | -1.0728 (-53.99) | 1.0000 | -1.0677 (-19.61) | 1.0000 | -1.0623 (84.777) |
| Series pair | Series pair 4C11 | | Series pair 4C12 | | Series pair 4C13 | | Series pair 4C14 | |
| Adjustments Parameter ($\boldsymbol{\alpha}$) (t-stat) | $\boldsymbol{\Delta LBL_{t-1}}$ | $\boldsymbol{\Delta LCF1_{t-1}}$ | $\boldsymbol{\Delta LBL_{t-1}}$ | $\boldsymbol{\Delta LCF2_{t-1}}$ | $\boldsymbol{\Delta LBL_{t-1}}$ | $\boldsymbol{\Delta LCF3_{t-1}}$ | $\boldsymbol{\Delta LBL_{t-1}}$ | $\boldsymbol{\Delta LCF4_{t-1}}$ |
| | -0.2038 (-5.9805) | 0.0096 (0.2942) | -0.2722 (6.9823) | -0.0462 (1.3481) | -0.2190 (6.1875) | -0.0392 (1.3435) | -0.1556 (5.1352) | -0.0230 (0.9791) |
| LM t-stat at 12 lags (*P*-value) | 1.8118 (0.7703) | | 3.3626 (0.4991) | | 5.9691 (0.2015) | | 6.5681 (0.1606) | |

*All figures in parentheses are t-statistics except those in the LM row which are the p-values*

Similarly, as can be clearly seen, the results in Table 5.27 portray the same characteristics as the ones obtained in Table 5.26. Thus, by this development, we could infer the same concluding remark about them as with the results in Table 5.26. Hence the results from VECM for WT spots clearly support the position implied by the results from BL spots. As can be seen from the results in both Tables 5.26 and 5.27, their respective LM-test results are within the acceptable region, with the *p*-values rejecting any serial correlation.

**Table 5.27: VECM for *WT* spots and future contracts (*CF1-4*) at level and differenced**

| **Series pair** | **Series pair 4B11** | | **Series pair 4B12** | | **Series pair 4B13** | | **Series pair 4B14** | |
|---|---|---|---|---|---|---|---|---|
| Cointegration Vectors $\boldsymbol{\beta}$ (t-stat) | $LWT_t$ | $LCF1_t$ | $LWT_t$ | $LCF2_t$ | $LWT_t$ | $LCF3_t$ | $LWT_t$ | $LCF4_t$ |
| | 1.0000 | -0.9984 (1886.4) | 1.0000 | -0.9929 (196.57) | 1.0000 | -0.9850 (94.976) | 1.0000 | -0.9762 (64.521) |
| Series pair | Series pair 4D11 | | Series pair 4D12 | | Series pair 4D13 | | Series pair 4D14 | |
| Adjustments Parameter $\boldsymbol{\alpha}$ (t-stat) | $\Delta LWT_{t-1}$ | $\Delta LCF1_{t-1}$ | $\Delta LWTS_{t-1}$ | $\Delta LCF2_{t-1}$ | $\Delta LWT_{t-1}$ | $\Delta LCF3_{t-1}$ | $\Delta LWT_{t-1}$ | $\Delta LCF4_{t-1}$ |
| | -1.4705 (7.8263) | -0.4924 (2.6434) | -0.2133 (-3.3582) | -0.0361 (0.6431) | -0.0956 (2.3644) | 0.0047 (0.1394) | -0.0609 (1.9588) | 0.0127 (1.4889) |
| LM t-stat at 11 lags (*P*-value) | 3.7225 (0.4449) | | 3.1809 (0.5280) | | 5.3129 (0.2567) | | 604724 (0.1605) | |

*All figures in parentheses are t-statistics except those in the LM row which are the p-values.*

Tables 5.28 and 5.29 below represent the full representations of the fully fitted VECM in the case of all the tested series. Table 5.28 is the situation of changes in BL spots against the four separate futures contracts and Table 5.29 represents changes in WT spots against the futures contracts. Given the tables, each series pair has two potential VECM positions indicated as VECM1 and VECM2 which, as can be seen, has all the coefficients fully substituted to form a complete error correction representation.

**Table 5.28: VECM regression functions with estimated cointegration equations**

| Series pair | VECM | Estimated Regressions |
|---|---|---|
| Series pair 4C11 | VECM1 | $\boldsymbol{\Delta LBL_t} = 0.0021 - 0.2038(\boldsymbol{\Delta LBL_{t-1}} - 1.0779\boldsymbol{LCF1_{t-1}} + 0.3179)$ |
| | VECM2 | $\Delta \boldsymbol{LCF1_t} = 0.0018 + 0.0096(\boldsymbol{\Delta LBL_{t-1}} - 1.0779\boldsymbol{LCF1_{t-1}} + 0.3179)$ |
| Series pair 4C12 | VECM1 | $\boldsymbol{\Delta LBL_t} = 0.0021 - 0.2722(\boldsymbol{\Delta LBL_{t-1}} - 1.0728\boldsymbol{LCF2_{t-1}} + 0.3036)$ |
| | VECM2 | $\Delta \boldsymbol{LCF1_t} = 0.0019 - 0.0462(\boldsymbol{\Delta LBL_{t-1}} - 1.0728\boldsymbol{LCF2_{t-1}} + 0.3036)$ |
| Series pair 4C13 | VECM1 | $\boldsymbol{\Delta LBL_t} = 0.0021 - 0.2190\ (\boldsymbol{\Delta LBL_{t-1}} - 1.0677\boldsymbol{LCF3_{t-1}} + 0.2858)$ |
| | VECM2 | $\Delta \boldsymbol{LCF1_t} = 0.0019\ -\ 0.0392(\boldsymbol{\Delta LBL_{t-1}} - 1.0677\boldsymbol{LCF3_{t-1}} + 0.2858)$ |
| Series pair 4C4 | VECM1 | $\boldsymbol{\Delta LBL_t} = 0.0021\ -\ 0.1556\ (\boldsymbol{\Delta LBL_{t-1}} - 1.0623\boldsymbol{LCF4_{t-1}} + 0.2650)$ |
| | VECM2 | $\Delta \boldsymbol{LCF1_t} = 0.0020\ -\ 0.0230(\boldsymbol{\Delta LBL_{t-1}} - 1.0623\boldsymbol{LCF4_{t-1}} + 0.2650)$ |

*Complete representations for $\boldsymbol{\Delta LBL_t}$ against individuals$\boldsymbol{\Delta LCF1_t} - \boldsymbol{\Delta LCF4_t}$.*

**Table 5. 29: VECM regression functions with estimated cointegration equations**

| Series pair | VECM | Estimated Regressions |
|---|---|---|
| Series pair 4D11 | VECM1 | $\boldsymbol{\Delta LWT_t} = 0.0018 - 1.4705(\boldsymbol{\Delta LWT_{t-1}} - 0.9984\boldsymbol{LCF1_{t-1}} - 0.0056)$ |
| | VECM2 | $\Delta\boldsymbol{LCF1_t} = 0.0020 - 0.0230(\boldsymbol{\Delta LWT_{t-1}} - 0.9984\boldsymbol{LCF1_{t-1}} - 0.0056)$ |
| Series pair 4D12 | VECM1 | $\boldsymbol{\Delta LWT_t} = 0.0018 - 0.2133(\boldsymbol{\Delta LWT_{t-1}} - 0.9929\boldsymbol{LCF2_{t-1}} - 0.0218)$ |
| | VECM2 | $\Delta\boldsymbol{LCF1_t} = 0.0019 - 0.0361(\boldsymbol{\Delta LWT_{t-1}} - 0.9929\boldsymbol{LCF2_{t-1}} - 0.0218)$ |
| Series pair 4D13 | VECM1 | $\boldsymbol{\Delta LWT_t} = 0.0018 - 0.0956(\boldsymbol{\Delta LWT_{t-1}} - 0.9850\boldsymbol{LCF3_{t-1}} - 0.0501)$ |
| | VECM2 | $\Delta\boldsymbol{LCF1_t} = 0.0019 - 0.0361(\boldsymbol{\Delta LWT_{t-1}} - 0.9850\boldsymbol{LCF3_{t-1}} - 0.0501)$ |
| Series pair 4D4 | VECM1 | $\boldsymbol{\Delta LWT_t} = 0.0018 - 0.0609(\boldsymbol{\Delta LWT_{t-1}} - 0.9762\boldsymbol{LCF4_{t-1}} - 0.0834)$ |
| | VECM2 | $\Delta\boldsymbol{LCF1_t} = 0.0020 + 0.0127(\boldsymbol{\Delta LWT_{t-1}} - 0.9762\boldsymbol{LCF4_{t-1}} - 0.0834)$ |

*Complete representations involving* $\boldsymbol{\Delta LWT_t}$ *against individuals* $\boldsymbol{\Delta LCF1_t} - \boldsymbol{\Delta LCF4_t}$.

#### 5.5.3.8 Findings

The above results are in almost all instances significant, thus suggesting that for hypothesis ***H5B*** we reject the null hypothesis (***H₀***) of no short-run adjustment back to long run equilibrium in the variables relationships in favour of the alternative hypothesis (***H₁***). An important revelation for these results is that their coefficients were unable to portray a consistent pattern for successive maturing contracts. This situation is in contrast to the research by Hammoudeh et al. (2003), which found the first month's future price (in VECM analysis) to have better speed of error recovery as compared to the subsequent months. What is clear from the results in Tables 5.25 and 5.26 is a situation of faster speed in the interaction between spots and first month contracts (CF1), which gradually diminished with subsequent months' contracts. Technically, this could be explained via EMH with the CF1 possessing better information symmetry than the subsequent month's contracts (CF2-4), as a result of which their power of predicting spots prices was weakened. These outcomes make our interest in CF1 as a predictor of BL spots more reliable and a good decision point.

#### 5.5.3.9 Impulse Response Analysis Results

Impulse response functions are good at capturing the impacts of shocks and sudden changes in variables. Crude oil is a commodity that is very much in the news due to different factors that impact on its price. Essentially, the founding VAR structure of the model has a dynamic effect such that a shock from one variable is easily transmitted to another. This section presents the results from the generalised responses of the futures contracts to innovations in both the BL and WT spots. Tables 5.30 and 5.31 below present the results of accumulated responses view with figures 5.7 and 5.8 showing their graphical form. In Table 5.30 we see the accumulated responses of WT spots and the individual future contracts, all in their log forms, to innovations in BL spots. The results indicate a similar pattern of responses from all the tested variables to the BL spots, thus suggesting and confirming that the WT spots and their futures contracts are closely linked.

Over the 520 periods (10 years) tested, we see the accumulated responses of WT spots and the individual future contracts due to generalised innovations in BL spots to represent an increasing pattern over a sustained period. These results thus confirmed the potential for predicting the BL spots from both futures contracts and WT spots, given the pattern of their responses to price shock impact. Also, in Table 5.33, the results suggest how BL spots and futures contracts respond in an accumulated manner to generalised innovations in WT spots over the 520 weeks. Again we see a representation of an increasing pattern over a sustained period, thus prompting a similar conclusion to the results from Table 5.30. Therefore, this is another level of information that is able to point to the variables' responses to each other due to changed macro economic or political conditions, hence becoming useful in the overall prediction process.

**Table 5. 30: Accumulated responses of $WT_t$ and future contracts to changes in $BL_t$**

| *Period* | $LWT_t$ | $LCF1_t$ | $LCF2_t$ | $LCF3_t$ | $LCF4_t$ |
|---|---|---|---|---|---|
| 1 | 0.034159 | 0.034408 | 0.032460 | 0.030347 | 0.028458 |
| 12 | 0.446248 | 0.445193 | 0.421709 | 0.400006 | 0.380300 |
| 52 | 1.693195 | 1.690629 | 1.637001 | 1.592199 | 1.553487 |
| 104 | 3.076885 | 3.077021 | 3.031922 | 2.995854 | 2.965382 |
| 156 | 4.375431 | 4.378859 | 4.348942 | 4.326979 | 4.309292 |
| 260 | 6.804887 | 6.814637 | 6.814684 | 6.820392 | 6.827723 |
| 520 | 12.03623 | 12.05961 | 12.12440 | 12.18987 | 12.25122 |

*The figures are based on the generalised responses*

**Table 5. 31: Accumulated responses of $BL_t$ and future contracts to changes in $WT_t$**

| *Period* | $LBL_t$ | $LCF1_t$ | $LCF2_t$ | $LCF3_t$ | $LCF4_t$ |
|---|---|---|---|---|---|
| 1 | 0.033679 | 0.042626 | 0.037745 | 0.034583 | 0.032149 |
| 12 | 0.546264 | 0.535205 | 0.498706 | 0.469344 | 0.444420 |
| 52 | 2.057343 | 1.984585 | 1.912462 | 1.855626 | 1.808041 |
| 104 | 3.789576 | 3.596086 | 3.533735 | 3.486932 | 3.448824 |
| 156 | 5.425357 | 5.108869 | 5.064145 | 5.033721 | 5.010459 |
| 260 | 8.487947 | 7.939238 | 7.929330 | 7.931059 | 7.936865 |
| 520 | 15.08292 | 14.03388 | 14.09919 | 14.17037 | 14.23895 |

*The figures are based on the generalised responses*

Figures 5.5 and 5.6 are the graphical representations of futures contracts' generalised responses to innovations in LBL and LWT variables respectively, as pictorial representations of the results in Tables 5.30 and 5.31, given in their accumulated form. The commonest feature the variables' responses as seen from their movement is a persistent positive upward trend. This point to the fact that a common increase in the spots prices of LBL and LWT will naturally increase futures prices. Again a simple look at the responses of futures contracts to innovations in both LBL and LWT, reveals almost the same directional responses. This is, also, a proof that the WT spots could comfortably proxy for the BL spots.

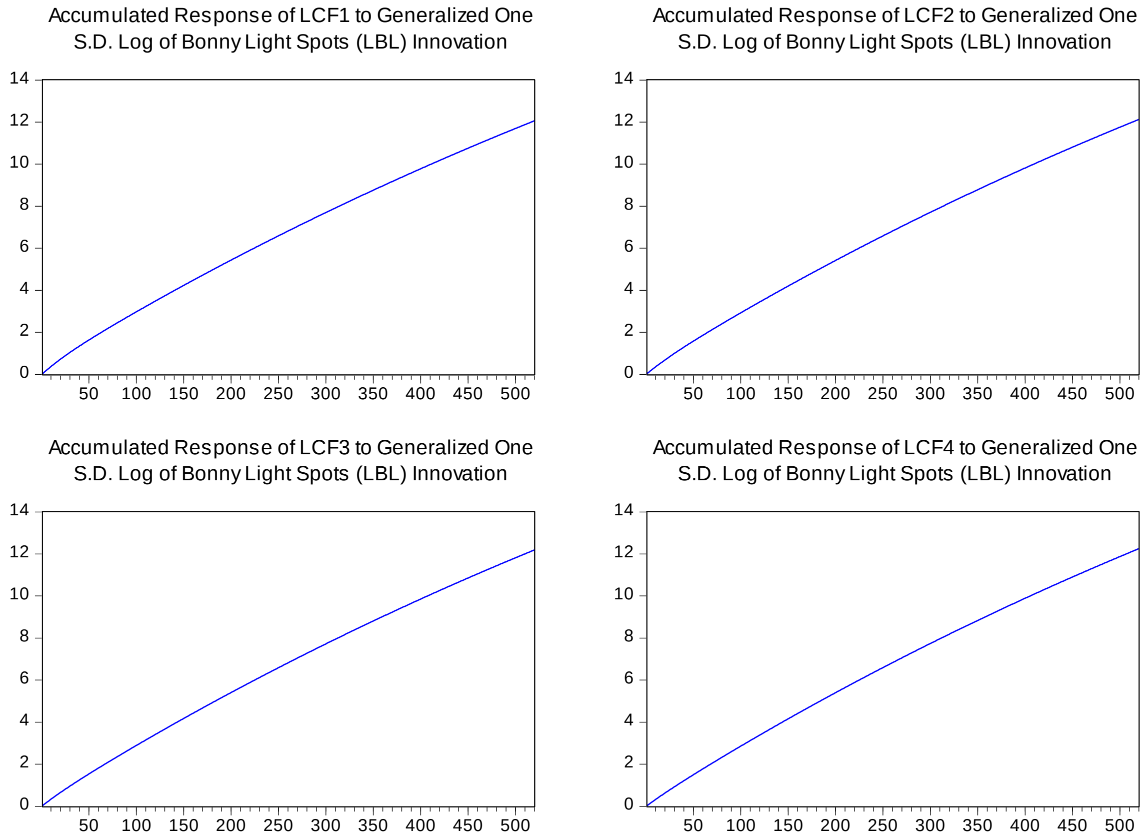



**Figure 5. 5: Futures contracts generalised responses to innovations in $LBL_t$**

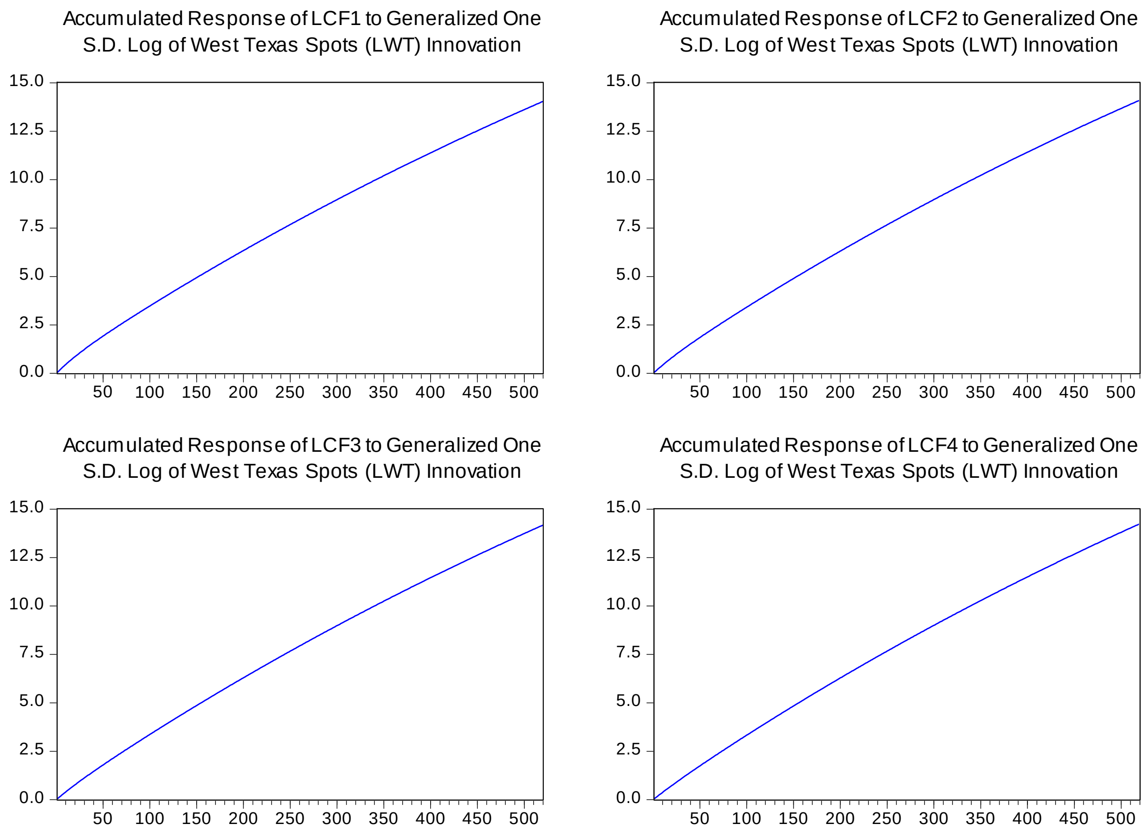



**Figure 5. 6: Futures contracts generalised responses to innovations in $LWT_t$**

### 5.5.3.10 Diagnostic Tests

Series of diagnostics tests were carried out on the datasets with the aim of attaining acceptable estimates and ensuring that misplaced models specifications were not applied. For example, in aiming for results assurance against autocorrelation, Langrage Multiplier (LM) tests were carried out at 12 and 11 numbers of lags in the VECM test as seen in Tables 5.25 and 5.26. Additionally, other acceptable measures were concurrently applied during the main tests. Among these measures, to ensuring that appropriate lag order selection criteria were applied in the VAR estimates, a definite measure generated by the system as seen in Appendix 13 was applied. In applying such a lag selection process, recognition was given to both SIC and AIC by using both measures and also, reaching a general compromise paying attention to the generated lag selection. Also, with regard to SIC and AIC, these information criteria were applied in dealing with all selections in the analysis. These processes, in addition to other forms of tests such as unit root were able ensure that as far as possible standard procedures were utilised. We could thus infer that the results based on this chapter's empirical process are of acceptable standards; hence, the assertions and conclusions made are seen as reliable.

#### 5.5.3.11 Synchronising Results

This subsection features a brief comparison of results from the different cointegration and ECM approaches adopted (Engle-Granger and Johansen). This is essential as the chapter used different measures of the same process. Thus, trying to see how each approach fares comparatively with the alternative is important. The results of cointegration tests from both the two approaches of Engle-Granger and Johansen returned virtually the same outcome; however, under ECMs test the results seam to differ immensely. While in the case of West Texas spots (WT) a significant, but irregular pattern of error correction was achieved in all variables relationships. In the case of Bonny Light spots (BL) there was only one significant incidence of error correction. One important issue observed on how the two different ECMs results relate to each other is that under the Engle-Granger ECM we had a series of non-significant results, but the situation is different for the Johansen VECM tests. Table 5.23 reveals that only series pair ***4A11*** returned a significant outcome, whereas all other possible series pairs are non-significant. Comparing the same series pairs tested in Table 5.23 with the Johansen VECM results seen in Table 5.25, we can see a significant difference as the VECM results are all significant, indicating that all error models tested under the VECM situation are corrected as against the Engle-Granger ECMs.

## 5.6 Conclusion

This chapter provided answers to the main question, *if West Texas Intermediate (WT) futures prices could become an efficient predictor of Bonny Light (BL) spot price, in addition to other secondary questions; of is there any need for BL futures market and at what point?* Both Engle-Granger two-step and Johansen tests with their respective ECMs in addition to other procedures for Granger causality and a host of other diagnostic tests were employed for this purpose. Given the results obtained under the cointegration tests, we are able to see overwhelming evidence for long run relationships, but under the ECMs we recorded mixed outcomes. As much as possible, the inability of the Engle-Granger ECM to return the much significant results will not hinder the ability of this chapter's analysis to draw a conclusion about error correction, given that the Johansen VECM was equally tested and largely returned significant outcomes in all the futures contracts (the four successive months) examined. Essentially, this outcome implies that we are able to confirm that WT futures prices are able to effectively predict the BL spots. Certainly, results from the Granger causality approach and other diagnostic measures explored are complementary as they overall aided the conclusions.

In practical finance, hedging is normally used to reduce the risk associated with price volatility. This is achieved by taking an investment position that reduces any potential price risk exposure. Usually, the investments so used could be in any form, but future contracts are more applicable. This Chapter has succeeded in examining the application of CF1 – CF4 in understanding the price behaviour pattern of BL as well as WT spots prices, which essentially is the price discovery for the spots of both these crude oil grades. Although the process did not suggest the physical taking of an investment position in order to avoid price volatility, attaining a price discovery could help in reducing the risk associated with price uncertainties of the examined crude oil grades and thus the revenues linked to them. In the case of the target commodity here (BL spots), it could be said that this analysis has helped to provide a meaningful measure that could help to predict future market prices. This is very important especially given that not much has been achieved with research of this nature in the past.

Given the wider picture of SWFs, this analysis will help to add value to the manner of perception of the fund's scope and unearned values, as it is unwise to focus unduly on trying to ensure investments of existing revenue without paying attention to guaranteeing their source. Therefore, this chapter has served the essential purpose of understanding price volatility associated with crude oil, which as seen in chapter I constitutes more than 60% of the SWFs. This is a necessary element of SWF investment, an aspect that has seen far more empirical attention than the price behaviour element. Expanding on this and the previous chapter's outcomes, a broader analytical approach aiming at a wider understanding of crude oil price volatility will be examined in the next chapter.

