Modelling the Relationship between Oil Prices and Economic Activity: Empirical Evidence from Ghana

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Dedication

To the entire Zankawah family

Abstract

This thesis investigates the macroeconomic effects of domestic oil prices and international crude oil prices in Ghana. We investigate the ability of oil prices to influence economic growth in Ghana using annual data from 1971 to 2014. We also examine the possibility of shock spillover and volatility spillover effects from domestic and crude oil prices to the Ghana currency exchange rates and the Ghana stock market index using monthly data from January 1991 to December 2015. To conduct these investigations, this study employed various econometric techniques including; unit root testing, cointegration testing, vector autoregressive model (VAR), structural VAR (SVAR), vector error correction model (VECM), scenario-based dynamic forecasting, the autoregressive distributive lag (ARDL) specification, and the generalized autoregressive conditional heteroscedasticity (GARCH) BEKK model.

Overall, this study seeks to address two central issues; i) whether domestic and world oil prices have the same effect on economic activities and financial variables in Ghana, and ii) whether the crude oil price and the macro economy relationship in Ghana is related to the treatment of crude oil prices as exogenous or endogenous. It is important to recognize the exogeneity of crude oil prices in the context of Ghana given the relatively small size of the Ghanaian economy. The findings suggest that the international crude oil price movements have an insignificant effect on output growth in Ghana both in the short run and in the long, regardless of whether the crude oil price is treated as exogenous or endogenous. However, domestic oil prices have a significant effect on the output growth rate only in the long run. The findings also indicate that world crude oil prices have significant spillover effects on the exchange rate, and this result is unaffected by the treatment of world crude oil prices as exogenous or endogenous. However, the relationship between crude oil prices

and the Ghana stock market depends on whether the crude oil price is exogenous or endogenous. In addition, domestic oil prices have significant spillover effects on the exchange rate and the stock market. Domestic oil prices are also found to have more influence on the stock market than crude oil prices do.

The results of this study have some implications for the government and investors; (i) Increases in crude oil prices do not put a binding constraint on the monetary authorities to loosen monetary policy to offset its effect on output. If inflation is a priority, policy makers could focus on inflation stabilization by tightening monetary policy during oil price rises. (ii) The government's tax policies on petroleum products should not only be focused on revenue generation, but also on ensuring that such policies do not lead to exorbitant domestic oil prices since higher taxes on petroleum products will increase domestic oil prices which can be detrimental to the economy in the long term. (iii) The government should formulate transport-related policies such as promoting mass transportation or encouraging the use of electrically powered vehicles. The government can also encourage the use of renewable energy such as solar to help reduce the country's dependence on oil (iv) Internationally diversified portfolio investors in Ghana should use hedging strategies such as currency forwards, futures, and options to protect their investments from exchange rate risk emanating from oil price shocks.

Chapter 1: Introduction

The main aim of this study is to examine the effects of domestic and world crude oil price movements on economic growth, the exchange rate, and stock market price in Ghana. The pioneering work of Hamilton (1983) laid the foundation for the development of this interesting line of research. Hamilton (1983) established that seven out of eight US recessions from World War 2 to 1983 followed oil price increases. This work brought the attention of researchers to the relationship between oil prices and the macro economy. Since then, researchers have extended the study to include other macroeconomic variables. Among many others, papers such as Hamilton (2003) Fofana et al (2009), Rafiq et al (2009), Ozlale and Pekkurnaz (2010), Ahmed and Wadud (2011), Park et al (2011), and Guivarch et al (2009) found a large negative effect of oil price shocks on output growth.

Despite the existence of both theoretical and empirical literature supporting Hamilton's seminal paper, the general opinion in the literature is inconclusive. For example, Segal (2011), Hooker (1996), Bernanke, Gertler and Watson (1997), Basky and Kilian (2004), and Leduc and Sill (2004) did not find significant macroeconomic effects of oil price shocks. Bernanke, Gertler and Watson (1997) and Leduc and Sill (2004) noted that oil price shocks by themselves do not cause recessions, but the resultant monetary tightening by the central bank to curb inflation arising from the oil shocks does. Also, Segal (2011) and Hooker (1997) showed that oil prices stopped having an impact on the economy sometime in the 1980s. Other papers such as Hamilton (2009a, 2009b) and Kilian (2009) considered the origin of oil price shocks by distinguishing between different types of shocks. Hamilton (2009a, 2009b) distinguished between demand-side shocks and supply-side shocks while Kilian (2009) divided the demand-side shock into aggregate demand and precautionary demand (oil specific) shocks. These papers and many others such as Chatziantoniou et al (2013) established that different oil price shocks generate different responses.

There are other streams of the literature that investigated the relationship between oil prices and exchange rates, and oil prices and stock markets. Examples of the papers that investigated the oil price-exchange rate relationship include Gosh (2011), Lizardo and Mollick (2011), Amano and Norden (2008), and Chen and Chen (2007), and most of these papers found evidence suggesting that an oil price increase leads to a depreciation of the currencies of mainly oil importing countries. According to Krugman (1980), oil price movements affect exchange rates through changes in the current account. That is, if rising oil prices lead to a worsening of the current account of an oil importing nation, then the exchange rate of that country will fall. With regards to oil prices and stock markets, this line of literature started with the seminal work of Jones and Kaul (1996). Jones and Kaul (1996) noted that oil prices are relevant to stock prices because of their effect on current and future cash flows. Some papers such as Basher and Sadorsky (2006), Chen (2010), Filis (2010), Lee and Zeng (2011), Masih et al (2011), and Baldanov et al (2015) also found significant impact of oil price shocks on stock prices, whilst other work including Cong et al (2008), Apergis and Miller (2009), Al-Fayoumi (2009) and Arnold et al (2015) found a weak relationship between the price of oil and stock market prices.

Clearly, the oil price-macro economy literature is extensive, and opinions are varied. However, some gaps have been identified in the literature. One such deficiency is the treatment of international oil prices, especially for small countries. In the literature, the models used by some papers have included the oil price as endogenous for small countries (e.g. Chang and Wong, 2003, Jumah and Pastuszyn, 2007, Adam and Tweneboah, 2008, Rafiq et al, 2009, Dawson, 2007, Masih et al, 2011, and Al-Fayoumi 2009). In essence, treating oil prices as endogenous when they are exogenous for small countries can be a problem. For most small developing countries, macroeconomic conditions in those countries are not likely to have a significant impact on world oil prices. Hence, including the international crude oil price as endogenous for those countries could lead to model misspecifications, or results that are theoretically unjustifiable. Secondly, most of the papers in the literature investigated the oil price-macro economy relationship using international crude oil prices. The studies that examined the link between domestic oil prices and macroeconomic activities are still scarce in the literature. Also, the majority of the previous studies focused their research on the relationship between oil prices and total GDP growth even for countries that produce some amount of oil. Studies that examined the relationship between oil prices and non-oil GDP growth are uncommon.

This study intends to explore and fill these gaps that have not been examined by the previous studies. In doing so, we shall examine the link between crude oil prices and macroeconomic variables in Ghana (mainly non-oil GDP growth, the Ghana stock market, and the Ghanaian currency exchange rate) by treating crude oil prices first as exogenous, and then as endogenous in our models. The aim is to determine whether the treatment of crude oil prices is important when examining the relationship between crude oil prices and macroeconomic variables for a small country like Ghana. For comparison purposes, we shall also consider models using the conventional measure of GDP growth (which is commonly used in the literature) that include oil prices. This study will also examine the effects of both domestic and world crude oil price movements on the macroeconomic variables mentioned above. This will also provide a basis to compare the effects of domestic and world oil price movements on macroeconomic variables.

1.1 Significance of the Study

Based on the deficiencies that have been identified above in the existing literature, this thesis serves to make contributions to the existing literature in a number of ways. Firstly, this thesis seeks to examine the relationship between crude oil prices and macroeconomic variables (i.e. economic growth, the stock market, and exchange rates) for a small open economy using various models where the crude oil price is treated as both exogenous and endogenous. In doing so, we shall also employ a dynamic forecasting exercise based on some scenarios to forecast the response of the Ghanaian economy to oil price shocks. This approach is currently non-existent in the oil price-macro economy literature to the best of our knowledge. The treatment of crude oil prices will also give a new insight into the oil price-macro economy relationship. In particular, this approach will be useful in determining whether the exogeneity of crude oil prices is important in the relationship between crude oil prices and the macroeconomic variables. This is one novel contribution of this thesis.

Secondly, this study will use data for both domestic oil prices and world oil prices to examine the oil price-macro economy relationship. The use of domestic oil prices is important because the domestic oil prices in Ghana did not automatically adjust to world oil price movements due to the government’s subsidies that have been in place for several years. Hence, using the domestic and world oil prices is useful in order to determine whether the different oil price series have different effects on macroeconomic variables. This approach represents a significant contribution of this thesis.

Furthermore, this study will use total GDP and non-oil GDP as measures of economic growth to model the oil price-macro economy nexus. Since Ghana became an oil producer in 2011, using non-oil GDP measure will give us a further understanding about how oil prices affect the macro economy of an oil producing country when oil production is separated from the country's gross domestic product. In essence, separating oil production from GDP treats the economy as mainly a nation dependent on oil imports, although the country produces some amount of oil. This will also enable us to disentangle any differences in results between the use of the two measures of economic growth, and it represents a further contribution of this thesis. This thesis will be the first to conduct such a study on Ghana since the country became an oil producer. The outcome of such a study could be useful for policy makers.

1.2 Motivation of the Study

Despite the existence of a large body of literature investigating the link between oil prices, macroeconomic variables, and the financial sector for both developed countries and developing countries, there has been little research for the sub-Saharan African countries such as Ghana. Hence, it is important to examine the relationship between oil prices, macroeconomic variables, the exchange rate, and the stock market for a small open economy in Africa such as Ghana, since the oil price effects for such a country could be different from the results that were found for developed countries and countries from other continents.

Besides, Ghana exhibits certain characteristics which make it an interesting country to study. Ghana's dependence on oil for energy has been rising annually for several years. Oil accounted for 28% of Ghana's total energy consumption in 2000, and this increased to 52% in 2014 (Energy Commission of Ghana 2015) which is very significant. Also, important sectors such as transport, agriculture, and to some extent industry (manufacturing and mining) depend solely on oil. In particular, petroleum products account for 100% of the energy used by the transport and agricultural sectors (Energy Commission of Ghana report 2016). Between 2004 and 2014, Ghana's oil consumption increased by about 54% - oil consumption increased from 45 barrels a day in 2004 to 83 barrels a day in 2014 (indexmundi). Despite becoming an oil producer in 2011, significant amounts of petroleum products consumed in Ghana are still imported, and the quantities of refined petroleum products imported continue to rise – petroleum product imports increased from 1,589.9 kilo tonnes in 2010 to 3,393.8 kilo tonnes in 2014 (Energy Commission of Ghana report 2015). This information highlights the extreme importance of oil and petroleum products to Ghana's developing economy. Ghana's oil dependence, oil consumption, and petroleum product imports are discussed in detail in section 2.4.

Ghana has also achieved some political and economic success in recent decades which makes the country attractive for both foreign and domestic investors. Since the return of multi-party democracy in Ghana in 1992, democratic governance has been uninterrupted. Since 1992, the country conducted successful elections and witnessed a series of peaceful transitions of political power – a practice that is rarely seen in Africa. Throughout the 1990s and 2000s, Ghana' neighbours in the West African sub-region were plagued with civil wars whilst Ghana remained largely peaceful. On the economic front, Ghana's economy expanded rapidly since the mid-

1990s. Total GDP grew from US$6.4 billion in 1995 to US$39.5 billion in 2011 (World Bank Development Indicators). By 2016, GDP stood at US$42.6 billion. In 2011, Ghana achieved an unprecedented growth rate of 14.4% - the record highest economic growth rate by any country in the world at that time. Also, Ghana's GNI per capita at purchasing power parity (PPP) of US$4,150 in 2016 is the third highest in West Africa, behind only Nigeria and Cape Verde (World Bank statistics 2016). In the UNDP report on human development index released in 2016, Ghana was classified among "Medium Human Development" countries. The report also ranked Ghana second in West Africa (behind Cape Verde) in terms of the human development index. Besides, Ghana's unemployment rate of 11.9% as at 2015 (International Labour Organisation) is among the lowest in Africa.

The above characteristics make Ghana worthy of investigating in a study of this kind. This thesis therefore, attempts to shed more light into the topic by examining the relationship between oil prices, macroeconomic variables, and the stock market in Ghana. The approach and findings of this research will represent some contributions to the limited literature about this topic on Ghana.