# Chapter 6: Interdependences between Oil, Equity and Gold Markets

## 6.1 Introduction

Chapter 4 of this thesis found evidence of crude oil price volatility impact on the "Bonny Light" (BL) crude oil spot price, GDP and also, the foreign reserve account. Given the range of macroeconomic variables affected, this suggests a widening influence of crude oil price volatility on the economy at large. With a view to identifying a hedging mechanism for this situation, chapter 5 confirmed that West Texas Intermediate's futures price is able to predict BL spot price. Thus, the outcome of the empirical process has provided the basic guarantee required for a stable pricing regime for BL spot. Attaining this is particularly important for the majority of crude oil export dependent countries like Nigeria, with up to 91% of foreign reserve account coming from the commodity. This essentially suggests a predictive stand could be taken toward revenue expectations, thereby translating into budget stability.

However, despite the empirical outcomes in chapters 4 and 5, this chapter still recognises the need for understanding the wider economic implications of crude oil price volatility, in the way it affects broad economic indicators such as the stock market returns. Hence, a further dimension here will include wider business activity measured by stock indices. This could be as intermediated through the health of the banking sector, which provides a further means to address the dependence of the economy on oil. Thus, the essential element of studying risk and return, largely linked to stock market activities, is relevantly extended to understanding the effect of oil price volatility on the stock market. Also, this will have implications for investing the proceeds of natural endowments into a fund for the future. Given this, the essentials of exploring alternative investments to the stock market are considered, with gold spot examined.

An increasing number of empirical studies are geared towards understanding the relationship between crude oil price volatility and stock market returns (Jones and Kaul, 1996; Sadorsky, 1999; Malik and Ewing, 2009); also between crude oil price shocks and gold spots (Zhang and Wei, 2010). A handful of others focus on emerging stock markets (Basher and Sadorsky, 2006; Basher et al., 2012), while others are targeting the key oil producing countries of the Gulf Cooperation Council (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011). Malik and Ewing (2009) focused on different sectors of the stock market when they investigated volatility transmission between oil prices and Dow Jones equity sectors and claimed to have found evidence in support of cross-market hedging. Empirical evidence based on Zhang and Wei's (2010) analysis of joint crude oil and gold market suggested the two commodities' prices move together and have long term equilibrium.

Despite the rich blend of preceding studies looking into how crude oil price shocks affect the stock markets and are also related to gold spots, certain important aspects are still yet uncovered. For instance, the broad application of crude oil price interdependence with global equity market index is not adequately covered. Also, not much focus has been directed into studying impacts of such interdependences with the stock market returns of crude oil export dependent economies. Again, expanding such investigations of crude oil impacts to include simultaneously another primary commodity as gold together with the equity returns, looking into investment alternatives, has not been achieved. These apparent gaps are central to the questions this chapter is intended to answer, namely: *What is the nature of different crude oil export dependent economies' reaction to the commodity price changes? Is there any volatility transmission between crude oil prices and global stock market returns? Could gold reserves serve as an alternative to the equity market?*

As the empirical process want to see the volatility through an autoregressive component and also examine the interdependence between the volatilities of different markets, a multivariate ARCH will be a suitable model. But, as the ARCH model alone is not sufficient to characterise the time series properties of volatility in commodity and equity markets, therefore, the chapter will adopt an approach common in the literature of using a GARCH model. Multivariate GARCH models do however suffer from the problem that a very large number of parameters need to be estimated, typically making such estimates intractable. As fully discussed in the methodology chapter, the solution is to restrict the parameter space for the MGARCH estimates, the form of restriction adopted here is that first proposed by Engle and Kroner (1995) known as BEKK. Additionally, a cointegration test is also applied in order to understand the long run relationships. Also it gives insight into the potential for volatility transmission and market efficiency among the applied variables. In the model specification, moreover attention is paid to the two important variables of mean and variance, as the measures of return and risk being modelled in this chapter. Essentially, other preliminary analyses and diagnostic measures will be applied, all aimed at improving the overall empirical process.

The applied data in this chapter are those of daily crude oil and gold spot prices, the closing prices of the Malaysia, Nigerian and Norwegian stock markets, in addition to the world stock index. The remainder of the chapter discusses issues relating to understanding the stock market's reaction to oil price changes, empirical application, applied data, empirical analysis and conclusion. Overall the chapter makes an empirical investigation of potential volatility transmission between oil price, stock market returns and gold spot, through understanding the interdependence between the listed variables, thereby confirming the extent of crude oil price shocks' impact in influencing the level of economic activities, especially given the equity sector as a window.

## 6.2 Understanding Stock Market's Reaction to Oil Price Changes

Stock markets normally have a dominant influence on the economy of a country, largely due to their position in capital market investments. Crude oil is increasingly becoming an important commodity whose price change ultimately affects the economies of both exporting and importing countries. A number of empirical studies examining the extent of interdependence between crude oil price changes and stock market return have suggested various interesting outcomes (Jones and Kaul, 1996; Sadorsky, 1999; Malik and Ewing, 2009). Also, some empirical studies were interested in the behaviour of specific stock market in response to oil price changes. Basher and Sadorsky (2006) and Basher et al. (2012) examine the case of emerging stock markets, while other research concentrated on the key oil producing countries of the GCC (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011). Zhang and Wei (2010) investigated crude oil and gold spots for evidence of integration.

The main concerns for a capital market investor are risk minimisation and guaranteeing efficient return. These related issues are central to the *mean-variance* efficiency consideration of Markowitz (1952). Markowitz's idea was effectively applied in the capital assets pricing model (CAPM) widely linked to Sharpe (1964) and Lintner (1965). A fundamental assumption behind Sharpe's CAPM is that investment's return depends principally on the associated risk and market beta ($\beta$) as a relative measure of sensitivity in an asset's return. To this day, the essential element of studying risk and return is largely linked to stock market activities, and this interest has extended to understanding the effect of oil price volatility on stock market activities; some references in this regard were cited in the opening paragraph of this section. Highlighting at few, Malik and Ewing (2009) highlighted the potential usefulness of their approach to estimating the *mean* and *variance*, pointing out the importance of volatility transmission information in making an efficient portfolio selection decision. Similarly, Karolyi (1995) when estimating the volatility transmissions between the United States and Canada, highlighted the implication of such study for the asset pricing.

Some studies concentrated on understanding whether crude oil futures against the spots prices have any potential impact on stock market activities (Hammoudeh, 2004; Galvani and Plourde, 2010). Galvani and Plourde (2010) employed the *mean-variance* optimisation framework to study portfolio diversification in the energy market, in contrast to the oil spot prices considered in this chapter, as employed by Malik and Ewing (2009). The approach in Galvani and Plourde primarily investigated whether energy futures improve the investment potential of crude oil firms. Although the result found evidence of risk minimising potentials for investors, it failed to ensure efficient return. This justifies investigating similar problem with crude oil spots prices, as applied in Malik and Ewing (2009) and several other cited references. Sadorsky (1999) jointly estimated oil price and oil price volatility's impact on real stock returns. The approach was similar to the way chapter 4 of this thesis investigated the impact of crude oil price changes and volatility on the economy of oil dependent countries. The approach could be seen as important in isolating each set of impacts, so that the relative nature of each variable's impact on the economy could be dealt with accordingly.

Narrowing to specific markets, Basher and Sadorsky (2006) and also, Hammoudeh and Choi (2006), examined the impact of oil price changes in the case of emerging economies stock market returns. Given that the majority of world oil exporting countries are either emerging or developing economies, this focus could highlight the effect where it matters most. In another study typical of extensions of Basher and Sadorsky (2006), Basher et al. (2012) introduced an exchange variable in the analysis of relationships between emerging countries' stock markets and oil prices. This could be seen as a better approach to capturing the economic impacts of oil price changes on emerging economies, given the degree of foreign exchange reliance in such economies, including oil being globally traded in US dollars. Again, Malik and Ewing (2009) investigated volatility transmission between oil prices and different equity sectors of the US's Dow Jones, and found evidence of volatility transmission across equity sectors and oil prices. Although the authors claimed the results could be useful for cross-market hedging and sharing market information among investors, this claim should be further examined.

Thus, as Malik and Ewing (2009) claimed to have found a potential means of cross-market hedging, one of this chapter's research questions will focus on testing this claim. The approach will essentially expand the stock markets being examined to a global coverage as against limiting to the single stock market analysed by Malik and Ewing. Therefore, the investigation here will focus on answering the research question; *is there any cross volatility transmission between crude oil prices and global stock market returns?* If yes, a further dimension to the development will be an examination of the outcome to see if such information could provide a useful means of hedging crude oil revenue. This is addressed by the ensuing research questions; *could the information of volatility transmission between oil price and stock market as discovered here provide any useful means of hedging crude oil revenue?,* also, *could such information be applied in building an asset pricing model for oil revenue?* Obtaining answers to such questions could help to verify the claim of Malik and Ewing and at the same time create a potential hedging option for the revenues of crude oil dependent countries. This could be relevant to consideration of the investment decisions of natural resource endowed countries, for which van der Ploeg and Venables (2011) analysed three (3) sets of decision points.

Although some studies (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011) have covered the interdependence between crude oil price changes and stock markets of the GCC countries, still not much has been achieved in terms of studying the impacts of such interdependences on the stock market returns of crude oil export dependent economies. Jones and Kaul (1996) have already found the stock markets cash flows of crude oil net importing countries of US and Canada to be affected by oil price shocks, but, the Japanese and United Kingdom stock markets manifested different sets of responses. Thus, with the case of oil importing countries being empirically covered, there is a real need for broader expansion that would integrate other oil exporting countries' stock market returns into this type of study, given their economies' common tendency to depend on crude oil revenue for growth. Also, doing this will create an avenue to contrast the ability of different oil producing economies (through stock markets) deal with the issue of crude oil price changes, particularly as we know that the countries are endowed with different economic characteristics.

For instance, Norway as an oil dependent economy has a different mode of dependence on crude oil as a commodity, as compared with other oil dependent economies such as Nigeria or even Malaysia. While Norway's economy is self sufficient in alternative energy sources and it exports almost all its crude oil, the same may not be said about Nigeria. Again, Norway with a population size of less than 5 million people, presents a country with small size economy, whereas Nigeria with a population of over 160 million is a bigger economy with potentially broader activities than Norway. Given this diverse nature of interdependence, the different stock markets' indices could be examined for a wider variety of reactions to crude oil price changes. Essential elements of business activities and health of the different economies under crude oil price changes could be understood by this means. Thus, the importance of the crude oil price of these countries, such as the Bonny Light determining the stock market activities of Nigeria, is crucial.

One of the research questions in this chapter aims to understand if investing in gold spots may be able to provide an alternative to stock market investments. This is because empirical study by Wei and Zhang (2010) found evidence of cointegration between the crude oil and gold markets' which suggested the two commodities' prices move together and have a long term equilibrium. In contrast, Tully and Lucey (2007) focused on the interdependence between gold price and stock market behaviour. Roache and Rossi (2010) examined gold as an investment alternative by analysing the responses of other commodities' prices (gas, crude and refined oil included) associated with bad news in relation to gold, especially during economic downturn. Understandably, the analysis focused on gold providing other commodities with the necessary hedge, as gold is perceived to be the deposit of last resort. Given the focus of these preceding studies, expanding investigations into oil and equity prices interdependence by including another primary commodity such as gold may provide further alternatives. Hence, one of the research questions to which this chapter aims to provide answer is; *could gold reserve serve as an alternative to the equity market?* The essential element here is that of inferring alternative investment potential for oil revenue.

Therefore, looking beyond the stock markets, investing in other government stocks, holding a foreign reserve account, etc, gold reserve could potentially provide an alternative for countries looking to invest their oil proceeds. One reason for looking towards gold reserve is the ability of its spot prices to remain more stable over time as compared with stock market indices and crude oil spot prices. Figure 6.1 below captures the common movements of gold spot and world stock index indices. It can be seen from the figure that gold spot exhibits a much more stable trend as compared to the world stock index. That is to say, even in a period of rise or fall in price, gold displays steady and far more predictable price changes than the world stock market index. The data for gold spots are based on the S & P gold spot index and those for the world stock index are based on the MSCI world price index.

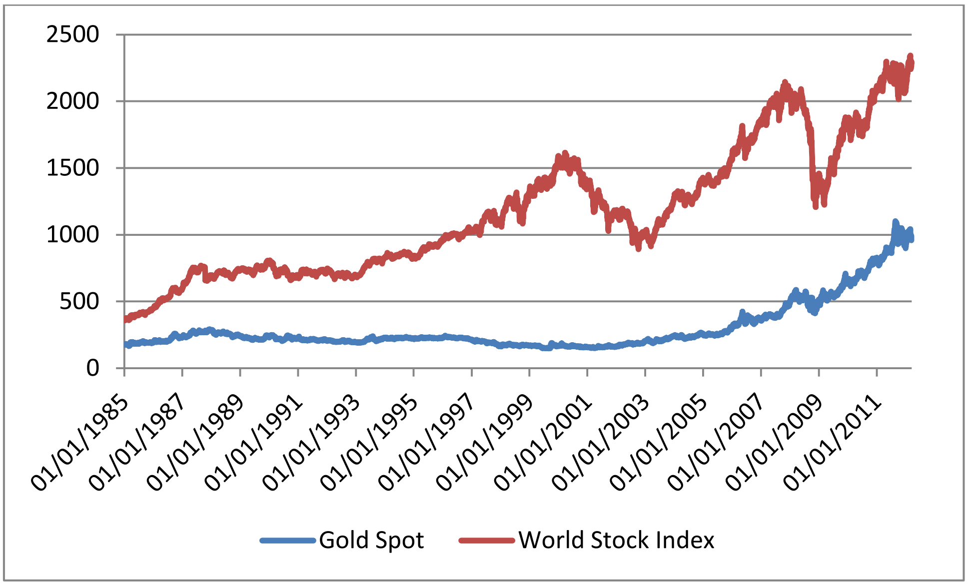



**Figure 6. 1: Joint movement of gold spot and world stock index**

### 6.2.1 Research Questions Arising

Following the literature review here and the identification of gaps, this chapter will focus on answering the research questions below:

- *What is the nature of different crude oil export dependent economies reaction to the commodity price changes?*
- *Is there any volatility transmission between crude oil prices and global stock market returns?*
- *Could gold reserve serve as an alternative to the equity market?*

### 6.2.2 Hypotheses

In order to answer the above questions three sets of hypotheses are formulated, coded as; ***H6A, H6B*** and ***H6C***. As before, $H_0$ in all cases is the null and $H_1$ the alternative;

Hypothesis ***H6A***-

$H_0$: *Crude oil export dependent countries' stock indices react differently to oil price volatility.*

$H_1$: *Crude oil export dependent countries' stock indices react to oil price volatility in a similar manner.*

Hypothesis ***H6B***-

$H_0$: *There is no volatility transmission between crude oil price changes and world stock market returns.*

$H_1$: *Crude oil price changes and world stock market returns exhibit volatility transmission.*

Hypothesis ***H6B*** will test for evidence of volatility transmission between oil and global stock market returns. Undertaking this test given the world stock index will give the analysis a global relevance.

Hypothesis ***H6C***-

$H_0$: Gold reserve cannot be used as an alternative investment for crude oil revenue.

$H_1$: Gold reserve could provide an alternative investment for crude oil revenue.

The emphasis here is to measure the null hypotheses of $H_0$ <u>against</u> alternatives $H_1$.

## 6.3 Empirical Application

Considering that the research questions this chapter is aiming to address are linked to price volatility and stock returns, a variety of volatility models could be applied in providing answers. This is evidenced by the either specific or combinations of time series volatility models, as reviewed in the preceding empirical studies which aimed to answer similar research questions (Sadorsky, 1999; Hammoudeh, 2004; Hammoudeh and Choi, 2006; Malik and Ewing, 2009; Zhang and Wei, 2010; Arouri et al., 2011; Basher et al., 2012). Among these models are those of autoregressive conditional heteroskedasticity (ARCH) origin, cointegration/error correction, vector autoregressions (VAR), etc (approaches already discussed chapter 3). However, the models most often applied in similar empirical studies are those of time-varying volatility, originating from ARCH. Karolyi (1995), Sadorsky (1999) also, Malik and Ewing (2009) are among a few other studies that adopted the generalized ARCH (GARCH) model in this regard. Thus, as this chapter concentrates on understanding the interdependence between crude oil and stock markets, a multivariate GARCH model specific to the diagonal BEKK, similar to the one applied in Malik and Ewing (2009) will be adopted.

### 6.3.1 Applied Models

The model application in this chapter will follow the GARCH model presentation in of chapter 3. We have seen how time-varying volatility models of ARCH origin are becoming increasingly applicable to the study of both crude oil price and stock market behaviour (Fong and See, 2002; Yang et al., 2002; Agnolucci, 2009; Kang et al., 2009; Malik and Ewing, 2009). Yang et al. (2002) employed GARCH to investigate the volatility of oil prices. An important reference to this chapter's empirical process is Malik and Ewing's (2009) adoption of a multivariate GARCH model in estimating the conditional mean and variance of selected sectors of US stock market and oil prices. The approach adopted and applied elements are essentially close to the empirical goals in this chapter, particularly finding volatility transmission between crude oil spots prices and different stock market indexes.

It is obvious from the research questions this chapter addresses, that a multiple dataset will be required. This may not be an immediate concern as innovations in the time-varying volatility models of ARCH origin have resulted in a multivariate GARCH approach, considered capable of estimating a multivariate problem. This is despite some academic thought pointing at the empirical difficulty associated with such multivariate GARCH estimation in its full form, given the large number of parameterisations that could result from the process (Wang, 2009). This is probably the reason why Malik and Ewing (2009), Arouri et al.(2011) and Karolyi (1995) all subjected their empirical procedure to a simple bivariate GARCH model. Similarly, since the bivariate GARCH process directly addresses the research questions in this chapter, it will be applied in a diagonal matrix form of positive definite parameterisation (BEKK), as the BEKK is suitable in dealing with fewer parameters, while remaining positive and definite under weak condition. The technical suitability in fitting the questions here relates to the GARCH model containing the two important variables of return and risk (mean and variance), which are being principally estimated in this chapter.

A cointegration test will also be applied in order to understand the long run relationships (market efficiencies) between oil, stock and gold markets. This level of knowledge will, in addition to providing preliminary information regarding long term joint behaviour of the variables, give insight into the potential for volatility transmission and market efficiency among them. Most importantly, since the main objective of the research questions lies in finding out if crude oil price volatility could influence stock and gold prices over a long term, the variables' long run relationships are key information. Also, since we have seen from section 6.1 that the data applied is over a long period of time (daily over a period of 16 years), it is only sensible to exploit long run relationships. A similar approach of combining cointegration with other models in analysing oil and stock markets was adopted in Basher et al. (2012), while Zhang and Wei (2010) applied the model in analysing cointegration between oil and gold prices.

#### 6.3.1.1 Cointegration Model

A typical cointegration model application here will follow the Engle-Granger two-step procedure of chapter 3 and is specified in relation to the test specification in this chapter, similar to the application in chapter 5. The econometric basis behind the procedure is given based on the general linear regression equation (6.1):

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad \mathbf{(6.1)}$$

Let $Y_t \sim X_t$ both be $I(1)$

Regressing and estimating the error term $(\varepsilon_t)$ as:

$$\hat{\varepsilon}_t = Y_t - \hat{\alpha} + \hat{\beta} X_t \qquad \mathbf{(6.2)}$$

Then $Y_t$ and $X_t$ are cointegrated if the estimated error is stationary $\hat{\varepsilon}_t \sim I(0)$

$$\hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \varepsilon_t \qquad \mathbf{(6.3)}$$

If $\rho < 1$, then the error $(\hat{\varepsilon}_t)$ is stationary and the series $Y_t$ and $X_t$ are cointegrated, implying they have a long run relationship. The application is carried out in testing for a cointegration relationship in section 6.5.2 below.

#### 6.3.1.2 Multivariate GARCH Model

Positive definite parameterisation (BEKK) is commonly applied in order to constrain volatility to be positive definite under very weak conditions. The diagonal BEKK specification following Engle and Kroner (1995) is given as:

$$\boldsymbol{H_t} = \boldsymbol{B_0'B_0} + \boldsymbol{B_i'\varepsilon_{t-i}\varepsilon_{t-i}'B_i} + \boldsymbol{C_j' H_j' C_j} \qquad \mathbf{(6.4)}$$

Where; $\boldsymbol{B_0}$ = $n$ x $n$ symmetric parameter matrices. $\boldsymbol{B_i}$ and $\boldsymbol{C_j}$ = $n$ x $n$ unrestricted parameter matrices. The model specification in equation (6.4) has a dynamic feature that enables the conditional variances and covariance to influence each other, again requiring estimation of smaller number of parameters. This enables the model to meet the restriction condition of the parameterisation, where *p* = *q* = *1*. In its practical implementation, the BEKK is normally applied given a diagonal representation which avoids complications related to large parameterisation, as specified below.

Chapter 3 has already presented a discussion of the time-varying volatility models, therefore, the applied models here will be limited to relevant model specifications used in the empirical analysis. As Engle and Kroner (1995) pointed out, the extension of the bivariate to multivariate GARCH model is here achieved by conditional variance and covariance matrix of multiple dimensional mean to rely on the available information. Again, the conditional variances and covariance are estimated based on the diagonal BEKK specification in equation (6.4), with models estimated based on equations (6.5a, 6.5b and 6.5c) below.

$$\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}} \qquad (\boldsymbol{6.5a})$$

$$\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}} \qquad (\boldsymbol{6.5b})$$

$$\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}} \qquad (\boldsymbol{6.5c})$$

Where; $\boldsymbol{h_{11,t}}$and $\boldsymbol{h_{22,t}}$ = conditional variances for the different series, here oil and stock index or oil and gold prices. Each represents the GARCH process used in assessing the impact of one series shock on the volatility of itself. $\boldsymbol{h_{12,t}}$ = conditional covariance equation. This could simultaneously assess the effect of the shocks and volatility impact on both series, thereby capturing the impact of cross volatility or volatility spillover between the two series of oil price and stock market return, as against the one direction test exhibited by the conditional variance process.

$\alpha_{01}, \alpha_{02}$ and $\alpha_{03}$= are the constant coefficient matrices testing the mean return of the different series, given as indefinite matrices. $\alpha_{11}$ , $\alpha_{22}$ and $\alpha_{33}$ = coefficient matrices for the series ARCH terms, given as diagonal matrices. $\beta_{11}, \beta_{22}$ and $\beta_{33}$ = coefficient matrices for the series GARCH terms, also given as diagonal matrices. All coefficients capture the level of impact of the shocks being measured. Here, the restriction imposed based on the parameters $B_i$ and $C_j$ in equation (*6.4*) above will see $\alpha_{22}$=$\alpha_{11} * \alpha_{33}$ and $\beta_{22}$=$\beta_{11} * \beta_{33}$ in equations (*6.5a*) and (*6.5c*), resulting into the covariance coefficients in equation (*6.5b*). $\varepsilon^2_1$ and $\varepsilon^2_2$ = unexpected volatility or shock, capturing the effect of news on each model or series and seen as a direct effect of shock. $\varepsilon^2_{t-1}$ = past volatility news or shock. $\varepsilon_{1,t}\ \varepsilon_{2,t}$ = cross effects of news, as originated from any of the series and affecting the other, seen as indirect effect of news.

Thus, following the above presentation, the major applied empirical model in this chapter will be a bivariate GARCH model specified in a diagonal BEKK form, applied as seen in equations (6.6a, 6.6b and 6.6c) above. The equations from the models will empirically estimate conditional variance and conditional covariance in all the tested series. In addition, the series mean will equally be estimated given the conditional mean equation (6.5c). In addition, the process will apply a cointegration procedure in order to understand the long run relationships between variables. The applied model is seen in equation (6.3) with the resulting application allowing for preliminary variables analysis and also giving information about market efficiencies in oil, stock and gold markets.

## 6.4 Data

The applied data in this chapter's empirical analysis will pay fundamental attention to the requirements of the variables in the research questions. Equally the empirical models specified in the above empirical section were carefully thought about in choosing the data. Moreover, attention was paid to the data type in past studies. Similar preceding studies have all applied data from crude oil spot prices and a mixture of different stock market indices, Basher and Sadorsky (2006), Malik and Ewing (2009) and also, Arouri (2011) are examples. These studies approached the issue of data selection based on the research questions being answered. Thus, given the need to understand the impact of crude oil price risk on emerging stock markets, Basher and Sadorsky (2006) applied the closing stock index of selected emerging stock markets, world stock index and oil price data. Therefore, following this trend and given the research questions in this chapter, a similar of data selection process is adopted, as explained below.