1.3 Aims and Objectives of the Study

The aim of this study is to examine the effects of domestic and world crude oil price shocks on economic growth, the exchange rate, and the stock market in Ghana. To this end, the study focuses on the following specific objectives:

- Examine the effects of domestic and crude oil price movements on output growth

- Model the dynamic interactions among oil prices (domestic and world crude oil prices), exchange rates, and stock market prices in Ghana

1.4 Research Questions

Based on the first objective, the thesis attempts to address the following questions:

- To what extent do domestic and world crude oil prices affect the real GDP/non-oil GDP growth in Ghana?
- Does the treatment of world crude oil prices as exogenous or endogenous affect the oil price-macro economy relationship in Ghana?
- Are there asymmetric effects in the relationship between international crude oil prices and the macro economy in Ghana? I.e. are positive and negative oil price shocks having the same size of effect on real GDP/non-oil GDP growth?
- Does the effect of crude oil price shocks on the Ghanaian economy change when oil became part of the economy in 2011?

Based on the second objective, the thesis will examine the following questions:

- Does the volatility of domestic and world oil prices influence the volatility of the Ghana stock market index and the Ghana cedi exchange rate?
- Are the effects of world oil prices on the Ghanaian currency exchange rate and the Ghana stock market related to the treatment of world crude oil prices as exogenous or endogenous?
- Are there asymmetric relationships between these variables? I.e. do negative shocks have higher effects than positive shocks?

- Do current volatilities of these variables depend on their own past shocks
- Are there any return linkages between these variables?

1.5 Outline of the Study

In achieving the stated objectives, the thesis is structured as follows;

Chapter two: this chapter presents an overview of the Ghanaian economy. It also examines the importance of crude oil and petroleum products to the Ghanaian economy and the financial sector.

Chapter three: this chapter discusses the theoretical and empirical review of the literature. It examines the literature on oil prices and economic growth, oil price and exchange rates, and oil prices and stock markets for both developed and developing countries that import oil.

Chapter 4: this chapter evaluates the effects of domestic and world oil price shocks on non-oil GDP/total GDP growth in Ghana using several models. Models that treat world oil prices as exogenous include: scenario-based forecasting using VAR with exogenous variable, structural VAR (SVAR), and ARDL. On the other hand, models that treat world oil prices and domestic oil prices as endogenous are the Johansen cointegration and VECM. The use of different models to treat world oil prices as exogenous is necessary in other to determine the robustness of the results. The chapter also discusses the variables to be included in the study and their justification. It then discusses the research methodology to be used in the study. Finally, the chapter presents the findings as well as the conclusions and recommendations of the study.

Chapter 5: the dynamic interactions between domestic and world oil prices, exchange rates, and the stock market are investigated in this chapter. Based on the properties of these variables, this chapter employs the multivariate GARCH-BEKK and the triangular BEKK models to evaluate the shock and volatility spillover effects of oil prices on the Ghana currency exchange rate and the Ghana stock market. World oil prices are treated as endogenous in the BEKK model whilst in the triangular BEKK model, they are treated as exogenous. The chapter also discusses the results, conclusions, and recommendations of the study.

Chapter 6: this is the final chapter and it contains a discussion of the main findings that emerged from the research. The chapter also presents the policy implications of the results, and some recommendations and directions for future research.

Chapter 2: Overview of the Ghana economy

This chapter aims to present the political and economic background information of Ghana, the statistical review of economic growth in Ghana and the structure of the Ghanaian economic economy. It will also review the importance of crude oil and petroleum products to the Ghanaian economy and the financial markets. Finally, the chapter will discuss the petroleum subsidies and the development of the stock market in Ghana.

2.1. Historical background information

Ghana is a country in West Africa, with a population of about 24 million (2010 EST.). Like many countries in Africa, Ghana's economy is dominated by primary sector production, with secondary and tertiary sectors playing very little role (although the tertiary sector has also become important in recent years). Since the attainment of independence in 1957 from Great Britain, cocoa and gold have been at the centre of the economic growth process. As the first country in sub-Saharan Africa to gain independence, Ghana inherited a relatively stable economy from her colonial masters (Great Britain). The post-colonial era witnessed a well-resourced economy with massive advantages especially in natural resources. At independence, Ghana was the world's largest producer of cocoa. Since the British economic policy set international prices of cocoa, Ghana profited immensely from the higher cocoa prices set by Great Britain. At the same time, Ghana was one of the world's largest producers of yet another most lucrative item; gold, whilst other precious minerals such as diamond, bauxite, and manganese were also in rich deposits. On the macro economy, Ghana had a negligible debt service ratio whilst foreign exchange reserves stood at $ 481 million (Joyce Meng, no date). As a result of the natural resources and a healthy economy, Ghana was regarded as a middle-income economy.

The post-independence economic strategy of Ghana was to restructure the economy by diversifying the export base in order to reduce the overdependence on a few primary export commodities. To achieve this goal, Ghana pursued an ambitious strategy called the ‘Big Push for Industrialization’ under the leadership of the first president Dr Kwame Nkrumah. The strategy emphasized high rates of capital formation through the production of domestic substitutes in state-owned enterprises. Under this strategy, the government embarked on expensive investment in ambitious projects, aimed at reforming the economy through the natural endowments that formed a strong financial base. However, the big push strategy did not prove successful. Through the aggressive government expenditure program, the budget deficit began to rise, and this culminated in higher debt stocks by the mid-1960s. Inflation and unemployment rose significantly during this period. As part of the program, an overvalued currency was maintained due to nationalistic pride, despite rising inflation. The overvalued currency further worsened the external sector by making exports uncompetitive, and damaging the cocoa industry. Overall, the economy became destabilized in the mid-1960s, and the Nkrumah administration became unpopular. Consequently, the government was overthrown through a military coup in 1966 as a sign of public discontent. This marked the end of the golden period of prosperity, and the beginning of a twenty-year period of constant regime changes and economic decline and chaos.