The applied data in this chapter will be analysed in their natural log form. This is partly to help address the issue of some of the variables being not near to normal distribution and also, the different datasets being far apart from each other in absolute values. Typical of this problem is the wide difference between the two variables of world stock index and gold spots, jointly examined in figure 6.1. In a similar manner, Sadorsky (1999) also carried out data application in their natural log form. This approach to data transformation was also applied given the data in both chapters 4 and 5. Other than this, not many adjustments of the datasets were needed as they were all provided in the manner required for the empirical analysis. Other key data assumptions necessary for the analysis will be explained in the section below.

### 6.4.1 Applied Data

The data applied in this chapter are of daily Bonny Light crude oil and gold spot prices, closing prices of the Malaysian, Nigerian and Norwegian stock markets, and the Morgan Stanley Capital International (MSCI) world stock index. The full data breakdown including their representations is presented in Table 6.1 below. All the data were accessed from the Thomson Reuters Datastream (TRD); however their primary sources differ, as each set of data was originally sourced by TRD from a specific source that deals with the specific data in question. For instance, the MSCI world index was originally sourced by TRD from MSCI, whereas the Bonny Light crude oil spots were sourced from ICSI pricing. As pointed out, all data are in daily frequencies beginning from March 1996 to March 2012, translating into 4362 observations for each variable as applied in their natural log form. The daily observations accounts for five working days a week from Monday to Friday, thus leaving out weekends.

**Table 6. 1: Applied variables and their representations**

| Variables | Representation | | |
|---|---|---|---|
| | Normal | Log level | Log Diff |
| Crude Oil Spot Price | $OIL$ | $LOIL_t$ | $\Delta LOIL_t$ |
| Gold Spot Price | $GLD$ | $LGLD_t$ | $\Delta LGLD_t$ |
| Malaysian Stock Index | $MSI$ | $LMSI_t$ | $\Delta LMSI_t$ |
| Nigerian Stock Index | $NSP$ | $LNSP_t$ | $\Delta LNSP_t$ |
| Norwegian Stock Index | $NSI$ | $LNSI_t$ | $\Delta LNSI_t$ |
| World Stock Index | $WSI$ | $LWSI_t$ | $\Delta LWSI_t$ |

The applied data were chosen with specific consideration of their ability to fit into the empirical models specified in the above empirical section and also to answer adequately the research questions in this chapter. Thus, to answer the first research question, *what is the nature of different crude oil export dependent economies' reaction to the commodity price changes?* the Malaysian, Nigerian and Norwegian stock markets data in conjunction with the oil spots prices will be applied, given the focus of the question on the nature of different crude oil export dependent economies' reaction to the commodity price changes. In contrast to addressing the question; *is there any volatility transmission between crude oil prices and global stock market returns?* the world stock index will be applied to give a broader perspective on the impact of crude oil price changes on the global stock market. For the last research question, *could gold reserve serve as an alternative to equity market?* gold spot prices will be analysed.

Some levels of assumptions related to the applied data are also put in place. For instance, the crude oil spot price being adopted is the Nigerian Bonny Light (BL) spot price. This is intended to represent an oil spot price of crude oil export dependent economy, also, due to the country's stock market index being equally applied, but most importantly because different crude oil spots prices have shown negligible variation over time. This point has already been confirmed in chapter 5, where West Texas Intermediate spots prices were shown to be a suitable proxy for BL spots. Again, figure 6.2 below presents common movement of Nigerian Bonny Light and West Texas Intermediate at log level. The movement is presented over the selected research period being analysed here and in daily frequency. Similarly, figure 6.3 shows the individual movements of the selected spots based on the global picture, which allows for clearer viewing of each trend. The figures suggest spot prices have a common trend and are not far apart. The picture captures the historical common movements of eight (8) purposely selected crude oil spots: Nigerian Bonny Light, Malaysian Tapis, Norwegian North Sea, UAE's Oil Dubai, OPEC's Oil basket, London Brent, Iran's Kirkuk and West Texas Intermediate. Each oil spot is selected to reflect a specific oil trading region of the world, thus giving the selection a global relevance, also included the three spots of Bonny Light, Tapis and North Sea being analysed in this chapter.

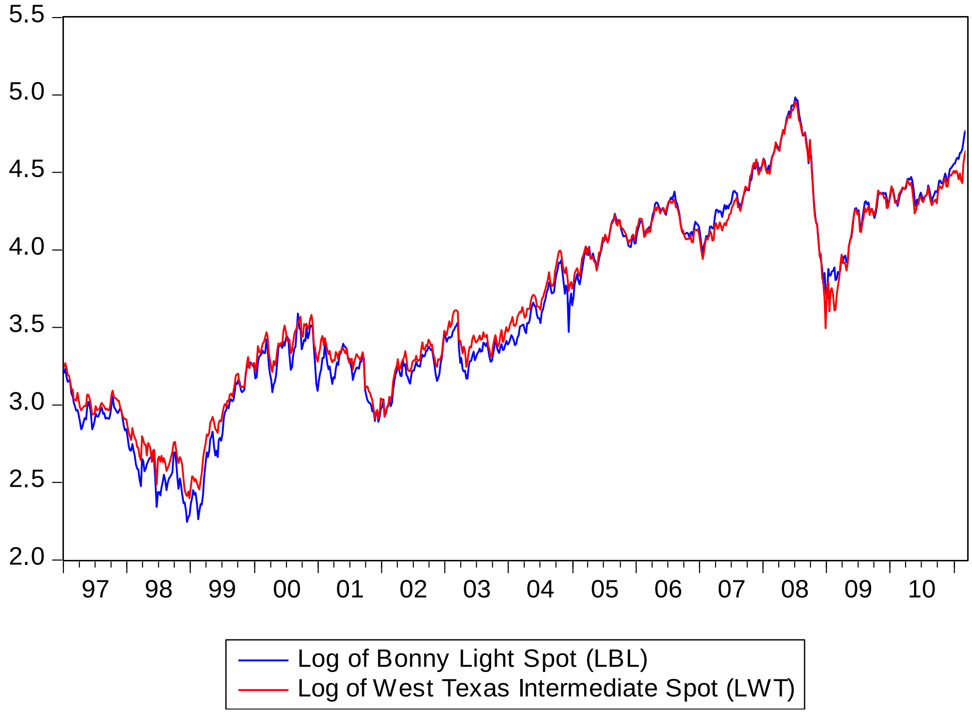



**Figure 6. 2: Joint movements of selected crude oil spot prices.**

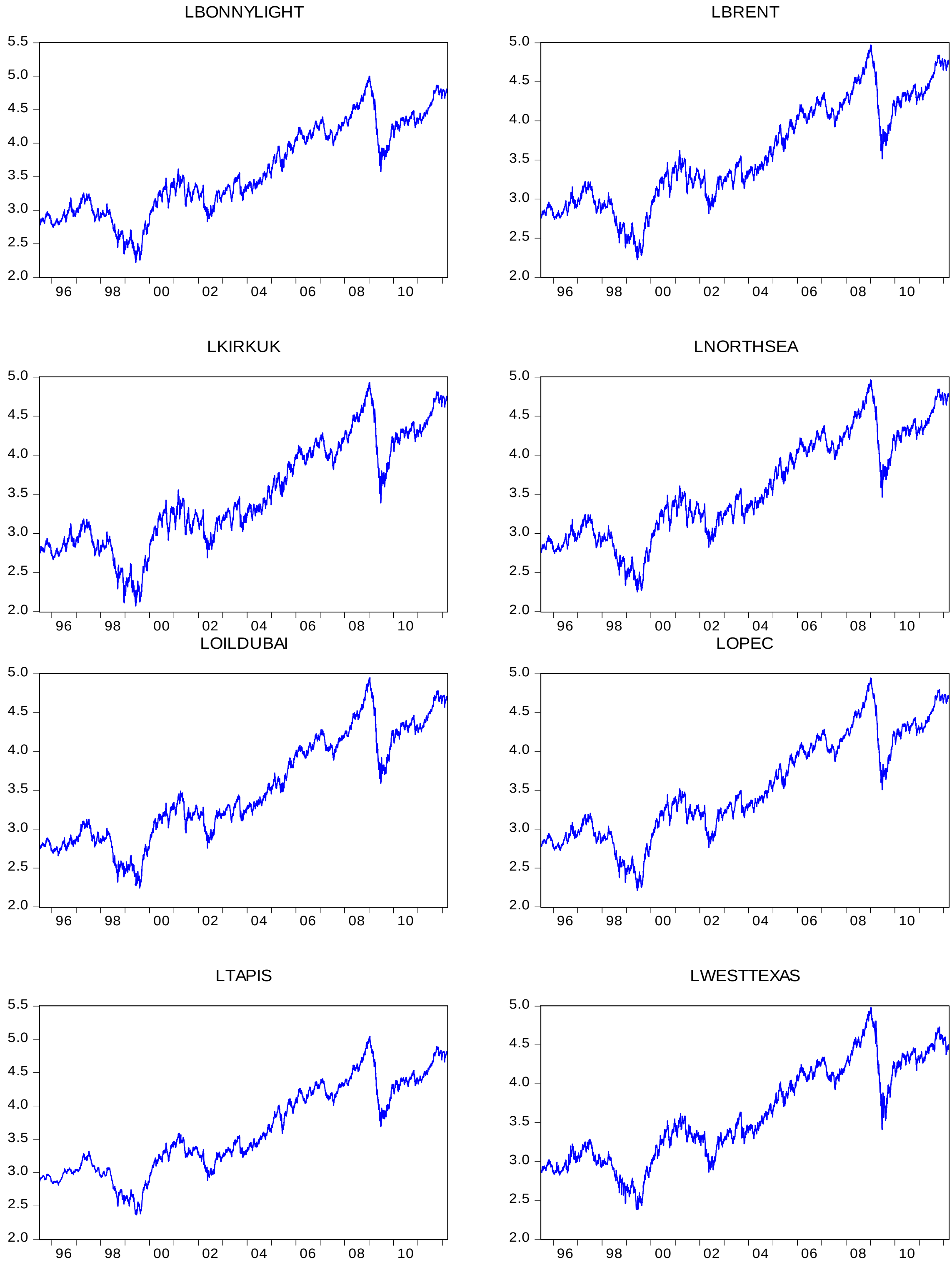



**Figure 6. 3: Individual movements of selected crude oil spot prices.**

Generally, the Nigerian data are employed as it is the primary country of interest in this analysis. However, for comparison and generalisation, data for Malaysia and Norway's stock markets data are also employed. The choice of these two countries is due to their status as crude oil export dependent countries like Nigeria, Norway being a developed oil producer and Malaysia a developing oil producer like Nigeria. This combination is purposely intended to give room for comparative analysis of the different countries' equity markets' reaction to oil price changes. The world stock market index data is assumed to be able to capture global stock market reactions, thus creating an avenue for broader comparison. Again, the world stock market could capture the situation of crude oil dependence in terms of consumption. In this category are the world's developed countries with crude oil net consumption status, like the USA, in contrast to the revenue dependence intended to be captured with Nigerian, Norwegian and Malaysian stock markets data. Finally, the gold spots are thought of as representative of gold prices, necessary for capturing the alternative investment avenue for crude oil revenue, and for consideration of a commodity which may not be serially correlated with stock return.

### 6.4.2 Preliminary Data Analysis

This section will initiate the empirical processes of the chapter by examining the behaviour of the applied data and its conformity with standards for the main empirical procedures. Descriptive statistics, unit root and Granger causality tests are conducted in this regard and the results presented.

#### 6.4.2.1 Descriptive Statistics

These descriptive statistics will provide a preliminary assessment of the applied data. Within this, a joint variables relationship of graphical movements and correlation is used to assess how well the data could answer preliminary level questions related to the chapter's main questions. Thus, Table 6.2 below presents the correlation matrix of the applied data. From the table it can be seen that some variables in the dataset are significantly correlated whereas others are not. For instance, the correlation between natural logarithm of oil spot prices ($\boldsymbol{LOIL_t}$) and that of gold ($\boldsymbol{LGLD_t}$) is highly significant at 0.8752. This means that both gold and oil spot prices move together in the same direction. This could provisionally said to be in agreement with the empirical finding in Zhang and Wei (2010), where the two commodities were found to be cointegrated. Again the correlations between oil and all of the four (4) stock markets considered (that is; $\boldsymbol{LNSP_t}$, $\boldsymbol{LNSI_t}$, $\boldsymbol{LMSI_t}$, and $\boldsymbol{LWSI_t}$) have significant positive outcomes. The relationships between oil and the Nigerian and Norwegian stock markets return highly significant correlations of the values 0.8429 and 0.8778 respectively. This is a preliminary indication, given the general level of positive correlations, that crude oil spot price changes move together in a similar direction with all the considered stock markets' prices.

**Table 6. 2: Variables Correlation Matrix**

| | $LMSI_t$ | $LGLD_t$ | $LNSI_t$ | $LNSP_t$ | $LOIL_t$ | $LWSI_t$ |
|---|---|---|---|---|---|---|
| $LMSI_t$ | 1.0000 | | | | | |
| $LGLD_t$ | 0.6993* | 1.0000 | | | | |
| $LNSI_t$ | 0.5927* | 0.7869* | 1.0000 | | | |
| $LNSP_t$ | 0.4360 | 0.6737* | 0.8539* | 1.0000 | | |
| $LOIL_t$ | 0.6278* | 0.8752* | 0.8778* | 0.8429* | 1.0000 | |
| $LWSI_t$ | 0.1199 | 0.3444 | 0.7056* | 0.5334* | 0.5629* | 1.0000 |

**indicates statistical significance*

The above initial investigation based on correlation outcomes is equally confirmed from the graphical positions of the variables. Figure 6.4 below is joint graphical representation of the applied variable in log levels. The figure tends to confirm the above correlation outcomes, as the movements of the oil and stock market variables show almost identical patterns. Also, the movement directions of gold and oil variables are the same as suggested by the correlation result. However, this analysis is inconclusive due the data being applied in level terms. A more detailed examination will be carried out in the section below, where the applied variables will be examined for unit root.

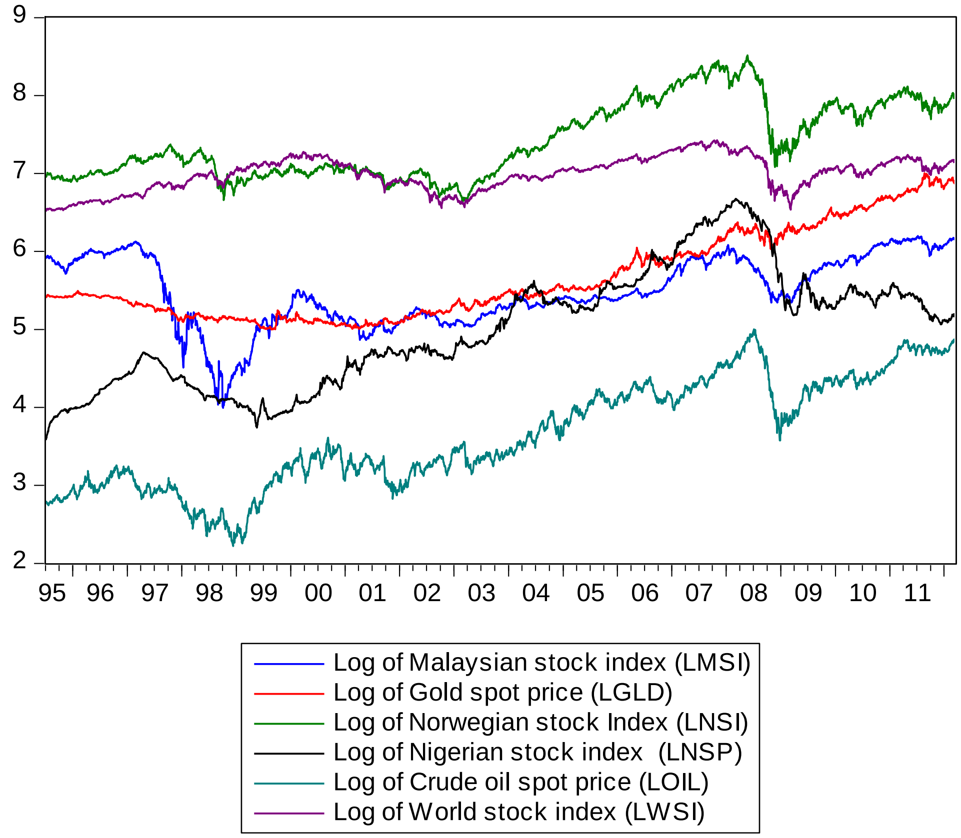



**Figure 6. 4: Graphical representation of applied variable in log level.**

### 6.4.2.2 Augmented Dickey-Fuller Unit root Test

Time series data are applied in this chapter, which have a common problem of unit root. This point was discussed in the ADF model specification in of chapter 3. Therefore, as was done with the dataset in both chapters 4 and 5, it is appropriate to subject the dataset here too to the process of unit root analysis. The Augmented Dickey-Fuller (ADF) unit root test as specified in equation (3.9) was implemented in this regard to check for stationarity. As pointed out, this is to ensure that the main empirical process is not threatened by spurious regression problem. Table 6.3 below has the results from all the variables unit root tests given the assumptions of intercept and trend.

As was the case with the previous empirical chapters, the given results were judged based on the standard decision rule in statistics when *ADF statistics > critical values, we do not reject null hypothesis and thus, implying that unit root exists*. Also, when *ADF statistics < critical values, we reject the null hypothesis*, consequently, implying that unit root does not exist. The tests were based on null hypotheses assumption of the series with unit root, against the alternative. Also as was done in chapters 4 and 5, the Schwarz information criterion (SIC) is adopted here, as the lag selection procedure is based on the Ng and Perron's (1995) simulation outcome. This is in order to avoid being caught up with the problem of over-parameterisation arguments, as seen in chapter 3. Again this follows the discussion about lag selection and information criteria in chapter 3.

Thus, given the above decision rule, from the result in Table 6.3, it could be seen that all the ADF *t*-statistics on the left hand side (normal level) of the table are greater than the critical values at the 1% and 5 % levels of significance. Therefore, the null hypothesis of unit root existing in all the variables cannot be rejected. The results (log difference level) on the right hand side of the table indicate ADF *t*-statistics are far lower than the critical values at the of 1% and 5 % level of significance. The implication of this outcome is that, the null hypothesis of unit root existing in all the variables is rejected. Thus, the variables are now free from the influence of unit root.

**Table 6. 3: ADF unit root results (intercept and trend)**

| Series | Lag length | ADF *t*-stat | Series | Lag length | ADF *t*-stat |
|---|---|---|---|---|---|
| $LMSI_t$ | 1 | -2.0438 | $\Delta LMSI_t$ | 0 | -59.999** |
| $LGLD_t$ | 0 | -1.8586 | $LGLD_t$ | 0 | -65.032** |
| $LNSI_t$ | 0 | -2.0273 | $\Delta LNSI_t$ | 0 | -65.318** |
| $LNSP_t$ | 3 | -0.6423 | $\Delta LNSP_t$ | 2 | -33.665** |
| $LOIL_t$ | 0 | -2.8251 | $\Delta LOIL_t$ | 0 | -64.238** |
| $LWSI_t$ | 2 | -2.2773 | $\Delta LWSI_t$ | 1 | -46.567** |

*Tests were conducted using Schwarz information criteria. ** indicates significance at 1%. Significant results indicate the null of unit root is rejected.*

## 6.5 Empirical Analysis

This section presents the main empirical analysis of the chapter. As pointed out in section 6.3, the main empirical model of the analysis is the bivariate GARCH model. This is made possible by the model specification shown in equation (6.4), which will be used in identifying the conditional mean from the data series. Also, the BEKK parameter restriction achieved in equations (6.5a, 6.5b and 6.5c) will be applied to compute the series conditional variance and covariance. Thus the following subsections will present the specified models as aligned to the requirements of this chapter's questions. This is followed by the results and interpretations.

### 6.5.1 Tested Series

Given that this chapter's data is multivariate and the empirical application is a achieved via a bivariate GARCH model, relationships between variables in a twofold procedure will be adopted, as the bivariate GARCH can only accommodate two investigative variables at a time. This is similar to the manner in which Malik and Ewing (2009) approached their empirical analysis. Table 6.4 below captures the estimated relationships reflected in five different series pairs. These relationships are further organised into types 1 and 2, thus, reflecting the tested series in both log and return forms. The test in log form is captured as relationship 1, whereas the return form is relationship 2.

Relationship 1 measures interactions between; Log of oil price *against* Log of Nigeria Stock Index **($LOIL_t$ $LNSI_t$)**, Log of oil price *against* Log of Norwegian Stock Index **($LOIL_t$ $LNSI_t$)**, Log of oil price *against* Log of Malaysian Stock Index **($LOIL_t$ $LMSI_t$)**, Log of oil price *against* Log of World Stock Index **($LOIL_t$ $LWSI_t$)** and Log of oil price *against* Log of Gold Price **($LOIL_t$ $LGLD_t$)**. Relationship 2 measures interactions between; Return of oil price *against* Return of Nigeria Stock Index ($\Delta LOIL_t$ $\Delta LNSP_t$), Return of oil price *against* Return of Norwegian Stock Index ($\Delta LOIL_t$ $\Delta LNSI_t$), Return of oil price *against* Return of Malaysian Stock Index ($\Delta LOIL_t$ $\Delta LMSI_t$), Return of crude oil *against* Return of World Stock Index ($\Delta LOIL_t$ $\Delta LWSI_t$) and Return of oil price *against* Return of Gold Price ($\Delta LOIL_t$ $\Delta LGLD_t$). All are characterised as series pairs ***6A1, 6A2, 6A3, 6A4*** and ***6A5*** respectively, as shown in Table 6.4 below.

**Table 6. 4: Description of tested series**

| Series pair | Relationship 1 |
|---|---|
| Series pair 6A1 | Log of oil price *against* Log of Nigeria Stock Index ($LOIL_t$ $LNSI_t$) |
| Series pair 6A2 | Log of oil price *against* Log of Norwegian Stock Index ($LOIL_t$ $LNSI_t$) |
| Series pair 6A3 | Log of oil price *against* Log of Malaysian Stock Index ($LOIL_t$ $LMSI_t$) |
| Series pair 6A4 | Log of oil price *against* Log of World Stock Index ($LOIL_t$ $LWSI_t$) |
| Series pair 6A5 | Log of oil price *against* Log of Gold Price ($LOIL_t$ $LGLD_t$) |
| **Series pair** | **Relationship 2** |
| Series pair 6A1 | Return of oil price *against* Return of Nigeria Stock Index ($\Delta LOIL_t$ $\Delta LNSP_t$) |
| Series pair 6A2 | Return of oil price *against* Return of Norwegian Stock Index ($\Delta LOIL_t$ $\Delta LNSI_t$) |
| Series pair 6A3 | Return of oil price *against* Return of Malaysian Stock Index ($\Delta LOIL_t$ $\Delta LMSI_t$) |
| Series pair 6A4 | Return of oil price *against* Return of World Stock Index ($\Delta LOIL_t$ $\Delta LWSI_t$) |
| Series pair 6A5 | Return of oil price *against* Return of Gold Price ($\Delta LOIL_t$ $\Delta LGLD_t$) |

### 6.5.2 Cointegration Results

In examining the interdependences between oil price, stock and gold markets, the starting point is to get information on the long run relationships between the variables and market efficiencies. Thus, a cointegration test is conducted to find out the long run relationships between the oil, stock and gold prices. The test is conducted based on the structured series pairs 6A1 – 6A5 in Table 6.4 using relationship 1. Applying the series pairs in log level terms in the cointegration analysis will capture the essence of variables' relationships in log level with the information useful in examining market efficiency. This leaves relationship 2 to be examined under the conditional mean, variance and covariance in the subsequent sections.

Table 6.5 provides results for the cointegration test. The results depict significant outcomes for the test involving series pairs 6A2- oil price and Norwegian stock market, 6A3- oil price and Malaysian stock market and 6A5- oil price and Gold price. This is based on the significant *t*-statistic values from the relationships, with series pair 6A2 being significant at -2.5540, 6A3 at -2.3463 and 6A5 at -2.6510. Both 6A2 and 6A3 are significant at the 5% level whereas 6A5 is significant at the 1% level. The ultimate outcome of the relationships in 6A2, 6A3 and 6A5 suggest there to be cointegration. The relationships in series pairs 6A1- oil price and Nigerian stock market and 6A4- oil price and World stock market are both non significant, hence, implying no long run relationships in the relationships among series pairs 6A1 and 6A4.

**Table 6. 5: Cointegration results for series pairs *6A1 – 6A5***

| **Series pairs** | **Relationship 1** | **Lag length** | ***t*-Statistics** | ***P*-value** |
|---|---|---|---|---|
| Series pair6A1 | $LOIL_t$ $LNSP_t$ | 1 | -1.4859 | 0.1374 |
| Series pair 6A2 | $LOIL_t$ $LNSI_t$ | 0 | -2.5540 | 0.0107* |
| Series pair 6A3 | $LOIL_t$ $LMSI_t$ | 0 | -2.3463 | 0.0190* |
| Series pair 6A4 | $LOIL_t$ $LWSI_t$ | 0 | -1.2038 | 0.2287 |
| Series pair 6A5 | $LOIL_t$ $LGLD_t$ | 0 | -2.6510 | 0.0081** |

***indicates significance at 1% and *indicates significance at 5%.*

With series pair 6A5- oil price and gold price being significant with a *t*-statistic value of -2.6510, this points to the long run relationship of oil and gold prices. A similar position was earlier found by Zhang and Wei (2010). Series pairs that returned evidence of cointegration imply a possibility of long run relationships between tested variables. This is useful in understanding if a particular variable's volatility could affect the other in the paired relations. This information will in turn determine the potential market efficiency outcome, which is useful in the next level of analysis. However, series pairs that failed to return evidence of cointegration are equally informative in their way. At least the results provide the first level of information useful in the next level of analysis and thus cannot be discounted.

### 6.5.3 Conditional Mean Results

As the cointegration analysis in the above section (6.5.2) is based on relationship 1, the conditional mean, variance and covariance are analysed based on the relationship 2, described in Table 6.4. This implies that the analyses are carried out based on the variables log difference, which is done to avoid the problem of autocorrelation discovered in the data series (see Table 6.3 in section 6.4.2.2). Therefore, Table 6.6 below presents the estimated conditional mean results for series pairs 6A1 - 6A5; the outcomes represent the return series from each of the considered variables in the series pairs. The estimation is carried out given the model specification in equation (6.5c), which is reflected in the estimated equation column in the table. As can be seen from the *z*-Statistics and *p*-values, all mean values from each of the series pairs are significant, except in the case of returns log variables of gold which returned a *z*-statistic value of 0.4077, thereby becoming insignificant with a *p*-value of 0.6835.

Additionally, the level of significance in oil returns in all cases is 1%, except in the case of the relationship with gold, where it is at 5% with *p*-value of 0.0248. Also, the returns series of all the other variables in relationship with oil are at the 1% level of significance, except in the case of the Nigerian stock market, that is where it is at 5% with a *p*-value of 0.0115. Thus, these results imply that the stock index returns from each of the considered markets (Nigerian, Norwegian, Malaysian and World stock indexes) given the significance in oil prices are efficient. So in the pairwise model involving the relationship between oil and gold prices the equation which models the autoregression in the gold price volatility, the mean value for volatility is not significantly different from zero. A possible interpretation of these results is that the returns in the stock markets are all efficient given the crude oil price changes and vice versa. However, this is not the case with the gold market, but this is not much of a problem here as the bigger analysis picture is focusing mainly on volatility transmission between the pairwise variables, which is to be examined below in the section below. The general implication for this chapter's empirical process is that efficient returns were attained with the stock markets, which left the volatility situation to be examined next.

**Table 6. 6: Conditional mean results**

| Series pairs | Estimated Equation | Coefficient | *z*-Statistic | *p*-Value |
|---|---|---|---|---|
| Series pair 6A1 | $\Delta \boldsymbol{LOIL_t} = \boldsymbol{\alpha_{01}}$ | 0.0008 | 2.7219 | 0.0065** |
| | $\Delta \boldsymbol{LNSP_t} = \boldsymbol{\alpha_{03}}$ | 0.0003 | 2.5257 | 0.0115* |
| Series pair 6A2 | $\Delta \boldsymbol{LOIL_t} = \boldsymbol{\alpha_{01}}$ | 0.0008 | 2.9104 | 0.0036** |
| | $\Delta \boldsymbol{LNSI_t} = \boldsymbol{\alpha_{03}}$ | 0.0008 | 3.9155 | 0.0001** |
| Series pair 6A3 | $\Delta \boldsymbol{LOIL_t} = \boldsymbol{\alpha_{01}}$ | 0.0008 | 2.5842 | 0.0098** |
| | $\Delta \boldsymbol{LMSI_t} = \boldsymbol{\alpha_{03}}$ | 0.0005 | 3.9643 | 0.0001** |
| Series pair 6A4 | $\Delta \boldsymbol{LOIL_t} = \boldsymbol{\alpha_{01}}$ | 0.0008 | 2.7264 | 0.0064** |
| | $\Delta \boldsymbol{LWSI_t} = \boldsymbol{\alpha_{03}}$ | 0.0005 | 4.4781 | 0.0000** |
| Series pair 6A5 | $\Delta \boldsymbol{LOIL_t} = \boldsymbol{\alpha_{01}}$ | 0.0007 | 2.2441 | 0.0248* |
| | $\Delta \boldsymbol{LGLD_t} = \boldsymbol{\alpha_{03}}$ | $4.90*10^{-5}$ | 0.4077 | 0.6835 |

*Estimated relationships are based on equation (6.5a and c);* $\Delta \boldsymbol{ly_t} = \boldsymbol{\alpha_{01}}$, *where* $\boldsymbol{\alpha_{01}}$=*Indefinite matrix. **indicates significance at 1% and *indicates significance at 5%.*

### 6.5.4 Conditional Variance and Covariance Results

Table 6.7 below presents the estimated parameters for both conditional variance and covariance based on the specified series pairs 6A1 – 6A5 estimation in Table 6.4 above, given relationship 2. Again, the empirical series pairs specification is based on equations (6.5a, 6.5b and 6.5c), as specified in section 6.3 above. The variances and covariance coefficients as captured in the equations capture the level of impact of shocks and the various parameters being measured, as signalled by the level of significance of their *z*-statistic values. Therefore, from Table 6.7 below, it could be seen that all examined coefficients from the five series pairs are all significant, except the two coefficients of $\boldsymbol{\alpha_{02}}$ from series pairs 6A1 and 6A3, with *z*-statistics of 1.16 and 1.61 respectively. These insignificant coefficients are those of the conditional covariance between oil price and the Nigerian stock index, and between oil price and the Malaysian stock index.

**Table 6. 7: Conditional variance and covariance results for relationships 2**

| Series pairs | $\alpha_{01}$ | $\alpha_{02}$ | $\alpha_{03}$ | $\alpha_{11}$ | $\alpha_{22}$ | $\alpha_{33}$ | $\beta_{11}$ | $\beta_{22}$ | $\beta_{33}$ |
|---|---|---|---|---|---|---|---|---|---|
| Series pair 6A1 | $2.84*10^{-6}$ *(4.54)* | $5.24*10^{-7}$ *(1.16)* | $8.71*10^{-6}$ *(18.68)* | 0.1656 *(24.96)* | 0.0809 | 0.4884 *(42.47)* | 0.9836 *(681.0)* | 0.8345 | 0.8484 *(144.1)* |
| Series pair 6A2 | $2.57*10^{-6}$ (4.30) | $8.05*10^{-7}$ *(3.79)* | $2.63*10^{-6}$ *(6.68)* | 0.1937 *(28.70)* | 0.0485 | 0.2505 *(32.57)* | 0.9789 *(597.9)* | 0.9432 | 0.9635 *(418.4)* |
| Series pair 6A3 | $3.23*10^{-6}$ *(4.76)* | $2.66*10^{-7}$ *(1.61)* | $9.53*10^{-7}$ *(8.03)* | 0.1741 *(25.80)* | 0.0525 | 0.3016 *(41.08)* | 0.9818 *(637.7)* | 0.9378 | 0.9551 *(518.4)* |
| Series pair 6A4 | $2.84*10^{-6}$ *(4.19)* | $2.88*10^{-7}$ *(2.45)* | $6.78*10^{-7}$ *(6.10)* | 0.1915 *(27.09)* | 0.0521 | 0.2719 *(32.25)* | 0.9792 *(576.5)* | 0.9396 | 0.9596 *(380.0)* |
| Series pair 6A5 | $3.50*10^{-6}$ *(5.04)* | $1.98*10^{-7}$ *(2.34)* | $2.00*10^{-7}$ *(5.04)* | 0.1883 *(26.52)* | 0.0355 | 0.1885 *(57.07)* | 0.9790 *(566.1)* | 0.9619 | 0.9826 *(2018)* |

$\alpha_{01,}\alpha_{02,}$ *and* $\alpha_{03}$ *are indefinite matrices, while* $\alpha_{11,}\alpha_{22,}$ *and* $\alpha_{33}$ *and* $\beta_{11,}\beta_{22,}$ *and* $\beta_{33}$ *are diagonal matrices.* $\boldsymbol{\alpha_{22}}=\boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ *and* $\boldsymbol{\beta_{22}}=\boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$.
*Figures in parenthesis represent z-Statistic values.*

Technically, the imposed restrictions given the diagonal BEKK do not allow simultaneous estimates of the coefficients for $\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}}$ and $\boldsymbol{h_{12,t-1}}$ as achieved with the case of conditional variances. Thus, $\boldsymbol{\alpha_{22}} = \boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ and $\boldsymbol{\beta_{22}} = \boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$ the coefficient measure was left out. Hence, if it is decided based on the significance of individual coefficients $\boldsymbol{\alpha_{11}}$and $\boldsymbol{\alpha_{33}}$, and also $\boldsymbol{\beta_{11}}$and $\boldsymbol{\beta_{33}}$ given their respective *t*-statistics for their joint t-statistic to be significant, it could be concluded that all coefficients are significant. However, for the sake of caution, it is rather left for the series $\boldsymbol{\alpha_{02}}$ coefficient to decide the level of significance in each relationship case. All the conditional variances and covariance returned significant outcomes, with the exception of the coefficients for Nigerian and Malaysian stock markets. This implies that the GARCH processes of individual series are affected by themselves, as the coefficient terms of both the GARCH and ARCH parameters are significant. The insignificant outcomes highlighted in the case of conditional covariance imply that no empirical evidence exists of volatility transmission between those stock markets' prices and crude oil price.

### 6.5.5 Interpreting Empirical Findings based on Research Questions

The above empirical results of the conditional mean, variances and covariance are interpreted below to answer the given research questions. The answers provided are extended to cover their broad implications, especially as their impacts are extended to related economic issues. The preliminary findings established from the descriptive statistics, unit root and cointegration processes are also reflected in this section.

#### 6.5.5.1 Interdependence between Oil Price and Export Dependent Stock Markets

In addition to examining the volatility transmission between crude oil price and crude oil export dependent countries, this section will mainly answer the question; *what is the nature of different crude oil export dependent economies' reaction to the commodity price changes?* As pointed out in section 6.2 above, each oil export dependent country has peculiar factors guiding its economic conditions; this point motivated the research question being answered here. The economic situations of the crude oil export dependent countries of Nigeria, Norway and Malaysia are examined via their stock markets' reaction to oil price changes, empirically channelled and answered through hypothesis ***H6A***.

Thus, the series pairs of consideration for this section are 6A1, 6A2 and 6A3. Together they examined the conditional mean, variance and covariance between oil price and Nigerian Stock index (6A1), oil price and Norwegian stock index (6A2) and oil price and Malaysian stock index (6A3). Therefore, given the level of significance of coefficients in the mean equations of the three series pairs, we have established them as being mean efficient, Series pair 6A1 relationships have a mean return with *z*-statistics 2.7219 and 2.5257 for oil price and the Nigerian stock index. Series pair 6A2 has a mean return with *z*-statistics 2.9104 and 3.9155 for oil and the Norwegian stock index, whereas, series pair 6A3 has a mean return with *z*-statistics 2.5842 and 3.9643 for oil and the Malaysian stock index. This signifies that, given oil price influences in the three countries, stock market returns are at the efficient level, as the conditional means are significant in each case.

Turning to the impact of volatility, given the level of significance in all the conditional variance coefficients of the three series pairs and also the error coefficients, it could be said that the conditional variances of each series has influence on itself. As seen from the GARCH 1 and 2 equations in Table 6.8 below, all the fitted equations in the series pairs 6A1, 6A2 and 6A3 have significant *z*-statistics. In series pair 6A1, the GARCH 1 equation has a $\boldsymbol{\varepsilon^2_{1,t-1}}$ coefficient with *z*-statistic 24.96 and the GARCH 2 component coefficient of $\boldsymbol{\varepsilon^2_{2,t-1}}$has a *z*-statistic of 42.47. As these coefficients measure the effects of past and present volatility, the implication of these outcomes is that volatility factors relating to shocks or news events both in the present and past on a series could affect the future outcome of the same series. Thus, since the series pair 6A1 considers the oil market and the Nigerian stock index, the effect of news or volatility in the oil market has impact on itself, and the same is the case with the Nigerian stock index. In examining the conditional variances, the $\mathbf{h_{11,t-1}}$ coefficient was found to have a significant *z*-statistic of 681.0 in GARCH 1 and $\mathbf{h_{22,t-1}}$ coefficient 144.1 in GARCH 2. Therefore, the conditional variance in both oil and Nigeria stock index (series pair 6A1) affect themselves.

**Table 6. 8: Co/variances for returns of oil price and Nigerian stock**

| Series pairs | Equation | Model |
|---|---|---|
| | | Model; $\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}}$ <br> $\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}}$ <br> $\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}}$ |
| Series pair 6A1 | *GARCH1* | $\boldsymbol{h_{11,t}} = 2.84 * 10^{-6} + 0.1656\boldsymbol{\varepsilon^2_{1,t-1}} + 0.9836\boldsymbol{h_{11,t-1}}$ <br> *(4.54)* *(24.96)* *(681.0)* |
| | *Covariance* | $\boldsymbol{h_{12,t}} = 5.24 * 10^{-7} + 0.0809\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}} + 0.8345\boldsymbol{h_{12,t-1}}$ <br> *(1.16)* |
| | *GARCH2* | $\boldsymbol{h_{22,t}} = 8.71 * 10^{-6} + 0.4884\boldsymbol{\varepsilon^2_{2,t-1}} + 0.8484\boldsymbol{h_{22,t-1}}$ <br> *(18.68)* *(42.47)* *(144.1)* |

*$\boldsymbol{\alpha_{22}}$=$\boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ and $\boldsymbol{\beta_{22}}$=$\boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$in equations (6.5a) and (6.5c) and are based on the imposed restriction within the models. All other non substituted elements of the regressions are as defined in the model specification section. Figures in parentheses are z-statistics.*

Tables 6.9 and 6.10 below have similar outcomes with Table 6.8 as the tested series pairs 6A2 and 6A3 could be said to posses the same conditional variance characteristics with series pair 6A1. This is as the GARCH 1 equation in series pair 6A2 has a significant $\boldsymbol{\varepsilon^2_{1,t-1}}$ coefficient with z-statistic 28.70 and the GARCH 2 has a $\boldsymbol{\varepsilon^2_{2,t-1}}$ coefficient *z*-statistic of 25.80. In series pair 6A3, the GARCH 1 and 2 equations have significant $\boldsymbol{\varepsilon^2_{1,t-1}}$ and $\boldsymbol{\varepsilon^2_{2,t-1}}$ coefficients with *z*-statistics 25.80 and 41.08 respectively. Since series pair 6A2 examines oil price and the Norwegian stock index, while series pair 6A3 looks at oil price and the Malaysian stock index, it could be concluded that the volatility of each series affects itself. Testing for conditional variances in the two series pairs, the $\boldsymbol{h_{11,t-1}}$ and $\boldsymbol{h_{22,t-1}}$ coefficients in series pair 6A2 were found to have significant z-statistics of 597.9 and 418.4 respectively, while in series pair 6A3, the two coefficients of $\boldsymbol{h_{11,t-1}}$ and $\boldsymbol{h_{22,t-1}}$ were found to be significant, with *z*-statistics of 637.7 and 518.4 respectively. These results suggest the conditional variances in oil price and Norwegian stock index (series pair 6A2) and also, oil price and the Malaysian stock index (series pair 6A3) affect themselves.

**Table 6. 9: Co/variances for returns of oil price and Norwegian stock index**

| Series pairs | Equation | Model; |
|---|---|---|
| | | $\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}}$ |
| | | $\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}}$ |
| | | $\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}}$ |
| Series pair 6A2 | *GARCH1* | $\boldsymbol{h_{11,t}} = 2.57 * 10^{-6} + 0.1937\boldsymbol{\varepsilon^2_{1,t-1}} + 0.9789\boldsymbol{h_{11,t-1}}$ |
| | | *(4.30)* *(28.70)* *(597.9)* |
| | *Covariance* | $\boldsymbol{h_{12,t}} = 8.05 * 10^{-7} + 0.0485\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}} + 0.9432\boldsymbol{h_{12,t-1}}$ |
| | | *(3.79)* |
| | *GARCH2* | $\boldsymbol{h_{22,t}} = 2.63 * 10^{-6} + 0.2505\boldsymbol{\varepsilon^2_{2,t-1}} + 0.9635\boldsymbol{h_{22,t-1}}$ |
| | | *(6.68)* *(32.57)* *(418.4)* |

*$\boldsymbol{\alpha_{22}}=\boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ and $\boldsymbol{\beta_{22}}=\boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$ in equations (6.5a) and (6.5c) and are based on the imposed restriction within the models. All other non substituted elements of the regressions are as defined in the model specification section. Figures in parentheses are z-statistics.*

**Table 6. 10: Co/variances for returns of oil price and Malaysian stock index**

| Series pairs | Equation | Model; |
|---|---|---|
| | | $\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}}$ |
| | | $\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}}$ |
| | | $\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}}$ |
| Series pair 6A3 | *GARCH1* | $\boldsymbol{h_{11,t}} = 3.23 * 10^{-6} + 0.1741\boldsymbol{\varepsilon^2_{1,t-1}} + 0.9818\boldsymbol{h_{11,t-1}}$ |
| | | *(4.76)* *(25.80)* *(637.7)* |
| | *Covariance* | $\boldsymbol{h_{12,t}} = 2.66 * 10^{-7} + 0.0525\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}} + 0.9378\boldsymbol{h_{12,t-1}}$ |
| | | *(1.61)* |
| | *GARCH2* | $\boldsymbol{h_{22,t}} = 9.53 * 10^{-7} + 0.3016\boldsymbol{\varepsilon^2_{2,t-1}} + 0.9551\boldsymbol{h_{22,t-1}}$ |
| | | *(8.03)* *(41.08)* *(518.4)* |

*$\boldsymbol{\alpha_{22}}=\boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ and $\boldsymbol{\beta_{22}}=\boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$ in equations (6.5a) and (6.5c) and are based on the imposed restriction within the models. All other non substituted elements of the regressions are as defined in the model specification section. Figures in parentheses are z-statistics.*

In measuring the cross volatility between each series pair of variables, coefficient significance in the covariance equation in the case of each series pair is used. From Table 6.8 only the case of series pair 6A2 has a significant outcome, with a *z*-statistic value for $\boldsymbol{\alpha_{02}}$ of 3.79. This is in contrast with series pairs 6A1 and 6A3, which respectively have insignificant *z*-statistic values for $\boldsymbol{\alpha_{02}}$ of 1.16 and 1.61. Technically speaking, the imposed restrictions given the diagonal BEKK fail to make it possible to estimate simultaneously the coefficients of $\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}}$ and $\boldsymbol{h_{12,t-1}}$ as achieved with the case of conditional variances. Thus, it is assumed that the coefficient element of the $\boldsymbol{\alpha_{02}}$ accounts for the significance or otherwise of the entire covariance equation. Hence, it is concluded that on the issue of volatility transmissions from one series to another, given the conditional covariance outlook, mixed outcomes were found for the different tested series pairs.

Series pairs 6A1 and 6A3, the cases of oil price and the Nigerian stock index and oil price and the Malaysian stock index respectively returned insignificant covariance coefficients, with z-statistics of 1.16 and 1.61 respectively. This implies that volatility is not transmitted from either series to the other. In practical terms, oil prices are not able have impact on the stock markets of these countries. This result is in contrast with the finding of Arouri et al. (2011) of evidence of volatility transmission between oil price and the stock markets of GCC countries, despite these countries being oil export dependent too. However, the case of oil price and the stock market of Norway returned a significant outcome with a *z*-statistic value of 2.62. This significant conditional covariance coefficient, in contrast to the case of oil price with Nigeria and Malaysia, implies that there is volatility transmission between oil price and the Norwegian stock market. Essentially, this result confirmed that crude oil price has an impact on the Norwegian stock market performance. Thus, in subjecting this outcome to hypothesis test via ***H6A,*** we accept $\boldsymbol{H_0}$ and reject $\boldsymbol{H_1}$. Hence, d*ifferent crude oil export dependent economies react to the commodity price changes in different manner*.

Examining further the failure to establish evidence of volatility transmission across the oil and equity sectors of Nigeria and Malaysia, it can be seen that both countries have developing economic status. In the case of Nigeria, the result seems to be mixed; whilst this may be acceptable given that the country has a still developing stock market, the outcome may be questioned given the practical presence of the Nigerian banking sector as the distributing agents of crude oil proceeds internally, since the banking sector has in recent years made huge gains in the country's stock exchange, by becoming the biggest gainer of the market. The case of Malaysia may be explained as the country has a diversified economy with flourishing manufacturing and services sectors (BNM, 2009:

p.37). Also, the presence of other viable export commodities like palm oil, tin (BNM, 2011: p.11) could explain why oil may not be the only factor in its stock market return. As for Norway, it is understandable for its stock market to react to oil price, given its huge oil export and also, since it is a developed economy.

#### 6.5.5.2 Volatility Transmission between Oil Price and World Stock Market

In addition to the essential element of understanding crude oil net consuming countries' stock markets' reaction to oil price changes, this section mainly answers the question; *is there any volatility transmission between crude oil prices and global stock market returns?* Answering this question could help to expand further the perspective within which Malik and Ewing (2009) applied their research and also, have implications for further researchable questions such as; *could the information provide any useful means of globally hedging crude oil revenue?* Thus, the question follows the finding by Malik and Ewing on volatility transmission between oil price and different sectors of the US stock market and also, the above sections' findings regarding oil price and crude oil export dependent countries. The empirical process is channelled through hypothesis ***H6B***.

The series pair considered in answering this question is 6A4, which looks at the interactions between oil price and the global stock index. Given that the conditional mean coefficient of the series pair from Table 6.6 is significant, the mean investment level is efficient, as the series pair 6A4 relationships have mean return for oil price and world stock index with significant *z*-statistics 2.7264 and 4.4781 respectively. This therefore implies that mean return of oil price and stock markets are efficient, as the conditional mean are significant in all cases.

As for volatility impact, judging from Table 6.11 below it could be seen that all the conditional variance coefficients of series pairs and also the error coefficients are significant. Thus, it could be said that the conditional variances of each series have influence on itself, as the GARCH 1 and 2 equations in the table given the fitted equations have significant *z*-statistics. The GARCH 1 equation has a $\boldsymbol{\varepsilon^2_{1,t-1}}$ coefficient with a *z*-statistic 27.09 and the GARCH 2 component coefficient of $\boldsymbol{\varepsilon^2_{2,t-1}}$ has a z-statistic of 32.25. Since the coefficients measure the effects of past and present volatility, the implication of these outcomes is that volatility factors relating to shocks or news events both in the present and past on a series could affect the future outcome of the same series. As the series pair 6A4 considers the oil market and the world stock index, the effect of news or volatility in both oil price and world stock index impact on themselves. In the case of the conditional variances, $\boldsymbol{h_{11,t-1}}$ and $\boldsymbol{h_{22,t-1}}$ coefficients both have significant *z*-statistics of 576.5 and 380.0 for GARCH 1 and GARCH 2 respectively. Therefore, the conditional variances in both oil price and world stock index (series pair 6A4) are able to affect themselves.