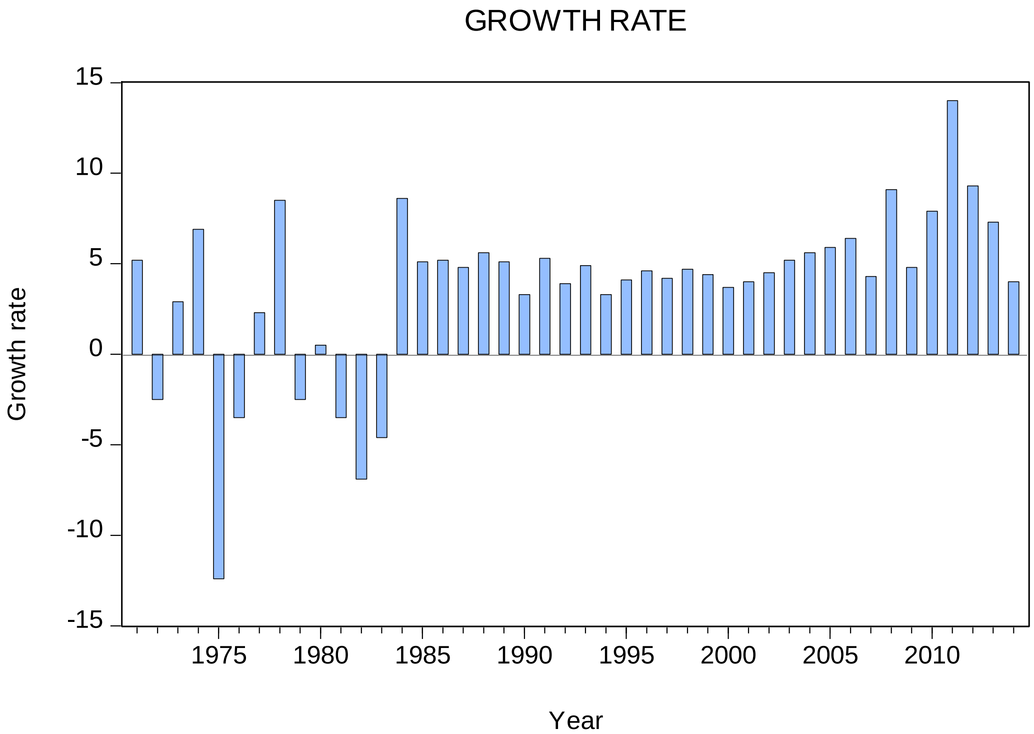
From the fall of the first administration to the mid-1980s, Ghana witnessed coups and counter coups, which significantly retarded economic progress. With no meaningful economic plans as a result of the highly unstable political environment, Ghana faced dramatic economic decline with hyperinflation, food shortages, and massive unemployment from the mid-1970s to the early 1980s. Moreover, the overvalued exchange rates set by the first administration was still maintained. By the early 1980s, Ghana's economy was in complete distress. Between 1980 and 1983, annual GDP grew at a negative rate (see table 2.1). Thus, in 1983, under the guidance of the IMF and the World Bank, the government developed and implemented the Structural Adjustment/Economic Recovery Program (ERP). The overriding purpose of the ERP was to reduce Ghana's debt, and improve its trading position in the global economy. Overall, structural adjustment was meant to improve the performance of the Ghanaian economy. As part of the agreement with the IMF and the World Bank under the program, Ghana would abandon its fixed exchange rate and liberalize the financial sector to allow competition. In 1983, under the economic recovery program, the government began to devalue the local currency which has been maintained at an overvalued rate since the post-colonial era. From 1983 to 1986, the cedi was devalued from 2.75 per US dollar, to 160 per US dollar (IMF IFS database).

The ERP did generate some gains as the economy grew in the mid-1980s. However, by the late 1990s, Ghana's debt had mounted to record levels due to excessive borrowing from the IMF, the World Bank, and other international lenders. As a result, in 2001, the government decided to adopt the IMF's Highly Indebted Poor Countries (HIPC) initiative in order to qualify for debt relief from her international creditors. The HIPC initiative had helped to reduce Ghana's debt substantially, as the external debt fell from $7.5 billion in 2003 to $3.3 billion in 2006 (World Bank data). Despite the debt relief, the government's continued borrowing from bilateral and multinational organizations increased the external debt stock to beyond the pre-HIPC era by the end of 2010. By 2011, Ghana's external debt stock stood at $8.3 billion dollars indicating that the initial benefits of HIPC have been eroded. However, Ghana discovered crude petroleum oil in commercial quantities in 2007 which brought some new hope. In 2011, the exploration of crude oil started in the newly discovered oil field, and Ghana officially became an oil economy.

2.2. Performance trend

The Ghanaian economy experienced rapid growth during the early years of independence. The average growth rate for the first decade of independence was 2.9%. However, the growth rate stagnated in the 1970s, with negative growth rates being reported in some years during that decade (see figure 2.2.1). The political turmoil which Ghana endured from the mid-1960s through to the early 1980s, coupled with the fall in the international price of cocoa in the 1970s accounted for the negative growth rates. Economic policy during this turbulent period was generally ineffective. The economy was still in deep recession between 1981 and 1983. By 1986 however, the economy had recovered sufficiently; the growth rate rose to 5% in 1986, and 6% in 1988 as indicated in figure 2.2.1. It can be noted that GDP responded favourably to the economic adjustment policies in the mid-1980s during which the Economic Recovery Program (ERP) and liberalization policies were adopted. For the next thirty years, the performance of the economy remained rather impressive, with the lowest growth rate being 3% only in 1990 and 1994. In particular, the economy witnessed a steady growth rate between 2003 and 2012. The annual growth rate increased from 5% in 2003, to 8% in 2008. The strong growth has been achieved within a sound macroeconomic environment which resulted from prudent fiscal and monetary policies. The private sector responded positively to the government's development programs and the favourable business environment. However, in 2009, the growth rate dipped to 5% reflecting the effect of the global financial crisis – the impact of the 2008 crisis became noticeable in Ghana several months into 2009. Also, the change in political leadership in December 2008 and the sense of uncertain policy strategies and direction slowed down investor activity. In 2010, the economy rebounded to achieve an average annual growth rate of 7% and reached an all-time record of 14.4% in 2011. Since the record growth rate in 2011, the economy has surprisingly been growing at a declining rate – a growth rate of 4% was recorded in 2014. Figure 2.2.1 illustrates the pattern of the GDP growth rate in Ghana between 1971 and 2014.

Figure 2.2. 1: GDP Growth Rate of Ghana from 1971 to 2014



Source: World Bank Development Indicators

2.3. Structure of the Ghanaian Economy

The Ghanaian economy can broadly be divided into three main sectors, namely; the primary sector which is made up of agriculture and natural resources, the secondary sector which comprises of processing and manufacturing, and the tertiary/service sector. The economy is also categorized into structural compositions with respect to sectoral contribution to GDP. These compositions include agricultural, industry, and services sectors. The agricultural sector is predominantly subsistence farming although some modern farming techniques are also being practiced. At the time of independence, Ghana was predominantly a cocoa economy. However, the cocoa and mining industries were largely underutilized during the post-colonial era because the government at the time felt dependence on a few commodities would engender economic instability. From this period, agriculture was the chief driver of economic growth. Agriculture continued to dominate the economy for nearly four decades. As at 1970, agriculture accounted for about 54% of GDP (table 2.3.1). This rose to 60% by 1980 before declining to 48% in 1985. Since 1985, agriculture's contribution to GDP continued to decline steadily, and by 2006, the service sector surpassed the agricultural sector to become the chief contributor to GDP. In the ERP, greater attention was given to the cocoa and mining industries at the expense of the agricultural sector because of the underutilization of the two industries since independence. Agriculture has also become less attractive to the youth workers in recent times as most of them tend to prefer 'white-collar' jobs. Perhaps, the government neglect, coupled with the low interest in farming by the work force has contributed to the consistent decline of agriculture's contribution to the economy. In an effort to boost agricultural production, the government announced several measures in 2016 designed to encourage the youth to go into farming