**Table 6. 11: Co/variances for returns of oil price and World stock index**

| **Series pairs** | **Equation** | **Model;** $\boldsymbol{h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}}$<br>$\boldsymbol{h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}}$<br>$\boldsymbol{h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}}$ |
|---|---|---|
| Series pair 6A4 | *GARCH1* | $\boldsymbol{h_{11,t}} = 2.84 * 10^{-6} + 0.1915\boldsymbol{\varepsilon^2_{1,t-1}} + 0.9792\boldsymbol{h_{11,t-1}}$<br>*(4.19)* *(27.09)* *(576.5)* |
| | *Covariance* | $\boldsymbol{h_{12,t}} = 2.88 * 10^{-7} + 0.0521\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}} + 0.9396\boldsymbol{h_{12,t-1}}$<br>*(2.45)* |
| | *GARCH2* | $\boldsymbol{h_{22,t}} = 6.78 * 10^{-7} + 0.2719\boldsymbol{\varepsilon^2_{2,t-1}} + 0.9596\boldsymbol{h_{22,t-1}}$<br>*(6.10)* *(32.25)* *(380.0)* |

$\boldsymbol{\alpha_{22}}=\boldsymbol{\alpha_{11}} * \boldsymbol{\alpha_{33}}$ *and* $\boldsymbol{\beta_{22}}=\boldsymbol{\beta_{11}} * \boldsymbol{\beta_{33}}$ *in equations (6.5a) and (6.5c) and are based on the imposed restriction within the models. All other non substituted elements of the regressions are as defined in the model specification section. Figures in parentheses are z-statistics.*

In understanding the volatility transmission between the oil price and world stock index, the coefficient for $\boldsymbol{\alpha_{02}}$ has a significant outcome, with a *z*-statistic value 3.79. Hence, it is confirmed that there is significant volatility transmission between oil price and the world stock index. This result practically implies that crude oil price has a significant impact on the world stock market performance and vice versa. If this outcome is seen through the research hypothesis in ***H6B,*** thus, we reject $\boldsymbol{H_0}$ and accept $\boldsymbol{H_1}$. Therefore, *there is a volatility transmission between crude oil prices and global stock market returns.* The further implication of the empirical finding here is that it points to the existence of volatility transmission between oil price and the stock market of crude oil net consuming countries, such as the USA, Canada, China, etc. Already, Malik and Ewing (2009) and also, Jones and Kaul (1996) have established the existence of volatility transmission between oil price and the stock markets of the USA and Canada. Therefore, by establishing that volatility transmission exists between crude oil price and the global stock index, which by extension includes the stock markets of these countries, this study confirms the findings of similar preceding research.

Another implication, given the finding in this section, is the existence of opportunity for further empirical pursuit in answering the arising questions**;** *could the information of volatility transmission between oil price and stock market as discovered here provide any useful means of hedging crude oil revenue? How about using such information in building an asset pricing model for oil revenue?* This question largely arises due to the assertion by Malik and Ewing (2009) that such finding is useful for cross market hedging and also, for building an accurate assets pricing model. This empirical finding has largely confirmed the existence of volatility transmission similar to the manner in which the study by Malik and Ewing has done; hence, going further to investigate empirically the validity of their hedging assertions with regard to the empirical finding here should be the next step, especially as finding this out could have relevance to oil revenue SWFs, currently lacking in a good level of empirical engagement.

#### 6.5.5.3 Examining Gold Reserve as Alternative to Stock Market Investment

This section mainly answers the question; *could gold reserve serve as an alternative to equity markets?* Answering this question is channelled through hypothesis ***H6C***. One of the essential area in which the answer to this question could have significance is the growing search for alternative investment avenue for natural resource revenue. This is in line with the three (3) sets of decision points analysed in van der Ploeg and Venables (2011). Among these decision choices is the approach of investing natural resource proceeds in securities traded in stock exchanges, a strategy followed by the sovereign wealth fund (SWF). Thus, answering the research question in this section could present an opportunity for further empirical research in the area of SWF. Series pair 6A5 which looks into the interactions between oil price and the gold spot is effectively investigated in answering the research question in this section.

The results for the conditional mean return in the case of series pair 6A5 in Table 6.6 have different outcomes for the relationship in the two series of oil price and gold spot price, as the coefficient in the case of oil price is significant with *z*-statistic 2.2441, but for gold price it is insignificant with *z*-statistic and *p*-value of 0.4077 and 0.6835 respectively. This therefore implies that while the mean return of oil price is efficient, the same cannot be said of gold. However, since the volatility transmission is the major issue of concern here, the volatility impact on the two series are significant.

Table 6.12 below presents the fitted equations for both the GARCH and covariance equations. From the table, it can be seen that all the conditional variance coefficients of the series pairs and also the error coefficients are significant, suggesting that conditional variances of each series have influence on itself, as the GARCH 1 and 2 equations in the table have significant *z*-statistics. The GARCH 1 equation has a $\boldsymbol{\varepsilon^2_{1,t-1}}$ coefficient with *z*-statistic 26.52 and the GARCH 2 component coefficient of $\boldsymbol{\varepsilon^2_{2,t-1}}$has a *z*-statistic of 57.07. Again, since the coefficients measure the effects of past and present volatility, the implication of these outcomes is that volatility factors relating to shocks or news events both in the present and past on a series could affect the future outcome of the same series. As the series pair 6A5 considers oil price and the gold price, volatility in both oil price and gold spot price have impact on themselves.

In the case of the conditional variances, $\boldsymbol{h_{11,t-1}}$ and $\boldsymbol{h_{22,t-1}}$ coefficients both have significant *z*-statistics of 566.1 and 2018 for GARCH 1 and GARCH 2 respectively. Therefore, the conditional variance in both oil price and gold price (series pair 6A5) affect themselves. Volatility transmission between oil price and gold price is measured given the coefficient for $\boldsymbol{\alpha_{02}}$ which has a significant *z*-statistic value of 2.34, confirming the existence of volatility transmission between oil price and gold spot price. This outcome means, that in ***H6C***, $\boldsymbol{H_0}$ cannot be rejected. Hence, *Gold reserve could provide an alternative investment for crude oil revenue*. The outcome here is consistent with the findings of Zhang and Wei (2010).

**Table 6. 12: Co/variances for returns of oil and Gold prices**

| Series pairs | Equation | Model; |
|---|---|---|
| | | $h_{11,t} = \alpha_{01} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1}$<br>$h_{12,t} = \alpha_{02} + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{22}h_{12,t-1}$<br>$h_{22,t} = \alpha_{03} + \alpha_{33}\varepsilon^2_{2,t-1} + \beta_{33}h_{22,t-1}$ |
| Series pair 6A5 | *GARCH1* | $h_{11,t} = 3.50 * 10^{-6} + 0.1883\varepsilon^2_{1,t-1} + 0.9790h_{11,t-1}$<br>*(5.04)* *(26.52)* *(566.1)* |
| | *Covariance* | $h_{12,t} = 1.98 * 10^{-7} + 0.0355\varepsilon_{1,t-1}\varepsilon_{2,t-1} + 0.9619h_{12,t-1}$<br>*(2.34)* |
| | *GARCH2* | $h_{22,t} = 2.00 * 10^{-7} + 0.1885\varepsilon^2_{2,t-1} + 0.9826h_{22,t-1}$<br>*(5.04)* *(57.07)* *(2018)* |

$\alpha_{22}=\alpha_{11} * \alpha_{33}$ *and* $\beta_{22}=\beta_{11} * \beta_{33}$ *in equations (6.5a) and (6.5c) and are based on the imposed restriction within the models. All other non substituted elements of the regressions are as defined in the model specification section. Figures in parentheses are z-statistics.*

Given the above results, therefore, it could be inferred that oil rich and other SWF countries could see gold reserve as an alternative investment avenue to the capital market. Coupled with the outcome in ***H6A***, which suggested that crude oil export dependent countries' stock markets react differently to oil price changes, it is ideal to think of diversifying oil proceeds investments into another class of investable. Another potential approach is for the crude oil revenue endowed countries to think of ways in which they could have the revenues impact into the real sector of their economy. Nigeria for instance, should learn that oil proceeds, which account for up to 91% of its foreign reserve earning, need to directly impact on the equity sector of the economy. The experience of other countries like Norway, which is making good equity investments of its crude oil revenue, is exemplary. The Norway petroleum fund could provide a good example, given that it is crude oil based and invests heavily in the stock market.

## 6.6 Conclusion

This chapter examined the potential for cointegration, market efficiency and volatility transmission between crude oil price and the stock markets of selected oil export dependent countries (Nigeria, Norway and Malaysia), in addition to examining similar interaction between the oil price and global stock index and also, gold spot price. These examinations were channelled through research hypotheses motivated by the research questions: *What is the nature of different crude oil export dependent economies' reaction to the commodity price changes? Is there any volatility transmission between crude oil prices and global stock market returns? Could gold reserve serve as an alternative to equity markets?*

The overall outcome confirmed the existence of volatility transmission between oil price and stock market returns, and between, oil price and gold spot, given the interdependence between the considered variables. Also, the cointegration test reveals significant outcomes for the test involving oil price and each of the Norwegian stock market, Malaysian stock market and Gold price. This confirmed long run relationships and efficiency in the tested variables' markets. However, the relationships between oil price and the Nigerian and Malaysian stock markets are both non significant. In addition to the unit root and descriptive measures, this level of analysis provided the initial information for the main empirical procedures. Therefore, following the empirical findings and their eventual interpretations, the objectives set out were successfully attained. In order to do so, the above highlighted research questions were structured into series pairs that recognise volatility transmissions between oil price and oil export dependent countries stock markets, oil price and the world stock index and also oil price and gold spot.

From the findings, it was established that for all the series pairs, the conditional mean were significant, thus, implying that all series pairs' returns given the influence of oil price were efficient. Thus, these results imply that the stock index returns from each of the considered markets (Nigerian, Norwegian, Malaysian and World stock indexes) given the significance in oil prices are efficient. However, the gold spot price return, given its insignificant level in relationship with oil price, is not efficient. In the case of conditional variance, too, all the series pairs' results established significant outcomes. The implication of these results is that volatility factors relating to shocks or news events both in the present and past on a series could affect the future outcome of the same series, given all the tested series pairs. However, regarding the role of conditional covariance in determining the issue of volatility transmission from one series to another, mixed outcomes were obtained for the different tested series pairs. The cases of oil price and the Nigerian stock index and oil price and Malaysian stock index yielded results of no volatility transmission between the tested series. In contrast, the results for oil price and the Norwegian stock index, oil price and the World stock index and oil price and gold spot all showed evidence of volatility transmission in the tested series pairs.

Therefore, the empirical analysis failed to establish evidence of volatility transmission across the oil and equity sectors of Nigeria and Malaysia, which could be related to their nature as developing economies. This results implies that oil prices are not able have impact on the stock markets of these countries. In theory, Nigeria's stock market should have done better than it has, given the presence of the country's banking sector as the distributing agents of crude oil proceeds internally, with the sector in recent years becoming the biggest gainer the market. Malaysia's results may be explained by its being a diversified export economy with other viable export commodities like palm oil and tin, so that oil may be a less influenced factor in the country's stock market return. As for Norway, it is understandable that its stock market will react to oil price, given its huge oil exports and also, being a developed economy. As for the other side of the results that confirmed the existence of volatility transmissions among tested variables, this could be seen as a confirmation of the similar research findings in Malik and Ewing (2009) and also, Jones and Kaul (1996).

Given that this chapter's empirical findings have largely confirmed the existence of volatility transmission in most tested series pairs, resulting implications that follow the overall outcome are diverse. It could be inferred that oil rich and other SWF countries could see gold reserve as an alternative investment avenue to the capital market. Again, it is ideal to think of diversifying oil proceeds investments into other classes of investable. Also, an opportunity exists for crude oil endowed countries to think of ways in which they could have the revenues impact into the real sector of their economy. Nigeria, for instance, should learn that oil proceeds, which account for up to 91% of its foreign reserve earning, need to directly impact on the equity sector of the economy. The implications for further empirical work are equally broad, for instance, to address the arising questions**;** *could the information of volatility transmission between oil price and stock market as discovered here provide any useful means of hedging crude oil revenue?* Also, *is it possible to use such information in building an asset pricing model* *for oil revenue?* The policy and empirical implications highlighted here provide opportunities for further extension and should be pursued vigorously.

# Chapter 7: General Discussion and Conclusion

## 7.1 Introduction

The empirical work reported in this thesis found evidence for interdependence between crude oil price and GDP, crude oil price and foreign account, crude oil and gold prices, crude oil and futures prices, and crude oil price and stock markets. In investigating the impact of crude oil price shocks on the commodity export dependent countries, chapter 4 examined the null hypotheses; *Crude oil price volatility has no impact on Nigeria's GDP*, *Oil market shocks do not increase oil price volatility for Nigeria* and *Nigeria's foreign reserve account is not sensitive to oil price volatility*. The results found evidence of crude oil price volatility impact on the Bonny Light (BL) crude oil spot price, GDP and also, the foreign reserve account. In identifying a hedging mechanism for this situation, chapter 5 confirmed how West Texas Intermediate's futures price is able to predict the BL spots prices. Chapter 6 findings largely confirmed the existence of volatility transmission in most tested series pairs, with the details suggesting volatility transmission exists between oil price, world and Norwegian stock indices, as well as gold spot. However, in the case of oil price, Malaysia and Nigeria's stock indices, volatility transmission was missing. Given the range of macroeconomic variables affected, these results suggest a widening influence of crude oil price volatility on the commodity's export dependent economies in general.

From the empirical findings, several extensions could be inferred. For instance, although the research did not directly address the issues of Sovereign Wealth Funds (SWFs) and oil revenue, they are well implied. Similarly the usefulness of the research findings to other primary commodities' price movements could be inferred, given that preceding empirical studies suggest oil and primary commodities' prices move in a similar manner (Pindyck and Rotemberg, 1990; Lescaroux, 2009; Zhang and Wei, 2010). Thus, this research's outcomes could be extended to studying other commodities and SWFs alike.

In addition to the highlighted potential for this research's application, its ability to make useful academic impact in the areas suggested for further extensions of the research outcomes is examined. Just as this research was motivated by the issues arising from existing literature, it is important that it also leaves a legacy for further academic extensions. This is seen as part of the potential research questions which could arise following the outcomes of the empirical work in this thesis. For instance, following the empirical finding in chapter 4 concerning the impact of crude oil price volatility on Nigeria's foreign accounts position, future research could be directed at cyclical effects volatility may have on the Nigerian foreign account. A typical research question in this direction could be, *is the impact of crude oil price change long lasting or short for the Nigerian foreign account?* Similar extension could be geared towards the GDP variable, with general application for other crude oil net exporting countries.

More practical impact on the policy positions of oil export dependent countries will be examined and discussed. The essential element of having the empirical outcomes of this research explain the existing policy directions for oil revenues of export dependent countries, in terms of how their oil revenues are spent and invested will be evaluated. For instance the government pension fund of Norway, the Norwegian government's petroleum Sovereign Wealth Fund, which is the world's second largest (SWFI, 2012b), is said to operate an investments ratio of 60% invested in equities, 35% in fixed income securities and 5% in real estate, and has a mixed asset policy spanning across all continents (NBIM, 2011).

As the empirical outcome in chapter 6 suggested a volatility transmission between oil and world stock index, this result suggests that, should oil prices changes lead to any distortions in the stock market returns, the resulting consequences will lead to loss of value for the Norwegian fund, , which is vulnerable to any negative impact on the world stock market. Again, as the Norway fund spans all continents and is a crude oil based, it is important for the fund managers to have an understanding of volatility transmission between oil price changes and stock market returns from a global perspective.

Again, the experiences of countries like Norway and the Gulf Co-operation Council (GCC) members in managing their oil export proceeds are examined to see how the approach could benefit other oil export dependent countries. Nigeria, for instance, derives over 91% of its foreign reserve from crude oil (CBN, 2011b), should learn to recognise oil income's influence on the equity sector of the economy. On a practical level, Nigeria could learn from the way other crude oil rich countries invest their oil revenues. Experiences of countries like Norway, Malaysia and the GCC countries could be useful in this regard; Malaysia's experience in terms of what it is has been able to achieve through its PETRONAS, Norway given its investment activities via Norges Bank Investment Management and the GCC through their various SWFs. This is important, given that the country recently established Nigeria Sovereign Investment Authority (SWFI, 2012a).

In addition to discussing what other oil export dependent countries such as Nigeria could learn from the already established investing countries like Norway, potential for learning to overcome the problems of running an SWF should be discussed. Again, Nigeria as a country just establishing an SWF should be examined for factors impeding the smooth running of the recently established fund. Usually, political and factors and corruption are among the big problems, with another being competing needs in the economy. For Nigeria, both corruption and political wrangling setbacks reflected in the clear lack of agreement between the federal and the state governments on the need for such a fund. While the state governments prefer excess oil revenue to be shared and applied for immediate consumption, the federal government favours investing for the future. Both of these options features among the choices of investment in the domestic economy or in foreign assets pointed out by van der Ploeg and Venables (2011); the choice is just a matter of priority.

Thus, from the empirical outcomes of this research, a series of impacts could be inferred, primarily for oil export dependent countries, but also extensive implications could be attained. This chapter, therefore, discusses the implications of this research's findings in relation to practical impact, usefulness for academic application and extensions. The discussion will be largely guided by the entire research findings, but where appropriate, personal opinion supported by practical experience and academic knowledge will also feature prominently.

## 7.2 Findings, Implications and Potential for other Applications

This section discusses the research's findings, implications, potentials for application and further academic research. The discussions will be in relation to impacts on crude oil net importing countries, other primary commodities, oil revenue optimisation and

Sovereign Wealth Funds. Wide ranging issues specific to oil export dependent countries are addressed in such a way as to highlight relevant lessons from and for their oil revenues. For Nigeria, the lack of good management of the country's oil revenue has been highlighted; Mehlum et al.(2006b) listed the country in the category of growth losers owing to this problem. However, countries as Norway and the GCC members are seen as already making the right effort in managing their oil wealth at least on the basis of transparency (SWFI, 2011). However, the outcomes of this research offer these countries potential for improvement, especially as the research by Caner and Grennes (2010) found the portfolio risk in the case of Norway's fund to be riskier than the stock market risk.

In addition to implications for the issues directly addressed, this research's empirical outcomes have extended implications for other areas not directly addressed. For instance, although this research did not directly address the empirical problems of Sovereign Wealth Funds (SWFs), its empirical outcomes succeeded in providing a framework for such study, due to the broad applicability of data coming from oil producing countries with existing SWFs, and the extensibility of the empirical processes. As seen in the literature review chapter, majority of SWFs literature are more descriptive than empirical; thus, this thesis' empirical contribution could pave way for more and better empirical application relating to SWFs. Also, other primary commodities price changes are covered by extension, given that preceding empirical studies found evidence of relationships among commodity prices (Lescaroux, 2009; Zhang and Wei, 2010). Chapter 6 studied oil and gold spots movement, with the results suggesting volatility transmission between the two variables' prices.

Just as this research has answered some salient questions, it has also stimulated numerous other researchable questions, in addition to the extension of the empirical procedures. This section summarises and discusses the identified ideas, refining them to potential further researchable questions that may be of interest for future academic research and application to other commodities and economic conditions. Also, since in addition to contributing to theoretical and empirical literature, good academic research should aim to provide practical impact, the empirical outcomes in this research provides oil exporting countries with information to reformulation of the required policies to enhance their economic capacities.

### 7.2.1 Discussion of Chapter 4

As the first part of the empirical testing process chapter 4 concentrated on understanding the impact of crude oil price volatility on the macroeconomic variables of oil producing countries, using Nigeria's data as a proxy. The chapter specifically sought to understand the impact of oil price volatility on the economic variables of GDP, export earnings account and others. Essentially the task was that of addressing whether crude oil price volatility has any impact on the commodity's export dependent economies such as Nigeria. The related questions are recapitulated below with the outcomes and their implications for both policy and academic work.

#### 7.2.1.1 Research Questions

Chapter 4 answered the following research questions;

- *Does crude oil price volatility impact on Nigeria's GDP?*
- *Does oil market shock alter the commodity's price volatility for Nigeria?*
- *Is Nigeria's foreign reserve account sensitive to crude oil price volatility? If yes; how sensitive, in what pattern, over what period and how does it affect government financial position?*

#### 7.2.1.2 Findings

In answering the question; *does crude oil price volatility impact on Nigeria's GDP?* For hypothesis ***H4A*** the null hypothesis ($\boldsymbol{H_0}$) is rejected and the alternative hypothesis ($\boldsymbol{H_1}$) accepted. Hence, Crude oil price volatility has impact on Nigeria's GDP. This situation implies that with every round of crude oil price shocks, particularly relating to Nigeria's Bonny Light spots, the resulting impact will increase the country's GDP with increasing effect lasting for more than 10 years. Given the question; *does oil market shock alter the commodity's price volatility for Nigeria?* For hypothesis ***H4B*** the null hypothesis ($\boldsymbol{H_0}$) is rejected and the alternative hypothesis ($\boldsymbol{H_1}$) accepted. Thus, *crude oil market shocks increases oil price volatility for Nigeria.* This implies that with every round of crude oil price shocks relating to the Nigerian Bonny Light spots, the situation will essentially increase the volatility prospects of crude oil spots. On the question*; is Nigeria's foreign reserve account sensitive to crude oil price volatility?* Hypothesis ***H4C*** was examined and the null hypothesis ($\boldsymbol{H_0}$) was rejected and the alternative hypothesis ($\boldsymbol{H_1}$) accepted. Hence, *Nigeria's foreign reserve account is sensitive to crude oil price volatility*. Effectively, this means that Nigeria's foreign account position will naturally grow with price increases and vice versa.

Therefore, the summarised findings are; crude oil price shocks impacts positively on Nigeria's GDP, Bonny Light's standard deviation and foreign account, but negatively on inflation and exchange rates. Obviously, the question of the government's financial position was considered, given the tendencies of the price shock being able to impact on the foreign account ($\boldsymbol{FRA_t}$) variable. It was found that the Nigerian foreign account increases with increasing crude oil price. As for other examined variables, the results portray mixed outcomes of increasing and decreasing responses to innovations in $\boldsymbol{LBLA_t}$. Generally, the results are not far from their expected outcomes. For instance, given the outcome of hypothesis ***H4A*** with oil accounting for 91% of Nigeria's foreign income and also, since Nigeria is a developing economy with high government expenditure, it should be expected that the government's main revenue earner will strongly influence GDP.

In comparing the results with previous empirical studies, some level of consensus and a certain degree of variability with others are found. However, like the results in this chapter, what has become evident in most of the past research is the agreement on crude oil price shock as the source of volatility in the oil market. For instance, the results confirmed crude oil price shock as the dominant source of price volatility, consistent with the finding of Jiménez-Rodríguez and Sánchez (2005) that the contribution of oil price to variability in the GDP of all countries tested was very high. It is also consistent with similar analysis in Sadorsky (1999) who found that oil price movements accounted for the largest proportion of the forecast error in the sample tested. Again, the findings on the GDP of some OECD countries in Jiménez-Rodríguez and Sánchez (2005) showed oil price increase rather than decrease causes larger GDP growth impact in most countries. Also, as Jiménez-Rodríguez and Sánchez (2005) found, the GDP of net oil exporting countries such as Norway grows with oil price increases. This was supported with the Nigerian case examined in this chapter.

#### 7.2.1.3 Implications

This chapter's empirical findings have a variety of implications for both academic and policy positions. Part of the academic impact is the ability to extend the studies by Sadorsky (1999), Jiménez-Rodríguez and Sánchez (2005) and also, Rafiq et al (2009) among others, which analysed the impact of crude oil price volatility on the economies of net oil importing countries. Chapter 4 examined similar problems, but in respect of oil export dependent economies. In addition, the questions answered have been able to bring in additional implication to academic research by examining the impact of crude oil price volatility on the Nigerian foreign account, in addition to GDP which has been more focused in preceding studies. On the policy side, the finding that Nigeria's foreign reserve account is sensitive to crude oil price volatility implies an effect on the country's budget, especially as the country's budget is pegged to crude oil prices.

An additional policy implication for the finding on foreign account impact concerns protection of Nigeria's local currency, the Naira. Since the country's foreign exchange trading relies heavily on the size of the country's foreign reserve, the falling of the country's foreign reserve due to negative oil price shock could expose the local currency to loss of value, as a strong (high) foreign reserve is required in order to defend the local currency value. Another potential policy implication concerns the determination of the country's currency value against the US dollar, which is the international currency used in pegging the local currency (Naira) value and also the currency used internationally in trading of crude oil. Therefore, as the relevance of maintaining a high and stable foreign reserve account is explained, this chapter's finding that Nigeria's foreign reserve account is sensitive to crude oil price volatility has a policy implication.

The increased volatility of crude oil prices due to price shocks, uncovered in this chapter's empirical test, suggests Nigeria is exposed to crude oil price risk. This situation may imply oil price increase could benefit the country's income and decrease could be damaging. Hence, the policy position here is for the country and others in a similar position to devise means of avoiding such risk; the empirical outcomes in chapter 5 could be useful in this respect. Also, the research reveals that the BL spot is more like a price taker, therefore, reflecting that the price is determined by outcomes in the global crude oil market, rather than being dictated by Nigeria and other oil producing countries. Again, the country and other crude oil export dependent countries should devise a means of having a say in determining the price of their commodity. This outcome also has implications for the Organisation Petroleum Exporting Countries (OPEC) and contributes academically to the debate on whether the organisation has a say in determining global oil price. Thus, the findings of this chapter can be linked with the previous empirical outcome in Brémond et al. (2012) which concluded OPEC to be a price taker.

#### 7.2.1.5 Potential for other Applications and Further Academic Research

As chapter 4 showed empirically that oil price volatility impacts on the GDP and revenue of Nigeria, other commodity rich countries too could adopt the same or similar approaches in studying their specific commodities' price change impact. Thus, the empirical outcome of this chapter could have implications for studying other primary commodities price behaviour. This is because Lescaroux (2009) found evidence of high correlation among selected commodities prices and also, Wei and Zhang (2010) encountered cointegration between the prices of gold and oil. It could be generalised from this evidence that commodities' price behaviour tends to be similar, at least with regard to their price volatility pattern. This leads to the understanding that oil price behaviour could relevantly explain other commodities' prices.

Again, the empirical finding in chapter 4 concerning the impact of crude oil price volatility on Nigeria's foreign accounts position, could be directed for future research to confirm the cyclical effects volatility may have on the Nigerian foreign account. A typical research question in this direction could be; *is the impact of crude oil price change long lasting or short term for the Nigerian foreign account?* Also, *what time does it take the account to recover from the effect of such impact?* Similar extension could be geared towards the GDP variable and also for the economies of other commodities exporting countries.

### 7.2.2 Discussion of Chapter 5

Chapter 4 found evidence of crude oil price volatility impact on GDP, foreign reserve account, and Bonny Light (BL) spots prices in Nigeria, a typical oil revenue dependent country. Since other empirical studies show oil price shock is a source of problems for both net producing and consuming countries (Jiménez-Rodríguez and Sánchez, 2005; Rafiq et al., 2009), chapter 5 investigated whether an efficient hedging tool for BL spots is present in West Texas Intermediate (WT) futures prices or otherwise. This was achieved through providing answers to the research questions below.

#### 7.2.2.1 Research Questions

This chapter answered the following set of questions:

- *Is West Texas Intermediate (WT) futures price efficient predictor of Bonny Light (BL) spots price?*
- *Is there any need for a BL futures market?*
- Also, *at what point is the need tenable?*

#### 7.2.2.2 Findings

In answering the question; *is West Texas Intermediate (WT) futures price efficient predictor of Bonny Light (BL) spots price?*, the outcome returned evidence of long-run relationships among the tested variables. Hence, hypothesis ***H5A*** rejects the null hypothesis ($\boldsymbol{H_0}$) in favour of the alternative ($\boldsymbol{H_1}$). Essentially, this conclusion confirmed that WT futures price is able to predict the BL spots. Therefore, West Texas Intermediate futures are an efficient means of managing price risk in BL spots. This conclusion essentially answered the main research question, *are the WT futures prices able to predict the BL spots price?* and to the associated questions; *is there any need for BL futures market?* and *at what point is the need tenable?* For the main question the answer is ***yes***, WT futures are efficient predictors of the BL spot prices, whereas, the answer to the secondary questions is ***no.*** Therefore, the Nigerian government should not bother to invest in the very expensive process of creating a futures market for its BL.

The results also confirmed the short-run adjustment back to long run equilibrium in all the variables' relationships. Hypothesis ***H4B*** rejects the null hypothesis ($\boldsymbol{H_0}$) in favour of the alternative ($\boldsymbol{H_1}$). An important revelation for these results is that their coefficients did not display a consistent pattern for successive maturing contracts. This situation is in contrast with the research by Hammoudeh et al (2003) which found the first month's future price to have better speed of error recovery as compared to the subsequent months. The results in this chapter revealed a situation of faster speed in the interaction between spots and first month contracts, which gradually diminished with subsequent months' contracts. Theoretically, this could be explained through the Efficient Market Hypothesis (EMH) with the first month's contract possessing better information symmetry than the subsequent month's contracts consequently the power to predict the spots prices weakens.

#### 7.2.2.3 Implications

The empirical work reported in chapter 5 has extended the body of empirical studies looking into crude oil price movement (Quan, 1992; Schwarz and Szakmary, 1994; Hammoudeh et al., 2003; Maslyuk and Smyth, 2009). The empirical findings has established the seeming usefulness of the EMH in studying the futures market. This position is in agreement with the research by Crowder and Hamed (1993) which established a link between the futures market and EMH by using cointegration. It is also, in agreement with Maslyuk and Smyth (2009), who found WT and Brent crude oil futures and spots to be cointegrated. However, more than just confirming their conclusion, the approach here included broader empirical applications and a comparative analysis, as well as an implication for information transmission that is able to impact on the market factors between spot and futures, especially given the concern about getting the required information from the earliest maturing month. Already in this line, Hammoudeh et al (2003) found the first month's future price to have better speed of error recovery as compared to the subsequent months.

On the policy side, the chapter 5 findings gave rise to price discovery for BL spot. This finding has an implication for the oil revenue generation that gives rise to ability to guarantee stable crude oil revenue regime. By extension this will also contribute to knowing the future earning of the newly formed Nigerian Sovereign Investment Authority (NSIA). Also, the existence of the West Texas Intermediate futures market should be exploited to understanding the future inflows into the NSIA. Doing this will ensure that the investment potential of the fund is determined at every point in time. The broad aspect of this finding is West Texas Intermediate (WT) futures are an efficient means of managing price risk in BL spots. Given the finding that WT futures price is able to effectively predict the BL spots, the main implication for the Nigerian government is they should not bother to invest in the expensive process of creating a futures market for its BL, since the WT futures is able to perfectly predict or proxy for the missing BL futures market.

Another implication from the overall chapter's results is that they are able to provide crude oil base SWFs with helpful insight for price discovery. This could again be extended into empirical research on oil based SWFs particularly with the present tendency to focus on efficient investments of the existing revenues alone. This is despite crude oil based SWFs constituting more than 60% of the global SWFs composition, yet little empirical research has examined spots price determination of any SWFs in relation to any crude oil futures prices. Therefore, another highlight of this chapter's results is that they are able to provide crude oil based SWFs with helpful insight, based on applying BL spots price.

Also, the knowledge of BL future price movements as accounted for through chapter 5's empirical process will be just as useful to oil importing countries as it is to oil producing countries, since such price determination could stabilise the expected expenditure on oil imports of the net importing countries, thereby stabilising other macroeconomic indices such as inflation. Thus, this research provides net oil importing countries with a new lesson in addition to the outcomes of previous studies. Thus, despite the analysis focusing mainly on BL and WT spot prices, a wider implication can be drawn for other oil grades, particularly as the spots prices of the various grades of crude oil are not far from each other in terms of movement, as seen in chapter 6.

#### 7.2.2.5 Potential for other Applications and Further Academic Research

Given the empirical findings in this chapter that suggested West Texas Intermediate (WT) futures contracts can proxy for a BL futures market, future academic studies could extend this notion to other crude oil spots with no future market. Such extension could be useful both for confirming the findings of this research and as providing useful information for the tested oil spots. In general chapter 5's empirical procedure could be applied to identify price discovery for other commodities as well as to provide an additional tool for market efficiency. Also, as chapter 5's empirical analyses suggested that WT could proxy for BL spots, this outcome empirically confirms the closeness of different crude oil grades in terms of their spot price movement. Hence, we could generalise that based on similar oil spot prices, the outcomes of this research could be replicable to other crude oil rich countries.

Another extendable aspect of this chapter's empirical processes concerns the finding which confirms that Nigeria is an oil price taker. Thus, linking this finding with preceding empirical findings in Brémond et al. (2012) which concluded OPEC to be price taker could help to further understand other OPEC's member countries' positions. This will increase the level of appreciation given to the already contentious issue of OPEC's influence on its member countries and also in further understanding whether the organisation and its member countries are price takers. A question that could be further researched in this aspect may be; *what determines oil price globally*? Another question that arises is; *where lies the influence of OPEC in determining global oil price and could the organisation still be regarded as a cartel?*

### 7.2.3 Discussion of Chapter 6

Following the insights in chapters 4 and 5 concerning the impact of crude oil price volatility and a potential hedging tool, chapter 6 concentrated on understanding the wider economic implication of such price volatility, in terms of broad economic indicators such as stock market returns and business activity measured through stock indices. Also, alternative investments to stock market were considered and gold spot examined. Thus, the chapter empirically examined the potential for volatility transmission between crude oil price and the stock markets of selected oil revenue dependent countries (Nigeria, Norway and Malaysia), in addition to examining similar interaction between the oil price and global stock price and also, gold spot price.

#### 7.2.3.1 Research Questions

This chapter answered the research questions below:

- *What is the nature of different crude oil export dependent economies reaction to the commodity price changes?*

- *Is there any volatility transmission between crude oil prices and global stock market returns?*
- *Could gold reserve serve as an alternative to equity market?*

#### 7.2.3.2 Findings

In answering the question; *what is the nature of different crude oil export dependent economies reaction to the commodity price changes?,* the case of oil price and Nigerian stock index, oil price and Malaysian stock index returned insignificant outcomes, implying oil prices are not able have impact on the stock markets of these countries. This result is in contrast with the finding of in Arouri et al. (2011) which found evidence of volatility transmission between oil price and the stock markets of the *GCC,* which are oil export dependent countries too. However, the case of oil price and the stock market of Norway returned a significant outcome, thus suggesting that crude oil price has an impact on the Norwegian stock market's performance. Therefore, for hypothesis ***H6A,*** we accept $\boldsymbol{H_0}$ and reject $\boldsymbol{H_1}$. Hence, d*ifferent crude oil export dependent economies react to the commodity price changes in different manner*.

In understanding crude oil net consuming countries' stock market's reaction to oil price changes, this chapter answered the question; *is there any volatility transmission between crude oil prices and global stock market returns?* It was confirmed that crude oil price has a significant impact on the world stock market performance and vice versa. Hypothesis ***H6B*** rejects $\boldsymbol{H_0}$ and accepts $\boldsymbol{H_1}$. Therefore, *there is a volatility transmission between crude oil prices and global stock market returns.* The implication of crude oil price's significant impact on the world stock market, is that there is volatility transmission between oil price and the stock markets of crude oil net consuming countries, such as the USA, Canada and China. Already Malik and Ewing (2009) and also, Jones and Kaul (1996) have established the existence of volatility transmission between oil price and the stock markets of the USA and Canada. Therefore, by establishing that volatility transmission exists between crude oil price and global stock index, which by extension includes the stock markets of these countries, this study confirms previous research findings.

Answering the question; *could gold reserve serve as an alternative to equity markets?* the existence of volatility transmission between oil price and gold spot price was confirmed. Hence, hypothesis ***H6C***, $\boldsymbol{H_0}$ could not be rejected, so, *Gold reserve could provide an alternative investment for crude oil revenue*. This outcome is in agreement with the findings in Zhang and Wei (2010). Therefore, overall of the chapters' findings confirmed the existence of volatility transmission in most tested series pairs, since volatility transmissions exist between oil price and world, oil price and Norwegian stock indices, as well as oil price and gold spot, although in the case of oil price, Malaysia and Nigeria's stock indices, volatility transmission was missing.

#### 7.2.3.3 Implications

Chapter 6's empirical study extended empirical work geared towards understanding the relationship between crude oil price shocks and stock market returns (Malik and Ewing, 2009; Arouri et al., 2011; Basher et al., 2012), also between crude oil price shocks and gold spots (Zhang and Wei, 2010). Answering the question; *is there any volatility transmission between crude oil prices and global stock market returns?* expanded further the perspective within which Malik and Ewing (2009) applied their research. As the outcome suggested volatility transmission between oil price and world stock index, this gives room for the understanding of interdependence between oil price and the net oil importing countries' stock markets, particularly as, the world stock market could capture the situation of crude oil dependence in terms of consumption. Thus, a further implication of the empirical finding here points to the existence of volatility transmission between oil price and the stock market of crude oil net consuming countries like USA, Canada, China, etc. Therefore, by establishing that volatility transmission exists between crude oil price and global stock index, which by extension includes the stock markets of these countries, it implies an impact for the net oil importing countries as well.

Again, answering the question; *could gold reserve serve as an alternative to equity market?* provided implications for the growing search for alternative investment avenue for natural resource revenue, given the three set of decision points analysed by van der Ploeg and Venables (2011). Among these decision choices is the approach of investing natural resources proceeds in securities traded in stock exchanges, a strategy followed by the SWF. Given that chapter 6 confirmed the existence of volatility transmission between oil price and gold spot price, it could be inferred that oil rich and other SWF countries could see gold reserve as an alternative investment avenue to the capital market. Therefore, given this outcome, the Nigerian government may like to expand its crude oil proceeds investment into gold reserve, like other countries faced with a similar investment decision. Also, the research outcome could be used in understanding the means by which an SWF portfolio could be diversified.

In answering the research question; *what is the nature of different crude oil export dependent economies' reaction to the commodity price changes?* the empirical analysis failed to establish evidence of volatility transmission across the oil and equity sectors of Nigeria and Malaysia, but found transmission in the case of oil price and the Norwegian equity sector. These results have implications for understanding the nature of different reactions of different oil export dependent countries, which could explain the different reactions as being due to different economic conditions. For instance, the difference may be explained in terms of Nigeria and Malaysia's developing economic status, while for Norway, it is understandable that its stock market will react to oil price, given its huge oil exports and also, being a developed economy.

Hence, given the outcome of hypothesis ***H6A***, which suggested crude oil export dependent countries' stock markets react differently to oil price changes, it is ideal to think of diversifying oil proceeds investments into other classes of investable. Another potential approach is for the crude oil revenue endowed countries to think of ways in which they could have their revenues impact into the real sector of their economy. Nigeria, for instance, should learn that oil proceeds, which account for up to 91% of its foreign reserve earning, need to directly impact on the equity sector of the economy. The experience of other countries like Norway making good equity investments of their crude oil revenue is exemplary. The Norwegian petroleum fund could provide a good example, given that it is crude oil based and invests heavily in the stock market.

#### 7.2.3.5 Potential for other Applications and Further Academic Research

The empirical findings in chapter 6 largely supports the hypothesis of cross volatility between oil prices and stock indices of Malik and Ewing (2009) as well as oil and gold spots (Zhang and Wei, 2010). A further dimension for development in this direction will be an examination of the outcome to see if such information could provide any useful means of hedging crude oil revenue. This new level of research development could be adequately covered by the research questions: *Could the information of volatility transmission between oil price and stock market as discovered here provide any useful means of hedging crude oil revenue?,* also, *could such information be applied in building asset pricing model for oil revenue?* Thus, future research in this direction may be interested in empirically building an investment portfolio suitable for investing crude oil proceeds, especially as this could bear relevance for oil revenue SWFs, currently lacking in good level of empirical engagement.

Also, one of the research questions in chapter 6 was; *what is the nature of different crude oil revenue dependent economies reaction to the commodity price changes?* As this question found mixed outcomes for crude oil revenue dependent economies, a possible extension here is to further examine other crude oil dependent countries to find out their likely reaction. More generally, the empirical process could be further applied to the economic condition of other oil export dependent economies not examined in this research and also, crude oil net exporting countries. This is because the crude oil spots are usually not too far from each other, as the factors determining the prices in the global crude oil market are the same, largely allowing the quality of crude oil grades to account for the small price variations. This was seen in chapter 6 as some selected oil spots were found to have closely moved together for a long time.

Again, as this chapter applied data for crude oil spots, some of which are SWFs sources future research could focus on extending the current research's empirical outcomes to further empirical research in the direction of SWFs, especially as chapter 2 identified the largely descriptive nature of current SWFs literature. The empirical outcomes of this research could contribute to encourage academic extension and potential inferences are drawn. For instance, Nigeria being an SWF country rich in oil, with the country's BL spot being empirically examined here, the results could in addition to having empirical implications for the SWFs, also be extended to other crude oil based SWFs.

## 7.3 Lessons for Crude Oil Export Dependent Economies

This section will review and discuss the experiences of some successful resource rich countries in terms of revenue management effort and application potential for other countries rich in resources but poor in revenue management such as Nigeria. It will also include lessons for those successful countries with reference to how they could improve the revenue management processes. Again, oil consumption dependent countries analysed in this research as net oil importing countries will have something to learn as their experiences too are vital to the net producing countries. As discussed in chapters 1 and 2, in the category of those successful resources rich countries are Norway and the GCC countries. Therefore, the discussion will focus on oil export dependent countries, reflecting the theme of this research. However, given that commodities’ prices have similar behaviour (Lescaroux, 2009; Zhang and Wei, 2010), the outcome here is extendable to other countries rich in other commodities.

Therefore, with chapter 6’s empirical process having found oil price to impact on the Norwegian stock market index, it is important for other oil export dependent countries to allow oil price increase to impact positively on their stock indices. This is given that in the current research, the stock indices of Malaysia and Nigeria returned no evidence of volatility transmission with the oil price variable. However, this contradicts the discovery in various studies that oil price changes have impact on the stock market indices of the GCC countries (Hammoudeh, 2004; Hammoudeh and Choi, 2006, 2007; Arouri et al., 2011; Mohanty et al., 2011). Thus, it is important for both Malaysia and Nigeria to learn to improve on the process of allowing their oil sector to affect their equity sectors. Again, as chapter 5 provided empirical support for price discovery for the BL spot through the use of West Texas Intermediate’s futures price, this outcome could be extended to other oil producing countries, especially many countries lack any recognised futures market. Thus, the implication for them, as was stated for Nigeria, was that they do not need one, as they could benefit from the already existing futures market without needing to spend resources in founding their own. This conclusion is made possible as this research has found different crude spots to move together.

Even though it could be argued in the case of Malaysia that the country’s economy is already diversified, with other commodities as palm oil, tin, etc (BNM, 2011: p.11) being exported in abundance, as well as having a developed service sector (BNM, 2009:

p.37), this is not sufficient reason for the country to get away with the lack of the volatility transmission between oil price and its stock index, as much could still be gained in terms of letting the oil and gas sector to influence the equity sector. This is particularly given the country's daily oil export capacity of 0.65 million barrel (CIA, 2012) and also, because it is a world major exporter of liquefied natural gas, a commodity in which the country was the world's number three exporter in 2010 (EIA, 2010a).

As figures suggest over 91% of Nigeria's foreign reserve comes from crude oil (CBN, 2011b), the country should learn to see oil income as having an influence on equity sector of the economy, even more so as the country's economic activities are dominated by oil related expenditures, as the government is the largest sector. Again, this is given the practical presence of the Nigerian banking sector as the distributing agents of the crude oil proceeds internally. Thus, as the banking sector has in recent years made huge gains in the country's stock exchange, by becoming the biggest gainer of the market, theoretically the association of the banking sector with the oil wealth of the country needs to have an effect on the stock return.

On a more practical level, Nigeria could learn from other crude oil rich countries, given the manner in which they invest the proceeds of their oil resources. Experiences of countries like; Norway, Malaysia, the GCC countries, etc could be useful in this regard. Malaysia's experience in terms of what it is able to achieve through its PETRONAS, Norway given its investments activities via the Norges Bank Investment Management and the GCC through their various SWFs. This is salient, as figures from the sovereign wealth Fund Institute (SWFI, 2012b) suggests up to 60% of the global SWF's investments are crude oil and gas related. Again, as has recently been seen, an increasing number of crude oil endowed countries are following the footsteps of the likes of Norway, the GCC countries and others in instituting oil funds for the future.

Given their increased investments in equity, the GCC countries will have the accompanied power to influence decisions in the companies in which they invest. However, as good as this prospect is, it is important for those funds to exercise some degree of restraint, since the potential risks of loss associated with stocks investments at a time of financial crisis are real. This was experienced in the deal by ADIA and

Citigroup, when soon after investing in the bank, the company lost a staggering percentage of the investment due to downward market fluctuation, as reported in both the Guardian (2009) and the Telegraph (2009). However on the balance, FT (2009) reported Kuwait's Sovereign Wealth Fund to have made $1bn gain in selling the investment it bought from the same Citigroup at about the same time as ADIA. Again, given that the empirical evidence in chapter 6 has shown a volatility link between world stock market and oil price, this outcome could act as a guide for the GCC countries in terms of their financial investments in the equity market, especially as source of the GCC countries revenue is from oil. Also, a portfolio weighing strategy could go a long way in managing potential risk associated with such large equity investments being increasingly carried out by the countries.

## 7.4 Conclusion

This chapter has presented a general discussion of the research based on the empirical findings motivated by the formulated research questions. It largely reflects on the implications of the findings from the three empirical chapters for both academic and policy, also making recommendations for future academic studies and policy initiatives. Lessons for and from the crude oil export dependent economies were explored in making countries' experiences with oil wealth management work for others and also for improved practices of the countries concerned. A specific focus was given to Nigeria's experiences as a country which recently established a SWF to manage its excess oil revenue and its attempt to emulate the oil revenue investment practices of other export dependent countries like the GCC countries and Norway. These countries' practical experiences may be useful for Nigeria, given the problems associated to operational efficiencies and political factors the country is already facing with the fund's existence.

Also, empirical pointers were provided for enhancing the experiences of the GCC countries and Norway, like those of any other oil export dependent countries already adopting the SWF approach, as potential for better fund management was inferred from the empirical outcomes. For instance, for the Norway fund to have 60% of its portfolio invested in equity is unhealthy, given the empirical evidence in chapter 6 of volatility transmission between oil price and world stock index, and consequent risk of oil price related distortions in the stock market returns leading to loss of value for the fund. This point was practically demonstrated when the fund had a high negative equity return of -40.71% as a result of the global financial crisis that started in 2007 (NBIM, 2012). Therefore, potential or likely impacts of such outcomes were pointed out in this chapter based on personal opinion informed by practical experience and academic knowledge, but particularly the results of the empirical findings.

In general, this research focused on the problem of crude oil price volatility and its impact on economic variables of export dependent countries. Thus, the thesis empirically examined interdependences between crude oil price and GDP, crude oil price and foreign account, crude oil and gold prices, crude oil and futures prices, also, crude oil price and stock markets. Although the research did not directly address the empirical problems of SWFs and oil revenue optimisation, the empirical procedures and outcomes succeeded in providing a framework for such studies, given the broad application of data coming from oil producing countries with existing SWFs. For instance, as the empirical procedure in chapter 5 confirmed that the BL spot price could be determined from the futures price of WT, the process could be extended into determining the future inflow into an SWF. Also, the findings from chapter 6 could be used in understanding the means by which an SWF portfolio could be diversified. Also as the empirical findings in chapter 6 confirmed cross volatility between oil and gold spots, the information suggests a potential for investing crude oil proceeds into gold reserve as a tool of enhancing revenue management.

Chapter 1 revealed the general motivation for this research as coming from the need to understand and manage oil price volatility, due to the consequences for countries depending on the commodity's export for revenue. Particularly as existing empirical studies on the subject concentrated more on the aspect of impact on the economies of net oil import dependent economies, the present research was seen as desirable. The literature review in chapter 2 further identified problem areas that were reduced to researchable questions. For instance, in reviewing the body of literature relating to impact of oil price volatility specific to Nigeria, a question that arose was; *what impact does crude oil price volatility has on the economies of the commodity's produces as the one of Nigeria?* Also, with Nigeria identified as being exposed to revenue risk, due to the country having about 91% of its foreign reserve from crude oil, this situation motivated the questions; *how can a country survive the likely consequences of such risk?*

and *what are the likely mechanisms that such a country device in mitigating such risk?* Other additional questions were formulated, all of which were answered in the empirical chapters 4 – 6 as seen and discussed in this chapter. Chapter 3 concentrated on identifying the empirical models which the analyses in chapters 4 – 6 were carried out.

Broadly speaking, this research has been able to provide a basis for better understanding oil price volatility, not only for the problem of export dependent countries, but also for oil net importing countries. As a broad spectrum of empirical assessments aimed at a more global scale, that included oil producing countries and the world economy as a whole, were conducted. The empirical procedure in chapter 6 in addition to others examined interdependence between oil price and world stock index. As the outcome suggests volatility transmission between oil price and world stock index this gives room for the understanding of interdependence between oil price and the net oil importing countries' stock markets. Particularly as the world stock market could capture the situation of crude oil dependence in term of consumption, in this category are the world developed countries with crude oil net consumption status such as USA, Canada, China.

Hence, this thesis has successfully examined interdependences between crude oil price and GDP, crude oil price and foreign account, crude oil and gold prices, crude oil and futures prices, also, crude oil price and stock markets. As such, the outcomes revealed information about oil price volatility and economic variables of export dependent countries. Thus, with the outcomes discussed in this chapter, it could finally be said that the general results of this research addressed the overall research's questions and thus, have relevance to oil export dependent countries as the thesis's title implies. Also implications for other areas such as net oil importing countries, other primary commodities, SWFs and crude oil revenue management, etc are derived. For instance, oil revenue management could be a way of providing Nigeria and other oil export dependent economies with a potential means of better managing their oil revenue. Just as the thesis's empirical outcomes give scope for both application and future academic extensions, on a final note this research is able to make contributions for both academic work and policy, both in the present and in the future.