The decades of decline in agriculture also coincided with a rise in the service sector. As table 2.3.1 indicates, the contribution of services to GDP had risen since 1980. The service sector has been boosted by the booms in the banking and tourism/hospitality subsectors. As part of the ERP, Ghana's banking sector was reformed which led to the liberalization of the sector. Despite some challenges faced by the banking sector in the 1980s and 1990s, the sector expanded rapidly. This was mainly due to the liberalization of the banking sector which led to large capital injections, as well as political and economic stability. The hospitality and tourism industry also flourished from the end of the 1990s. In 2011, tourism was ranked the third largest foreign exchange earner in Ghana. Other service industries that witnessed rapid growth include transport and storage, information and communication, real estate services, education, health and social work, business, and social security. Thus, the services sector developed to become the largest contributor to GDP in 2006. As at 2014, the sector accounted for 50% of GDP.

Table 2.3. 1: Contribution of Agriculture, Industry, and Services to total GDP

Period	Agriculture (%)	Industry (%)	Service (%)
1970	54	21	25
1980	60	12	28
1990	45	17	38
2000	39	28	32
2001	39	28	33
2002	39	28	33
2003	40	28	32
2004	42	28	31
2005	41	27	32
2006	31	21	48
2007	30	21	49
2008	32	21	47
2009	33	20	47
2010	31	20	49
2011	26	26	48
2012	24	29	47
2013	23	29	48
2014	22	28	50

Source: World Bank Development Indicators

The industrial sector of Ghana comprises manufacturing, mining, cocoa, and electricity generation. Manufacturing has not made any significant contribution to the growth of the economy despite spirited efforts by successive governments. Ghana is import-dependent with very little non-primary exports due to a relatively weak capacity of manufacturing industries. In addition, cocoa and gold, which have been Ghana's traditional exports, have been unable to significantly power the economy partly due to the constant fluctuations in international prices of cocoa and gold. Industry has been the least contributor to economic growth for several decades since independence. In 1970, the contribution of industry to GDP was 21%. This contracted rapidly, declining to 12% in 1980. Industry's contribution rebounded however, rising to 17% in 1990. Since 2000, industry's contribution to GDP trended around 28% until 2006 when it dipped to 21%. In 2012, the sector surpassed agriculture to become the second largest contributor to GDP. By 2014, industry contributed 28% to GDP. It is important to note that the industrial sector has been boosted by the increase in aluminium smelting and textiles making in the 1990s, and the increase in cocoa production in the 2000s.

2.4: Significance of Oil in the Ghanaian Economy

Energy consumption plays an important role to economic growth in Ghana (e.g. see Akinlo 2008). As indicated in table 2.4.1, Ghana's oil dependence[1] has increased

[1] Oil dependence is the ratio of oil consumption to total energy consumption. It can be a useful indicator in determining Ghana's ability to easily switch from oil to other fuels during higher oil prices or during crisis in the oil market (World Bank 2005f).

[2] Fuel mix is the ratio of consumption (or production) of different fuels to the total energy consumed either at primary energy or final energy level. It indicates the level of diversification of a country's fuel supply and energy security. The more diversified the fuel mix, the less vulnerable the country is to fuel supply shocks (Bhattacharyya, 2010)

[3] In 1982, the bilateral exchange rate of the Ghanaian currency against the US dollar was ȼ2.75 per US$1. Ghana agreed to reform its exchange rate policy, to implement a flexible exchange rate regime and devalue the local currency. By 1990, the cedi declined in value to ȼ345 per US$1, and further to ȼ1754 per US$1 in

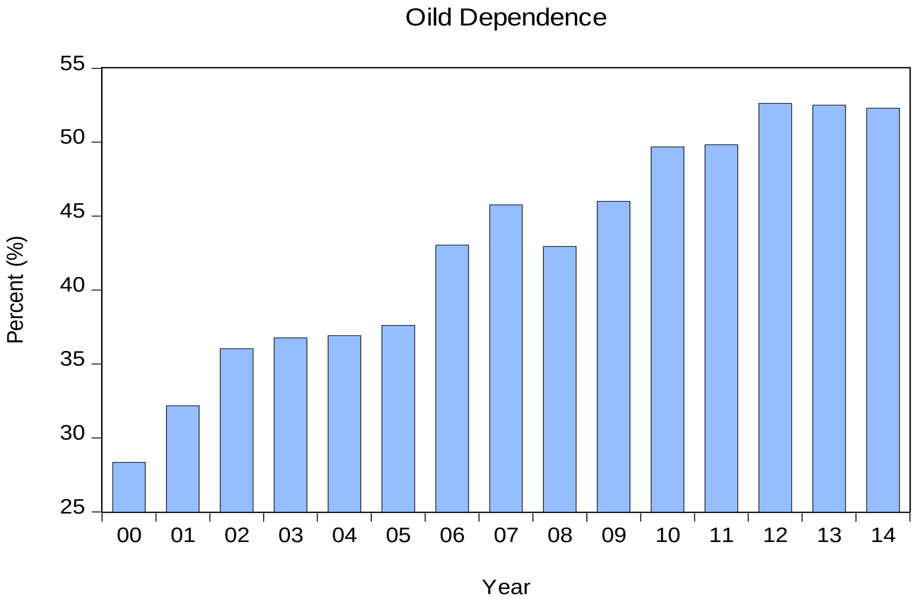
over the years. Between 2000 and 2014, oil dependence increased from 28% to 52%. Figure 2.4.1 shows a graphical representation of the rise in Ghana's oil dependence during this period. Oil consumption also increased from 37 thousand barrels per day, to 83 thousand barrels per day during the same period (see table 2.4.1).