# Appendices

## Appendix 1: Matrix Algebra

This appendix section will provide the basis of specific matrices applied in explaining some models presented in the methodology chapter.

### Basic Matrix Algebra

A matrix is a rectangular array of elements normally presented as:

$$\begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}$$

The matrix could be denoted as **A**, thus:

$$\mathbf{A} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}$$

**A** is a 2 x 2 matrix, suggesting that it has two rows and two columns, this could be generalised by having an $n$ x $n$ implying any number of rows and columns. If a matrix is 1 x $n$ it follows that it is a row vector matrix while $n$ x 1 is a column vector matrix.

Determinant of **A** is given as:

$$|\mathbf{A}| = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} = \alpha_{11}\ \alpha_{22} - \alpha_{21}\alpha_{12}$$

Transpose of **A** is given as:

$$\mathbf{A}' = \begin{bmatrix} \alpha_{11} & \alpha_{21} \\ \alpha_{12} & \alpha_{22} \end{bmatrix}$$

Inverse of **A** is given as:

$$\mathbf{A}^{-\prime} = \frac{\mathbf{1}}{|\mathbf{A}|} \boldsymbol{adj}\ \mathbf{A}$$

**Identity matrix:** An identity matrix is a $n$ x $n$ matrix with 1 in the diagonal and zeros in all other places. For instance an identity matrix of order $n$ is $\mathbf{I}_{\boldsymbol{n}}$, thus:

$$\mathbf{I_3} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Roots and Vectors**

Two vectors $\boldsymbol{a_1}$ and $\boldsymbol{a_2}$ are said to be orthogonal if $\boldsymbol{a_1'a_2 = 0}$. They are unit length if $\boldsymbol{a_1'a_1 = a_2'a_2 = 1}$. Therefore, orthogonal matrix **A** is a matrix with orthogonal rows and unit length as below:

$$\mathbf{A'A} \begin{bmatrix} \boldsymbol{a_1'} \\ \boldsymbol{a_2'} \\ \boldsymbol{a_n'} \end{bmatrix} [\mathbf{a_{1,}a_{2,}} \ldots, \mathbf{a}_{\boldsymbol{n}}] = \mathbf{I}$$

If both sides are multiplied by $\mathbf{A}^{-\prime}$, we arrive at:

$$\mathbf{A'} = \mathbf{A}^{-\prime}$$

Thus the inverse of an orthogonal matrix is its transpose.

Again if both sides are multiplied by **A** we get:

$$\mathbf{AA'} = \mathbf{I}$$

Therefore, by spectral decomposition, if **A** is given as an $n$ x $n$ symmetric matrix and minimising $\mathbf{x'Ax}$ subject to the above given condition $\mathbf{x'x = 1}$. Introducing $\boldsymbol{\lambda}$ as a Langrangian multiplier and minimising, we have;

$$\mathbf{x'Ax} - \boldsymbol{\lambda}(\mathbf{x'x = 1})$$

Differentiating with respect to $\mathbf{x}$;

$$\mathbf{2Ax} - \mathbf{2}\boldsymbol{\lambda}\mathbf{x} = \mathbf{0} \quad \text{or} \quad (\mathbf{A} - \boldsymbol{\lambda}\mathbf{I})\mathbf{x} = \mathbf{0}$$

Thus, becoming $|\mathbf{A} - \boldsymbol{\lambda}\mathbf{I}| = \mathbf{0}$ as a nonnull solution, whose root is called an eigenvalue. The equation is a nth-degree equation in $\boldsymbol{\lambda}$ and has $\mathbf{n}$ roots, corresponding to $\boldsymbol{\lambda_i}$ there is a vector $\mathbf{x}_{\boldsymbol{i}}$ called the eigenvector. The full solution is therefore; $(\mathbf{A} - \boldsymbol{\lambda_i}\mathbf{I})\mathbf{x} = \mathbf{0}$ with matrix representation in a 3 x 3 form as:

$$\begin{vmatrix} a_{11} - \lambda & a_{12} & a_{13} \\ a_{21} & a_{22} - \lambda & a_{23} \\ a_{31} & a_{32} & a_{33} - \lambda \end{vmatrix} = 0$$

**Matrix Ranking**

Matrix **A** of order $m$ x $n$ is regarded as a set of $m$ row vectors and of $n$ column vectors. The row rank of the matrix ($\leq m$) is the number of linearly independent row vectors, while, the column rank of the matrix ($\leq n$) is the number of linearly independent column vectors.

The matrix ranking is supported by the following laws:

- Row rank = column rank.
- If **A** and **B** are two matrices such that their product **AB** is defined, rank (**AB**) is not greater than rank **A** or rank **B**.
- Matrix rank is unaltered by pre or post multiplication given a non-singular matrix.

The above matrix ranking logic could be illustrated by considering a system of three unknown equations as:

$$\begin{matrix} a_{11}x_1 & a_{12}x_2 & a_{13}x_3 = & b_1 \\ a_{21}x_1 & a_{22}x_2 & a_{23}x_3 = & b_2 \\ a_{31}x_1 & a_{32}x_2 & a_{33}x_3 = & b_3 \end{matrix}$$

The matrix notation of the equations will be $\mathbf{Ax} = \mathbf{b}$, explicitly as:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{23} & a_{33} \end{bmatrix} \quad \mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \quad \mathbf{b} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

Therefore, when $\mathbf{b} = \mathbf{0}$ , the system of equations is homogeneous and it is nonhomogeneous when $\mathbf{Ax} = \mathbf{b}$. As stated, the above illustration is the case of three equations; the general case is the $\boldsymbol{n}$ equation whose condition is rank A $< n$. When rank A $= r < n$, there are $(n - r)$ linearly independent solution **x** satisfying $\mathbf{Ax} = \mathbf{0}$.

## Appendix 2: VAR Results based on 4 lags

| Lag Variables | VAR Equations | | | | | | |
|---|---|---|---|---|---|---|---|
| | $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
| $LBLA_{t-1}$ | 1.124250 [9.08808]* | 0.190426 [0.63890] | 0.206663 [1.26759] | -6.232157 [-1.35121] | -0.556528 [-0.10062] | -0.175447 [-0.48050] | 3.772352 [2.73430]* |
| $LBLA_{t-2}$ | -0.375701 [-2.09138]* | -0.253219 [-0.58504] | -0.067312 [-0.28431] | 5.252265 [0.78417] | -2.169308 [-0.27008] | -0.014003 [-0.02641] | -2.728379 [-1.36182] |
| $LBLA_{t-3}$ | 0.367382 [2.18421]* | 0.396579 [0.97860] | 0.210898 [ 0.95139] | -3.168805 [-0.50530] | 4.358648 [0.57956] | 0.633782 [1.27660] | 1.940970 [1.03471] |
| $LBLA_{t-4}$ | -0.121250 [-1.00967] | -0.173683 [-0.60028] | -0.190123 [-1.20127] | -4.654371 [-1.03952] | 5.620920 [1.04683] | -0.404741 [-1.14185] | -1.035015 [-0.77280] |
| $LFRA_{t-1}$ | -0.004019 [-0.08294] | 0.450418 [3.85791]* | 0.053736 [0.84142] | -1.107120 [-0.61278] | 0.446427 [0.20604] | 0.074438 [0.52044] | 0.181356 [0.33558] |
| $LFRA_{t-2}$ | -0.005646 [-0.10990] | 0.570558 [4.60970]* | -0.004418 [-0.06525] | 0.417199 [0.21782] | -3.916013 [-1.70486] | 0.032779 [0.21617] | -0.251725 [-0.43936] |
| $LFRA_{t-3}$ | 0.044872 [0.88624]* | -0.060217 [-0.49362] | -0.036816 [-0.55173] | 0.006283 [0.00333] | 0.737707 [0.32586] | -0.092602 [-0.61963] | 0.309527 [0.54815] |
| $LFRA_{t-4}$ | -0.008254 [-0.18586] | -0.130065 [-1.21559] | 0.018431 [0.31491] | 0.601456 [0.36325] | 3.884600 [1.95634] | 0.016106 [0.12287] | 0.590544 [1.19235] |
| $LGDP_{t-1}$ | 0.012170 [0.14474] | -0.254153 [-1.25461] | 0.730802 [6.59506]* | -23.48251 [-7.49083]* | 2.278233 [0.60601] | -0.195844 [-0.78915] | -0.519998 [-0.55455] |
| $LGDP_{t-2}$ | -0.184393 [-1.46008] | -0.572586 [-1.88180] | -0.137677 [-0.82718] | 22.44002 [4.76574]* | 2.729405 [0.48336] | 0.194781 [ 0.52254] | -0.287798 [-0.20434] |
| $LGDP_{t-3}$ | 0.054004 [0.37210] | 0.344907 [0.98637] | 0.160599 [0.83963] | -3.429550 [-0.63380] | -4.973629 [-0.76645] | -0.332026 [-0.77508] | 0.392787 [0.24267] |
| $LGDP_{t-4}$ | 0.099660 [0.88010] | 0.435443 [1.59603] | 0.142157 [0.95254] | 6.189176 [1.46594] | -4.906607 [-0.96908] | 0.328865 [0.98393] | 0.494549 [0.39160] |
| $BLS_{t-1}$ | -0.022429 [-2.20159]* | -0.010367 [-0.42235] | -0.028251 [-2.10411]* | 0.653221 [1.71974] | -0.134864 [-0.29607] | -0.029507 [-0.98129] | 0.232219 [2.04385]* |
| $BLS_{t-2}$ | -0.014030 [-1.25664] | -0.000152 [-0.00565] | -0.012365 [-0.84035] | 0.094055 [0.22595] | -0.026281 [-0.05265] | -0.008523 [-0.25862] | 0.113628 [0.91256] |
| $BLS_{t-3}$ | 0.007345 [0.67052] | -0.000210 [-0.00795] | 0.013926 [0.96461] | 0.049450 [0.12108] | -0.266168 [-0.54345] | -0.007063 [-0.21844] | -0.067522 [-0.55272] |
| $BLS_{t-4}$ | 0.003821 [0.35598] | 0.002714 [0.10495] | 0.004646 [0.32845] | 0.536890 [1.34160] | -0.538220 [-1.12149] | -0.002688 [-0.08483] | -0.183800 [-1.53545] |
| *C* | -0.092282 [-0.23866] | 1.571907 [1.68729] | 0.059316 [ 0.11640] | 7.793977 [0.54062] | 37.34793 [ 2.16023]* | 0.079115 [0.06932] | -12.52120 [-2.90357]* |
| **Adjusted $R^2$** | 0.9409 | 0.9254 | 0.9262 | 0.9917 | 0.9117 | 0.9713 | 0.5793 |

*Figures on right hand side of the lag values represent variables coefficients and the figures in square brackets are the t-statistics values. *indicates statistical significance.*

## Appendix 3: VAR lag order selection criteria

| Lag | Log L | LR | FPE | AIC | SIC | HQ |
|---|---|---|---|---|---|---|
| 0 | -1539.634 | NA | 64058.66 | 30.93269 | 31.11505 | 31.00649 |
| 1 | -836.1148 | 1294.476 | 0.132596 | 17.84230 | 19.30119* | 18.43274 |
| 2 | -732.5626 | 176.0386 | 0.045143 | 16.75125 | 19.48668 | 17.85833 |
| 3 | -692.5922 | 62.35390 | 0.056016 | 16.93184 | 20.94381 | 18.55556 |
| 4 | -663.5759 | 41.20309 | 0.089484 | 17.33152 | 22.62001 | 19.47187 |
| 5 | -636.5067 | 34.64859 | 0.155890 | 17.77013 | 24.33516 | 20.42712 |
| 6 | -578.4099 | 66.23036 | 0.155924 | 17.58820 | 25.42976 | 20.76182 |
| 7 | -523.9698 | 54.44014 | 0.183515 | 17.47940 | 26.59749 | 21.16965 |
| 8 | -480.5239 | 37.36341 | 0.304422 | 17.59048 | 27.98511 | 21.79737 |
| 9 | -384.6370 | 69.03860 | 0.210564 | 16.65274 | 28.32390 | 21.37627 |
| 10 | -292.7287 | 53.30679 | 0.203928 | 15.79457 | 28.74227 | 21.03474 |
| 11 | -183.5177 | 48.05287 | 0.210220 | 14.59035 | 28.81458 | 20.34715 |
| 12 | 41.34951 | 67.46015* | 0.044780* | 11.07301* | 26.57377 | 17.34645* |

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

## Appendix 4: Pairwise Granger Causality Test Results

| *Variables interaction ($H_0$)* | *F-Statistic* | *P-Values* |
|---|---|---|
| ***BLS*** does not Granger Cause ***BLA*** | 5.9507* | 0.0002* |
| ***BLA*** does not Granger Cause ***BLS*** | 22.334* | 4.E-13* |
| ***FRA*** does not Granger Cause ***BLA*** | 8.2437* | 9.E-06* |
| ***BLA*** does not Granger Cause ***FRA*** | 2.5484* | 0.0440* |
| ***NDE*** does not Granger Cause ***BLA*** | 2.1787 | 0.0769 |
| ***BLA*** does not Granger Cause ***NDE*** | 2.9865* | 0.0225* |
| ***NIR*** does not Granger Cause ***BLA*** | 0.4913 | 0.7421 |
| ***BLA*** does not Granger Cause ***NIR*** | 0.4423 | 0.7777 |
| ***USI*** does not Granger Cause ***BLA*** | 3.2131 | 0.0159* |
| ***BLA*** does not Granger Cause ***USI*** | 2.2490 | 0.0692 |
| ***GDP*** does not Granger Cause ***BLA*** | 0.3474 | 0.8453 |
| ***BLA*** does not Granger Cause ***GDP*** | 1.9101 | 0.1147 |
| ***FRA*** does not Granger Cause ***BLS*** | 9.8900* | 9.E-07* |
| ***BLS*** does not Granger Cause ***FRA*** | 4.8680* | 0.0013* |
| ***NDE*** does not Granger Cause ***BLS*** | 2.3057 | 0.0635 |
| ***BLS*** does not Granger Cause ***NDE*** | 0.9640 | 0.4308 |
| ***NIR*** does not Granger Cause ***BLS*** | 1.0530 | 0.3840 |
| ***BLS*** does not Granger Cause ***NIR*** | 0.4429 | 0.7773 |
| ***USI*** does not Granger Cause ***BLS*** | 1.3327 | 0.2632 |
| ***BLS*** does not Granger Cause ***USI*** | 1.9753 | 0.1041 |
| ***GDP*** does not Granger Cause ***BLS*** | 3.7770* | 0.0067* |
| ***BLS*** does not Granger Cause ***GDP*** | 2.5620* | 0.0431* |
| ***NDE*** does not Granger Cause ***FRA*** | 1.3252 | 0.2659 |
| ***FRA*** does not Granger Cause ***NDE*** | 2.1972 | 0.0748 |
| ***NIR*** does not Granger Cause ***FRA*** | 0.1151 | 0.9769 |
| ***FRA*** does not Granger Cause ***NIR*** | 0.3171 | 0.8660 |
| ***USI*** does not Granger Cause ***FRA*** | 0.9044 | 0.4645 |
| ***FRA*** does not Granger Cause ***USI*** | 1.5889 | 0.1832 |
| ***GDP*** does not Granger Cause ***FRA*** | 0.5170 | 0.7234 |
| ***FRA*** does not Granger Cause ***GDP*** | 1.6257 | 0.1738 |
| ***GDP*** does not Granger Cause ***NDE*** | 35.334* | 3.E-18* |
| ***NDE*** does not Granger Cause ***GDP*** | 2.8481* | 0.0278* |
| ***GDP*** does not Granger Cause ***NIR*** | 1.6509 | 0.1676 |
| ***NIR*** does not Granger Cause ***GDP*** | 0.8028 | 0.5262 |
| ***GDP*** does not Granger Cause ***USI*** | 1.8038 | 0.1341 |
| ***USI*** does not Granger Cause ***GDP*** | 2.1272 | 0.0830 |

*$H_0$ represents null hypothesis. *indicates rejection of $H_0$. Number of lags = 4.*

## Appendix 5: Accumulated responses of variables to innovations in $LBLA_t$

| *Period* | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
|---|---|---|---|---|---|---|
| 1 | 0.036550 | 0.038640 | 0.011730 | -0.368611 | 0.110878 | 0.388246 |
| 2 | 0.072132 | 0.085480 | -0.510680 | -0.367308 | 0.190303 | 0.778026 |
| 3 | 0.105314 | 0.137481 | -1.464801 | -0.080559 | 0.241580 | 1.138345 |
| 4 | 0.135038 | 0.192527 | -2.775518 | 0.423622 | 0.269106 | 1.458188 |
| 5 | 0.160569 | 0.248993 | -4.382044 | 1.088749 | 0.277339 | 1.734951 |
| 6 | 0.181446 | 0.305561 | -6.232364 | 1.867519 | 0.270399 | 1.969585 |
| 7 | 0.197428 | 0.361134 | -8.280784 | 2.720499 | 0.251940 | 2.164531 |
| 8 | 0.208452 | 0.414803 | -10.48675 | 3.615213 | 0.225129 | 2.322824 |
| 9 | 0.214593 | 0.465818 | -12.81419 | 4.525387 | 0.192666 | 2.447695 |
| 10 | 0.216030 | 0.513577 | -15.23115 | 5.430240 | 0.156826 | 2.542378 |
| 11 | 0.213019 | 0.557609 | -17.70940 | 6.313825 | 0.119504 | 2.610018 |
| 12 | 0.205870 | 0.597567 | -20.22425 | 7.164383 | 0.082256 | 2.653622 |
| 13 | 0.194927 | 0.633210 | -22.75420 | 7.973742 | 0.046346 | 2.676028 |
| 14 | 0.180549 | 0.664398 | -25.28079 | 8.736744 | 0.012782 | 2.679889 |
| 15 | 0.163104 | 0.691075 | -27.78831 | 9.450719 | -0.017647 | 2.667668 |
| 16 | 0.142955 | 0.713260 | -30.26362 | 10.11501 | -0.044339 | 2.641635 |
| 17 | 0.120449 | 0.731040 | -32.69590 | 10.73054 | -0.066850 | 2.603865 |
| 18 | 0.095920 | 0.744554 | -35.07646 | 11.29942 | -0.084870 | 2.556248 |
| 19 | 0.069677 | 0.753986 | -37.39853 | 11.82464 | -0.098200 | 2.500491 |
| 20 | 0.042006 | 0.759558 | -39.65709 | 12.30977 | -0.106730 | 2.438127 |
| 21 | 0.013167 | 0.761516 | -41.84867 | 12.75872 | -0.110429 | 2.370526 |
| 22 | -0.016608 | 0.760129 | -43.97116 | 13.17555 | -0.109324 | 2.298902 |
| 23 | -0.047109 | 0.755677 | -46.02367 | 13.56428 | -0.103493 | 2.224325 |
| 24 | -0.078157 | 0.748450 | -48.00635 | 13.92883 | -0.093049 | 2.147731 |
| 25 | -0.109594 | 0.738734 | -49.92025 | 14.27286 | -0.078138 | 2.069930 |
| 26 | -0.141284 | 0.726815 | -51.76721 | 14.59973 | -0.058928 | 1.991620 |
| 27 | -0.173114 | 0.712972 | -53.54965 | 14.91246 | -0.035604 | 1.913395 |
| 28 | -0.204990 | 0.697471 | -55.27054 | 15.21373 | -0.008361 | 1.835752 |
| 29 | -0.236835 | 0.680565 | -56.93323 | 15.50579 | 0.022595 | 1.759103 |
| 30 | -0.268586 | 0.662492 | -58.54139 | 15.79059 | 0.057057 | 1.683785 |
| 31 | -0.300197 | 0.643473 | -60.09888 | 16.06967 | 0.094812 | 1.610063 |
| 32 | -0.331631 | 0.623709 | -61.60970 | 16.34429 | 0.135652 | 1.538142 |
| 33 | -0.362862 | 0.603384 | -63.07790 | 16.61538 | 0.179367 | 1.468172 |
| 34 | -0.393873 | 0.582662 | -64.50754 | 16.88363 | 0.225753 | 1.400255 |
| 35 | -0.424654 | 0.561688 | -65.90260 | 17.14948 | 0.274609 | 1.334453 |
| 36 | -0.455202 | 0.540589 | -67.26696 | 17.41321 | 0.325741 | 1.270790 |
| 37 | -0.485517 | 0.519473 | -68.60436 | 17.67491 | 0.378960 | 1.209259 |
| 38 | -0.515605 | 0.498432 | -69.91838 | 17.93457 | 0.434085 | 1.149830 |
| 39 | -0.545472 | 0.477541 | -71.21236 | 18.19208 | 0.490942 | 1.092447 |
| 40 | -0.575130 | 0.456862 | -72.48947 | 18.44725 | 0.549365 | 1.037040 |

*Responses are based on generalised innovations.*

## Appendix 6: One unit Accumulated responses to innovations in $LBLA_t$

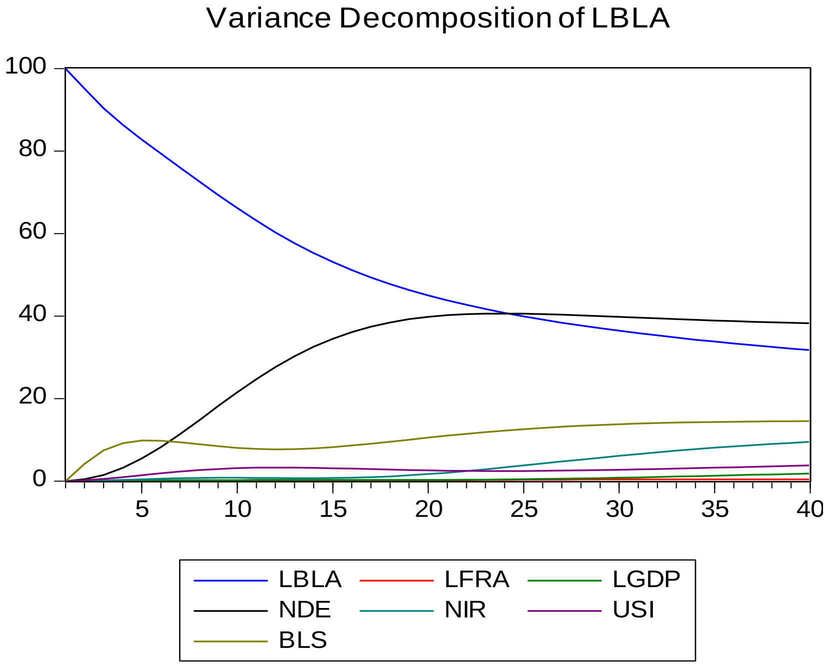
| Period | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ | $BLS_t$ |
|---|---|---|---|---|---|---|
| 1 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 2 | 0.043441 | 0.161534 | -6.300098 | 4.691338 | -0.083445 | 1.730190 |
| 3 | 0.108502 | 0.420567 | -16.93086 | 12.74441 | -0.308932 | 3.931038 |
| 4 | 0.177511 | 0.742273 | -30.80624 | 23.22260 | -0.672375 | 6.094118 |
| 5 | 0.236865 | 1.104765 | -47.23360 | 35.40372 | -1.147824 | 8.024363 |
| 6 | 0.276572 | 1.492315 | -65.70823 | 48.70379 | -1.704034 | 9.657717 |
| 7 | 0.289702 | 1.892529 | -85.82601 | 62.64251 | -2.310981 | 10.98490 |
| 8 | 0.271842 | 2.295147 | -107.2455 | 76.82548 | -2.942194 | 12.01936 |
| 9 | 0.220615 | 2.691511 | -129.6702 | 90.93311 | -3.575375 | 12.78358 |
| 10 | 0.135244 | 3.074321 | -152.8404 | 104.7120 | -4.192314 | 13.30321 |
| 11 | 0.016186 | 3.437487 | -176.5274 | 117.9675 | -4.778536 | 13.60440 |
| 12 | -0.135174 | 3.776034 | -200.5308 | 130.5562 | -5.322868 | 13.71261 |
| 13 | -0.316790 | 4.086016 | -224.6754 | 142.3797 | -5.816983 | 13.65199 |
| 14 | -0.526165 | 4.364435 | -248.8096 | 153.3775 | -6.254975 | 13.44513 |
| 15 | -0.760527 | 4.609160 | -272.8030 | 163.5215 | -6.632961 | 13.11290 |
| 16 | -1.016973 | 4.818848 | -296.5450 | 172.8098 | -6.948735 | 12.67443 |
| 17 | -1.292574 | 4.992860 | -319.9430 | 181.2617 | -7.201445 | 12.14714 |
| 18 | -1.584466 | 5.131176 | -342.9212 | 188.9131 | -7.391327 | 11.54671 |
| 19 | -1.889913 | 5.234321 | -365.4185 | 195.8121 | -7.519465 | 10.88726 |
| 20 | -2.206352 | 5.303279 | -387.3879 | 202.0156 | -7.587588 | 10.18131 |
| 21 | -2.531427 | 5.339421 | -408.7948 | 207.5858 | -7.597906 | 9.439975 |
| 22 | -2.863005 | 5.344432 | -429.6157 | 212.5877 | -7.552962 | 8.673016 |
| 23 | -3.199185 | 5.320242 | -449.8372 | 217.0871 | -7.455522 | 7.888943 |
| 24 | -3.538303 | 5.268966 | -469.4548 | 221.1482 | -7.308477 | 7.095125 |
| 25 | -3.878921 | 5.192843 | -488.4719 | 224.8328 | -7.114772 | 6.297883 |
| 26 | -4.219821 | 5.094184 | -506.8985 | 228.1988 | -6.877346 | 5.502586 |
| 27 | -4.559990 | 4.975328 | -524.7506 | 231.2996 | -6.599090 | 4.713744 |
| 28 | -4.898606 | 4.838599 | -542.0489 | 234.1838 | -6.282816 | 3.935093 |
| 29 | -5.235016 | 4.686271 | -558.8183 | 236.8945 | -5.931231 | 3.169672 |
| 30 | -5.568726 | 4.520540 | -575.0869 | 239.4694 | -5.546928 | 2.419905 |
| 31 | -5.899373 | 4.343497 | -590.8850 | 241.9411 | -5.132371 | 1.687664 |
| 32 | -6.226718 | 4.157111 | -606.2451 | 244.3370 | -4.689898 | 0.974337 |
| 33 | -6.550622 | 3.963212 | -621.2006 | 246.6796 | -4.221716 | 0.280885 |
| 34 | -6.871029 | 3.763482 | -635.7855 | 248.9872 | -3.729905 | -0.392099 |
| 35 | -7.187959 | 3.559451 | -650.0340 | 251.2738 | -3.216422 | -1.044347 |
| 36 | -7.501487 | 3.352487 | -663.9798 | 253.5503 | -2.683106 | -1.675867 |
| 37 | -7.811732 | 3.143804 | -677.6562 | 255.8239 | -2.131686 | -2.286900 |
| 38 | -8.118850 | 2.934457 | -691.0950 | 258.0995 | -1.563782 | -2.877889 |
| 39 | -8.423021 | 2.725355 | -704.3270 | 260.3797 | -0.980915 | -3.449439 |
| 40 | -8.724442 | 2.517261 | -717.3813 | 262.6654 | -0.384512 | -4.002289 |

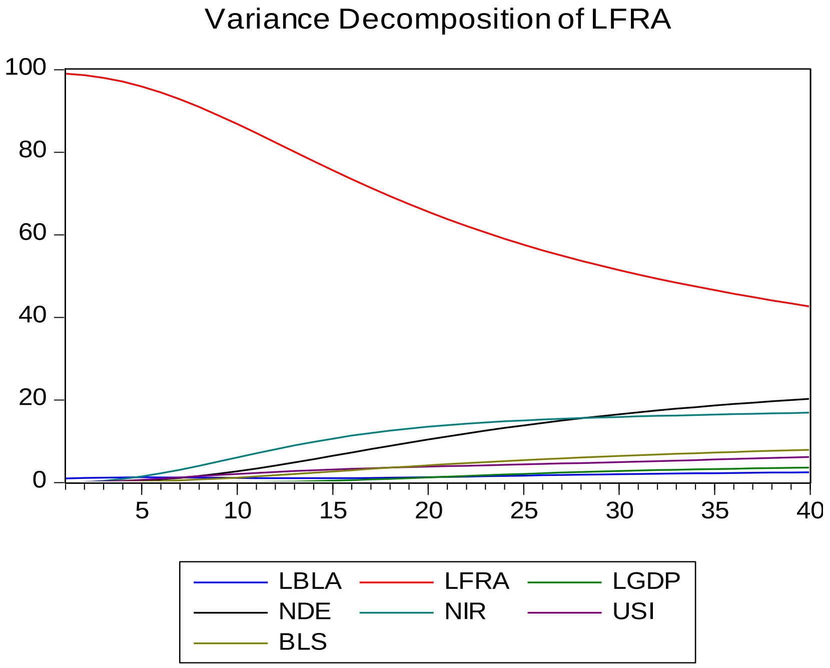
*Responses are based on one unit innovations.*

**Appendix 7: Accumulated responses of variables to innovations in $BLS_t$**

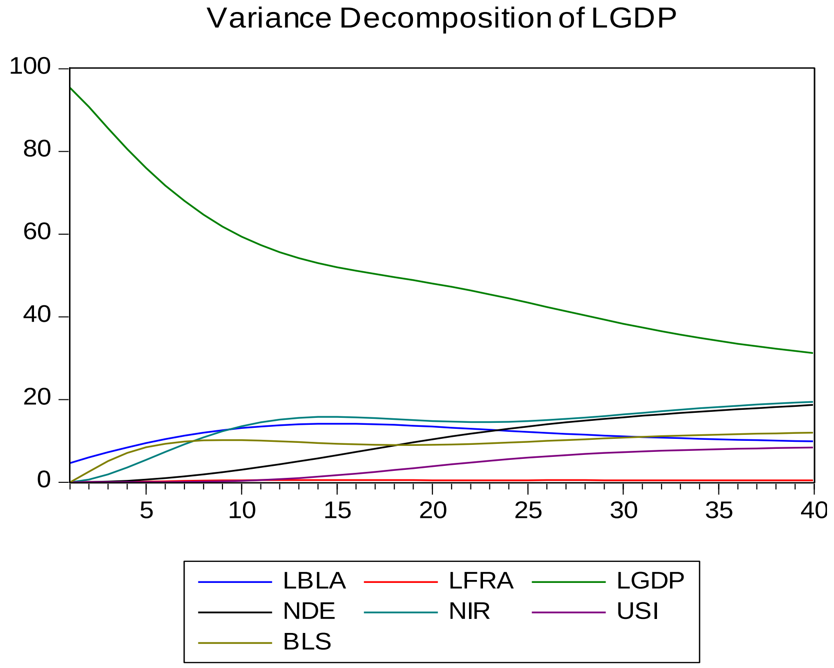
| *Period* | $LBLA_t$ | $LFRA_t$ | $LGDP_t$ | $NDE_t$ | $NIR_t$ | $USI_t$ |
|---|---|---|---|---|---|---|
| 1 | 0.036022 | 0.036283 | 0.004783 | -0.276578 | -0.473403 | -0.002233 |
| 2 | 0.028423 | 0.075820 | -0.026748 | 0.837600 | -1.128672 | -0.088924 |
| 3 | 0.006979 | 0.117486 | -0.071838 | 2.668263 | -1.749677 | -0.206349 |
| 4 | -0.016143 | 0.160737 | -0.120398 | 4.913672 | -2.259051 | -0.332376 |
| 5 | -0.036111 | 0.205259 | -0.167736 | 7.427964 | -2.637595 | -0.458007 |
| 6 | -0.051158 | 0.250826 | -0.211527 | 10.13139 | -2.890412 | -0.579715 |
| 7 | -0.060806 | 0.297248 | -0.250541 | 12.97317 | -3.032501 | -0.696273 |
| 8 | -0.065122 | 0.344354 | -0.284103 | 15.91612 | -3.082484 | -0.807426 |
| 9 | -0.064405 | 0.391987 | -0.311861 | 18.93035 | -3.059772 | -0.913344 |
| 10 | -0.059054 | 0.440006 | -0.333673 | 21.99062 | -2.983215 | -1.014386 |
| 11 | -0.049506 | 0.488284 | -0.349549 | 25.07520 | -2.870406 | -1.111003 |
| 12 | -0.036209 | 0.536713 | -0.359617 | 28.16542 | -2.737322 | -1.203692 |
| 13 | -0.019608 | 0.585200 | -0.364096 | 31.24531 | -2.598121 | -1.292968 |
| 14 | -0.000136 | 0.633670 | -0.363278 | 34.30152 | -2.465060 | -1.379353 |
| 15 | 0.021792 | 0.682064 | -0.357511 | 37.32303 | -2.348476 | -1.463366 |
| 16 | 0.045783 | 0.730338 | -0.347179 | 40.30108 | -2.256823 | -1.545513 |
| 17 | 0.071469 | 0.778463 | -0.332695 | 43.22890 | -2.196757 | -1.626282 |
| 18 | 0.098506 | 0.826419 | -0.314484 | 46.10161 | -2.173243 | -1.706136 |
| 19 | 0.126581 | 0.874199 | -0.292976 | 48.91598 | -2.189689 | -1.785510 |
| 20 | 0.155409 | 0.921803 | -0.268595 | 51.67026 | -2.248099 | -1.864805 |
| 21 | 0.184733 | 0.969239 | -0.241754 | 54.36397 | -2.349232 | -1.944385 |
| 22 | 0.214327 | 1.016519 | -0.212845 | 56.99777 | -2.492769 | -2.024575 |
| 23 | 0.243991 | 1.063659 | -0.182241 | 59.57324 | -2.677474 | -2.105664 |
| 24 | 0.273554 | 1.110678 | -0.150285 | 62.09272 | -2.901360 | -2.187896 |
| 25 | 0.302871 | 1.157596 | -0.117293 | 64.55916 | -3.161840 | -2.271478 |
| 26 | 0.331821 | 1.204435 | -0.083548 | 66.97602 | -3.455874 | -2.356578 |
| 27 | 0.360309 | 1.251214 | -0.049305 | 69.34706 | -3.780100 | -2.443325 |
| 28 | 0.388258 | 1.297954 | -0.014786 | 71.67629 | -4.130958 | -2.531812 |
| 29 | 0.415613 | 1.344671 | 0.019817 | 73.96784 | -4.504795 | -2.622102 |
| 30 | 0.442334 | 1.391383 | 0.054343 | 76.22585 | -4.897960 | -2.714223 |
| 31 | 0.468401 | 1.438103 | 0.088657 | 78.45445 | -5.306881 | -2.808178 |
| 32 | 0.493803 | 1.484844 | 0.122653 | 80.65764 | -5.728138 | -2.903945 |
| 33 | 0.518545 | 1.531614 | 0.156245 | 82.83925 | -6.158506 | -3.001479 |
| 34 | 0.542640 | 1.578422 | 0.189372 | 85.00293 | -6.595007 | -3.100720 |
| 35 | 0.566109 | 1.625273 | 0.221992 | 87.15206 | -7.034930 | -3.201589 |
| 36 | 0.588983 | 1.672171 | 0.254080 | 89.28978 | -7.475858 | -3.303996 |
| 37 | 0.611296 | 1.719117 | 0.285627 | 91.41894 | -7.915675 | -3.407842 |
| 38 | 0.633086 | 1.766113 | 0.316635 | 93.54212 | -8.352567 | -3.513021 |
| 39 | 0.654393 | 1.813156 | 0.347119 | 95.66160 | -8.785023 | -3.619421 |
| 40 | 0.675263 | 1.860246 | 0.377101 | 97.77939 | -9.211817 | -3.726931 |

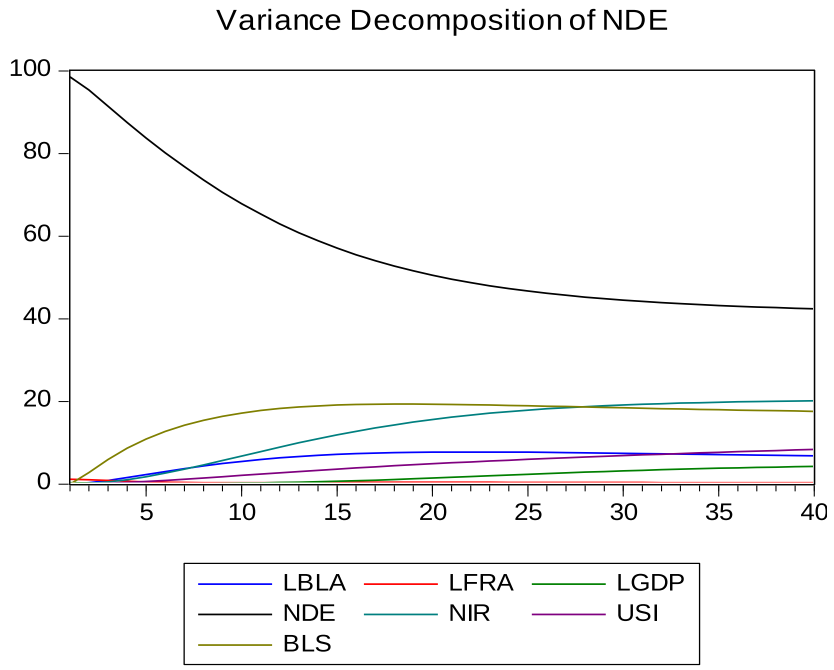
*Responses are based on generalised innovations*



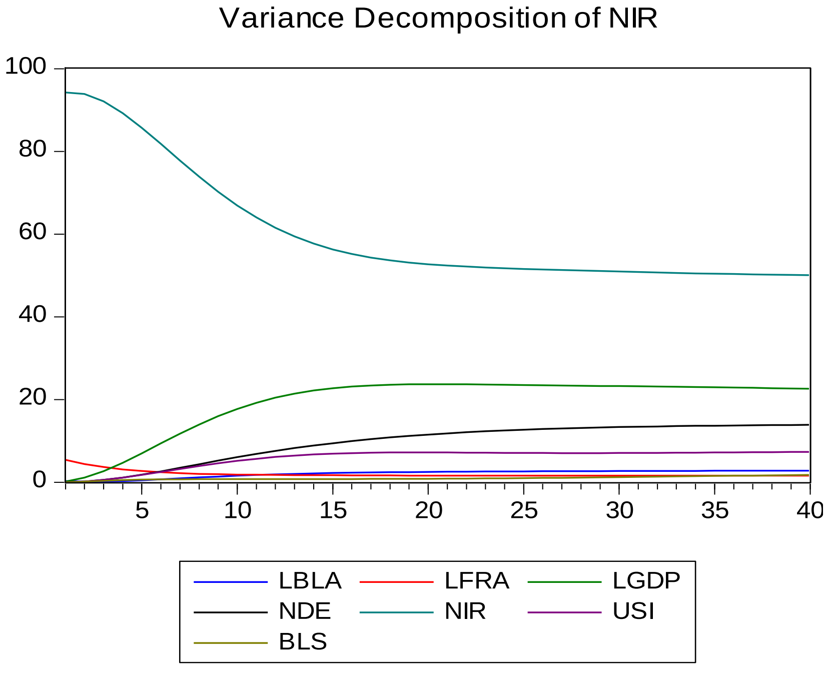



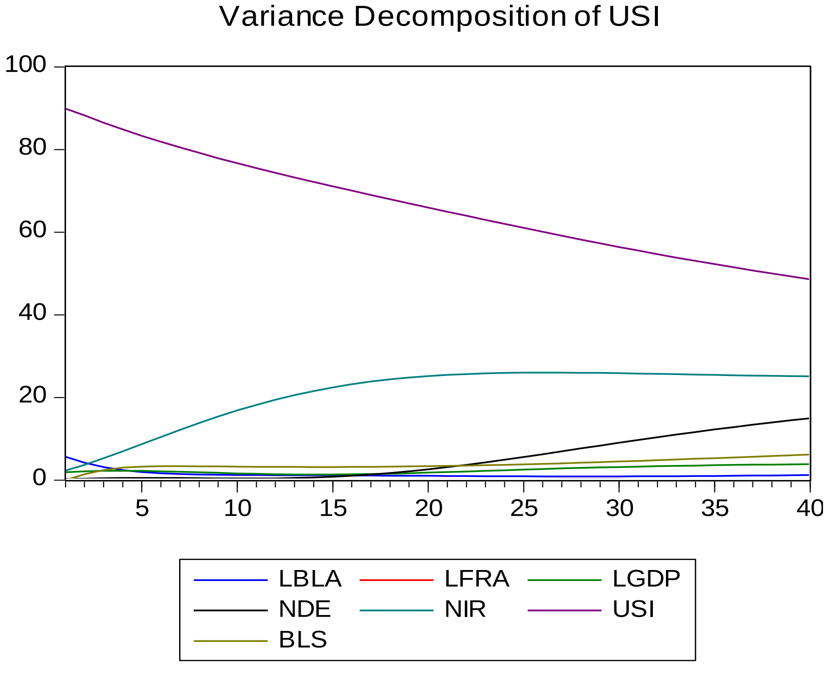

**Appendix 8: Variance Decomposition Graphs for $LBLA_t$ and $LFRA_t$**



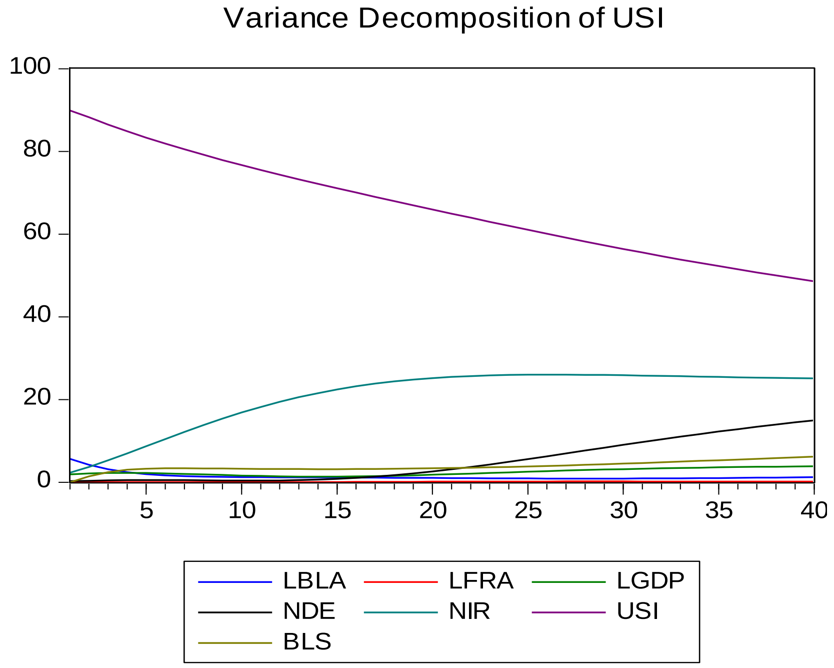



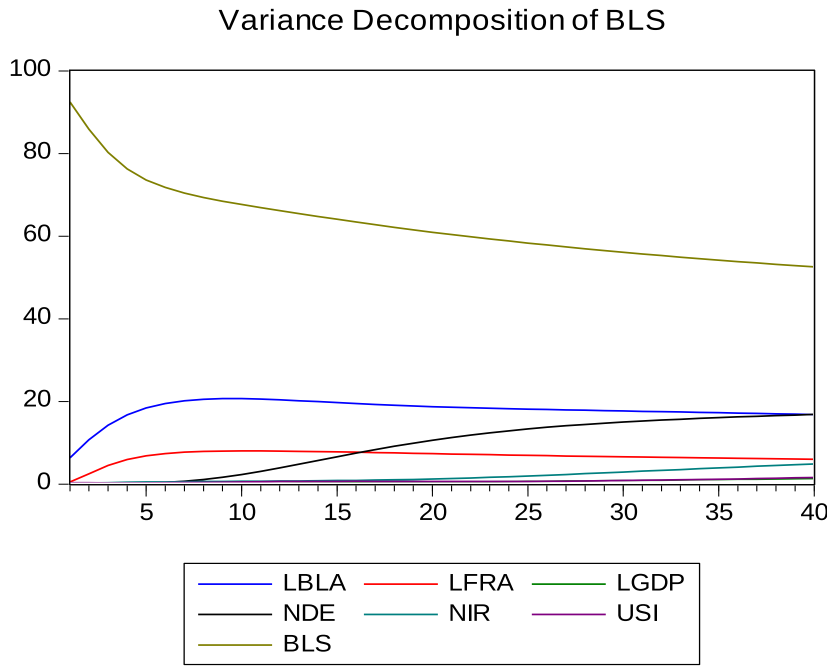

**Appendix 9: Variance Decomposition Graphs for $LGDP_t$ and $NDE_t$**




**Appendix 10: Variance Decomposition Graphs for $NIR_t$ and $USI_t$**




**Appendix 11: Variance Decomposition Graphs for $USI_t$ and $BLS_t$**

## Appendix 12: Explanatory Notes of Crude Oil Futures Contracts[7]

| Key Terms | Definition |
|---|---|
| Contract 1 | A futures contract specifying the earliest delivery date.<br> For gasoline, heating oil, and propane each contract expires on the last business day of the month preceding the delivery month. Thus, the delivery month for Contract 1 is the calendar month following the trade date.<br> For crude oil, each contract expires on the third business day prior to the 25th calendar day of the month preceding the delivery month. If the 25th calendar day of the month is a non-business day, trading ceases on the third business day prior to the business day preceding the 25th calendar day. After a contract expires, Contract 1 for the remainder of that calendar month is the second following month. |
| Contracts 2-4 | Represent the successive delivery months following Contract 1. |
| Crude Oil | A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Depending upon the characteristics of the crude stream, it may also include:<br> Small amounts of hydrocarbons that exist in gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure after being recovered from oil well (casinghead) gas in lease separators and are subsequently commingled with the crude stream without being separately measured. Lease condensate recovered as a liquid from natural gas wells in lease or field separation facilities and later mixed into the crude stream is also included;<br> Small amounts of nonhydrocarbons produced with the oil, such as sulfur and various metals;<br> Drip gases, and liquid hydrocarbons produced from tar sands, oil sands, gilsonite, and oil shale.<br>Liquids produced at natural gas processing plants are excluded. Crude oil is refined to produce a wide array of petroleum products, including heating oils; gasoline, diesel and jet fuels; lubricants; asphalt; ethane, propane, and butane; and many other products used for their energy or chemical content. |
| Futures Price | The price quoted for delivering a specified quantity of a commodity at a specified time and place in the future. |
| **Explanatory Notes** | The futures prices are the official daily closing prices at 2:30 p.m. from the trading floor of the New York Mercantile Exchange (NYMEX) for a specific delivery month for each product listed. |

[7] Table was reproduced from Energy Information Administration website (EIA, 2010c)

## Appendix 13: VAR Lag Order Selection Criteria

| Lag | LogL | LR | FPE | AIC | SIC | HQ |
|---|---|---|---|---|---|---|
| 0 | 10718.86 | NA | 7.22e-21 | -29.35030 | -29.31255 | -29.33573 |
| 1 | 14810.82 | 8105.451 | 1.08e-25 | -40.46253 | -40.19827 | -40.36057 |
| 2 | 14956.81 | 286.7857 | 7.97e-26 | -40.76388 | -40.27311* | -40.57454 |
| 3 | 15024.93 | 132.6872 | 7.30e-26 | -40.85187 | -40.13460 | -40.57514* |
| 4 | 15075.69 | 98.04472 | 7.01e-26 | -40.89231 | -39.94853 | -40.52819 |
| 5 | 15156.52 | 154.7941 | 6.20e-26 | -41.01513 | -39.84484 | -40.56362 |
| 6 | 15197.25 | 77.32753 | 6.13e-26 | -41.02808 | -39.63129 | -40.48919 |
| 7 | 15249.17 | 97.71626 | 5.87e-26 | -41.07169 | -39.44839 | -40.44541 |
| 8 | 15286.09 | 68.89108 | 5.85e-26 | -41.07422 | -39.22442 | -40.36055 |
| 9 | 15333.24 | 87.20423 | 5.68e-26* | -41.10478* | -39.02847 | -40.30373 |
| 10 | 15352.84 | 35.92415 | 5.94e-26 | -41.05985 | -38.75703 | -40.17141 |
| 11 | 15388.19 | 64.19729* | 5.96e-26 | -41.05805 | -38.52873 | -40.08222 |
| 12 | 15415.72 | 49.56806 | 6.11e-26 | -41.03486 | -38.27904 | -39.97164 |

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