Table 2.4. 1: Ghana's crude oil consumption and oil dependence, 2000-2014

Year	Oil consumption (thousand barrels per day)	Oil dependence (%)	GDP (billions of GHS)
2000	37	28	2.7
2001	36	32	3.8
2002	39	36	4.8
2003	42	36	6.6
2004	45	36	7.9
2005	46	37	9.7
2006	47	43	18.7
2007	48	45	23.1
2008	44	42	30.1
2009	54	46	36.5
2010	65	49	46.0
2011	69	49	59.8
2012	78	52	75.3
2013	81	52	94.9
2014	83	52	113.4

Source: Indexmudi.com and Energy Commission of Ghana
Note: Oil dependence is the ratio of oil consumption to total energy consumed.

Figure 2.4. 1: Oil consumption as a share of total energy consumption in Ghana



Source: Ghana Energy Commission report 2015 and author's calculations

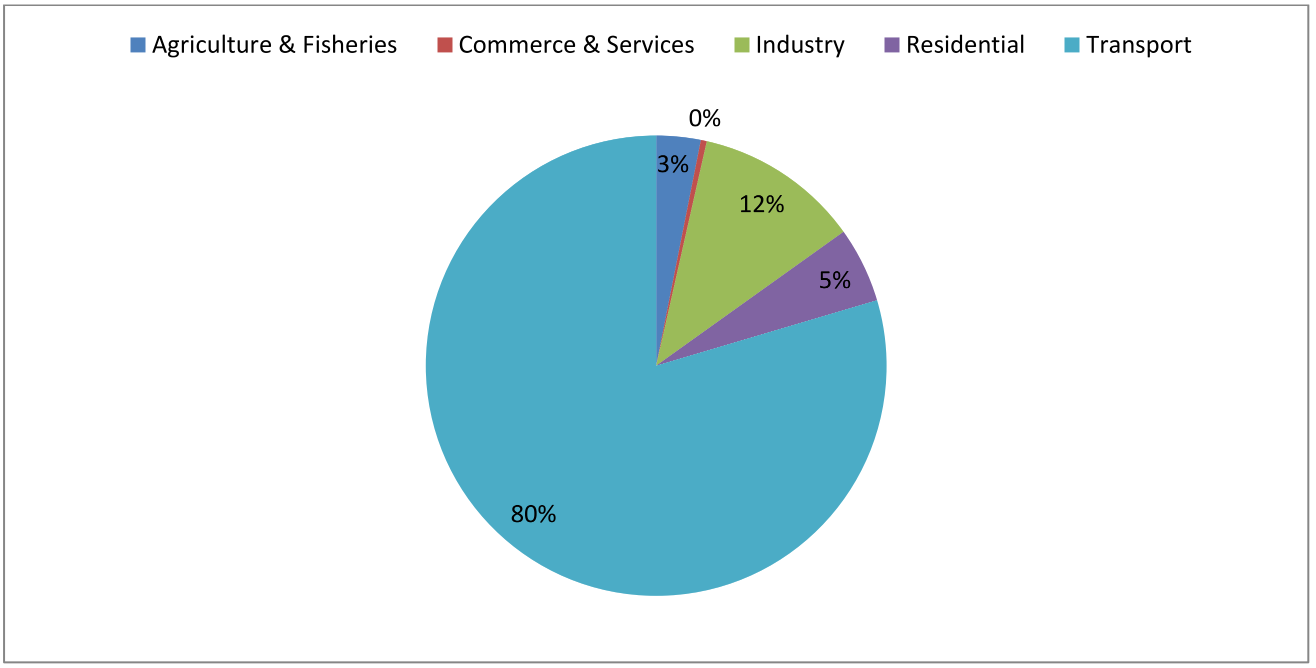
The importance of oil to the Ghanaian economy can also be examined by considering Ghana's fuel mix[2] at the sectoral level and sectoral fuel consumption. These have been illustrated in table 2.4.2 for some selected periods and figure 2.4.2 in 2015.

[2] Fuel mix is the ratio of consumption (or production) of different fuels to the total energy consumed either at primary energy or final energy level. It indicates the level of diversification of a country's fuel supply and energy security. The more diversified the fuel mix, the less vulnerable the country is to fuel supply shocks (Bhattacharyya, 2010)

Table 2.4. 2: Ghana's Fuel Mix for 1999, 2006, 2012, and 2016

Sector	Year	Coal	Oil Products	Natural gas	Hydro	Combustible renewals	Electricity	Total
Industry	1999	0	0.23	0	0	0.38	0.39	1
	2006	0	0.33			0.38	0.29	1
	2012	0	0.25	0	0	0.55	0.20	1
	2016	0	0.45	0	0	0.25	0.30	1
Transport	1999	0	1	0	0	0	0	1
	2006	0	1	0	0	0	0	1
	2012	0	1	0	0	0	0	1
	2016	0	1	0	0	0	0	1
Residential	1999	0	0.04	0	0	0.92	0.04	1
	2006	0	0.04	0	0	0.92	0.04	1
	2012	0	0.05	0	0	0.83	0.12	1
	2016	0	0.06	0	0	0.78	0.16	1
Commerce and services	1999	0	0.50	0	0	0	0.50	1
	2006	0	0.25	0	0	0	0.75	1
	2012	0	0.09	0	0	0.44	0.47	1
	2016	0	0.04	0	0	0.34	0.62	1
Agriculture/forestry	1999	0	1	0	0	0	0	1
	2006	0	1	0	0	0	0	1
	2012	0	1	0	0	0	0	1
	2016	0	1	0	0	0	0	1

Figure 2.4. 2: Ghanaian petroleum product consumption by sector for 2015



Source: Energy Commission of Ghana

The information in table 2.4.2 reveals that Ghana has been highly dependent on oil, with the transport and agricultural sectors depending almost entirely on oil products. This suggests that these two sectors are the least diversified in terms of oil usage. Figure 2.4.2 indicates that the transport sector is responsible for about 80% of petroleum consumption in Ghana in 2015. The second highest oil consumer was the industrial sector which accounted for about 12%. Note that although the agricultural sector depends entirely on oil products as indicated in the energy mix analysis in table 2.4.2, the sector is responsible for only about 3% of total petroleum consumption in Ghana according to figure 2.4.2. This is due to the fact that agriculture in Ghana is still largely peasant, with very low mechanised farming. Although a few commercial farmers use modern farming practices which entail the use of machines and fuel, the majority of farming in Ghana is still labour intensive.

Hence, oil usage in the sector mostly comes from the transport of farm produce from the farms to the consuming centres.

The analyses above show that petroleum forms an important part of Ghana's energy mix and, the importance of petroleum products to the Ghanaian economy cannot be underestimated. As mentioned in the previous chapter, Ghana became an oil producer in 2011, lifting oil in commercial quantities from the Jubilee oil field. However, the country's petroleum product imports continue to rise despite becoming an oil producer. Ghana's annual petroleum product imports and other petroleum products information are presented in table 2.4.3. As the table shows, the importation of petroleum products increased from 2,108.7 kilo tonnes of oil equivalent (KTOE) in 2011 to 3,393.8 kilo tonnes of oil equivalent (KTOE) in 2014. This information is represented graphically in figure 2.4.3a.

Table 2.4. 3: Ghana's Petroleum imports, consumption, and production (2005 to 2014)

Year	Petroleum Product Imports (KTOE)	Petroleum Products Consumed (KTOE)	Petroleum Products Produced (KTOE)	Net Petroleum Product Imports (KTOE)	Petroleum Import Dependence
2005	578.3	1568.4	1540.8	27.6	0.017598
2006	1387.4	1872.6	891.3	981.3	0.524031
2007	1238.3	2126.6	1194.9	931.7	0.438117
2008	1194	2071.3	1221.5	849.8	0.410274
2009	1844.6	2597.7	327.1	2270.6	0.874081
2010	1589.9	2491.1	946.4	1544.7	0.620088
2011	2108.7	2826.6	958	1868.6	0.661077
2012	2573.2	3317.5	454	2863.5	0.86315
2013	2945.6	3422.3	424.2	2998.1	0.876048
2014	3393.8	3377.5	129.2	3248.3	0.961747

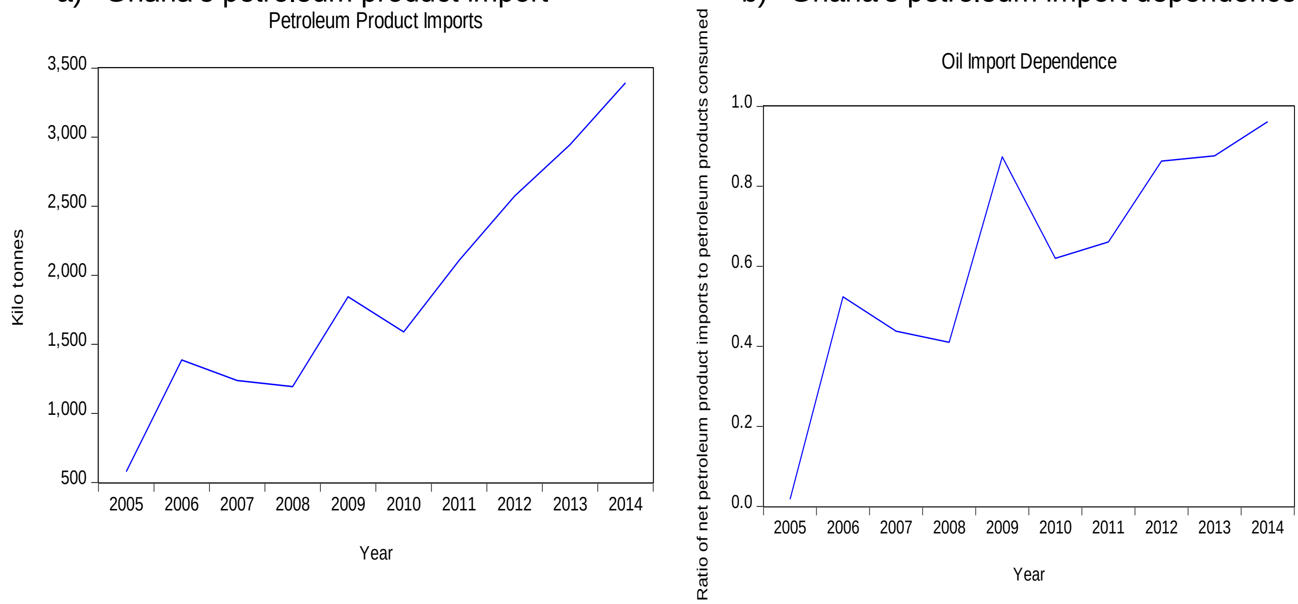
Source: Energy Commission of Ghana

Another indicator that can be used to illustrate a country's exposure to oil supply shocks is petroleum import dependence (Bhattacharyya 2010). This indicator is the difference between oil consumption and oil production (net oil imports) divided by oil production. Using available data of Ghana's petroleum products consumption and petroleum products production, we have computed Ghana's dependence on the imports of refined petroleum products. As depicted in figure 2.4.3b, petroleum import dependence has been erratic but generally trended on an upward trajectory between 2005 and 2014. The graphs in figure 2.4.3 both suggest that Ghana could be vulnerable to oil supply shocks despite becoming an oil producer.

Figure 2.4. 3: Ghana's Petroleum Product Imports and Oil Import Dependence

a) Ghana's petroleum product import

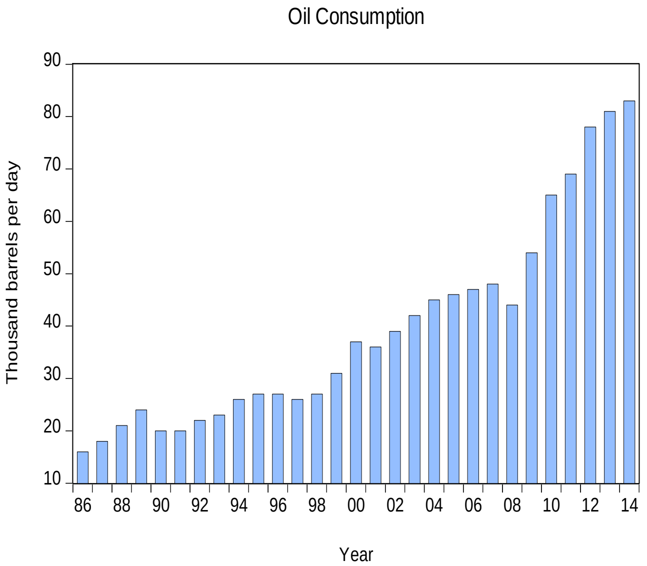
b) Ghana's petroleum import dependence



Ghana's continuous dependence on imported petroleum products can be attributed to two main factors; firstly, the Tema Oil Refinery (TOR), which is the only refinery in Ghana, has not been able to increase its production capacity for so many years, mainly due to management problems among others. However, the country's need for refined petroleum continues to increase, and this is propelled by rapid economic growth. Hence, Ghana tends to import significant amounts of refined petroleum oil from countries such as the Netherlands to meet the growing domestic demand for petroleum products. Secondly, the crude oil Ghana produces cannot be refined in Ghana at present due to some technical problems. As a result, the majority of crude oil produced in Ghana is being exported. In 2014 for example, the country produced 105 thousand barrels of oil per day whilst also exporting 104 thousand barrels per day (see figure 2.4.4b and c). At the same time, as figure 2.4.4d indicates, oil refinery in Ghana remained constant at 45 thousand barrels per day since 1999, whilst oil consumption continues to increase – reaching 83 thousand barrels per day in 2014 (see figure 2.4.4a).

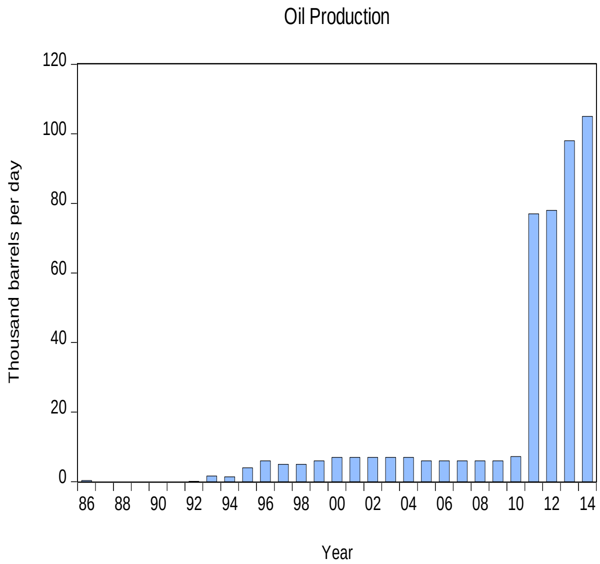
Figure 2.4. 4: Crude Oil Production, Consumption, Exports, and Refinery in Ghana

(a) Ghana' Crude Oil Consumption (thousand barrels per day



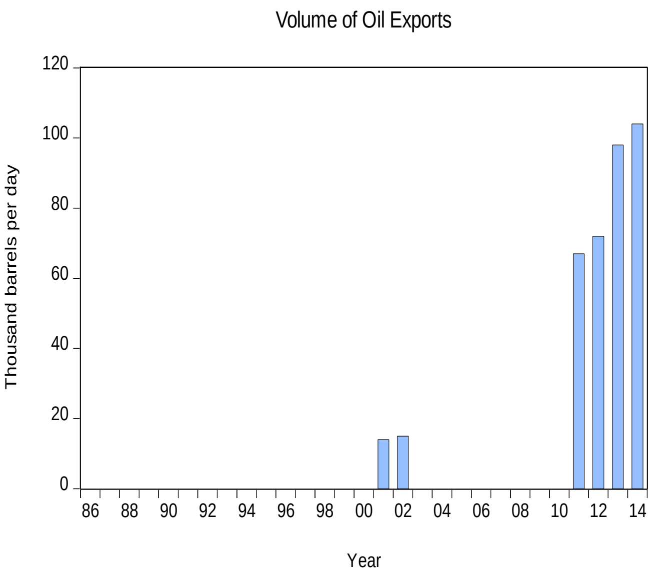
source: indexmundi.com

(b) Ghana's Crude Oil Production (thousand barrels per day)



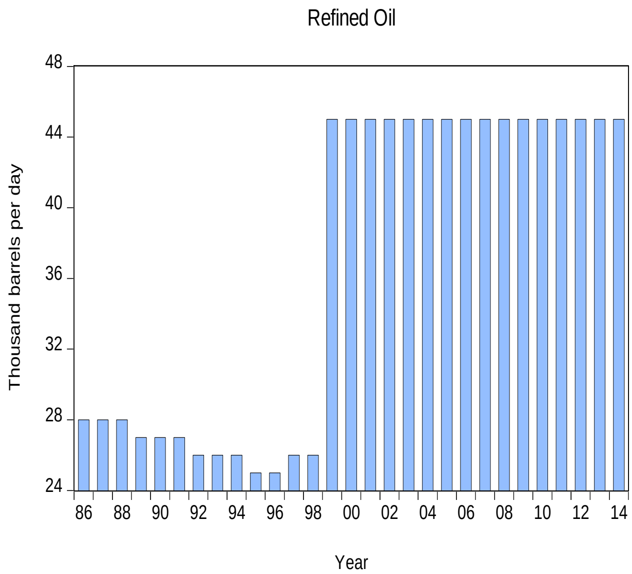
source: indexmundi.com

(c) Crude oil Exports in Ghana (thousand barrels per day)



source: indexmundi.com

(d) Annual Crude Oil Refinery in Ghana by TOR



source: opendataforafrica.org

It should be noted that the government of Ghana provided subsidies on petroleum products to consumers over the years, and the period for which the subsidies were in place coincides with the sample period of this study. Hence, it is worthwhile discussing the petroleum subsidies here briefly.

How Subsidies Arise

Until the government's announcement to withdraw all fuel subsidies in 2015, the full cost of petroleum products was not passed on to consumers through the ex-pump price. The government had the exclusive right to intervene in the price build up through the NPA. Consumer subsidies arise when the government puts a cap on the ex-pump price at a certain benchmark. When bulk distributing companies (BDCs) land petroleum products at the Tema port at a certain refinery price, and the government decides to set the ex-pump price below that price, then an under recovery amount or a subsidy component is provided to the BDCs by the government to reflect the full cost of landing the product. This form of subsidy arises when the prices paid by consumers (both households and firms) are below a certain benchmark price (Acheampong and Ackah 2015). In other words, the subsidy arises when the prices consumers pay is below supply cost – the international price adjusted for distribution and transportation. It typically comes in the form of a pre-tax subsidy, which means the total taxes, levies, and surcharges in the aforementioned price build up are not included.

The government itself does not import refined products or crude oil, but what it has been doing is to ensure that the BDCs are fully paid to cover the 65% component, whilst also reducing the full cost of this component for consumers. In essence, the system that prevailed was a capping mechanism of some sort where price adjustments on the global market (which constitute 65% of the price build up) do not reflect automatically in local prices taking into account inflation and exchange rate movements. Up until the government's announcement in 2015 to pursue the full deregulation policy, the NPA had been arguing for the withdrawal of subsidies but was forced to give in due to political pressures. However, after the 2015 announcement, all petroleum subsidies have been removed, and what prevails now is the automatic adjustment formula where price adjustments in the world market are automatically reflected in local prices. In effect, the government is now implementing its full-scale deregulation agenda.

2.5: Oil prices, exchange rates, and the stock market

Given the importance of oil and petroleum product imports to the Ghanaian economy, the price of oil could be important to the financial markets in Ghana such as the exchange rate and the stock market. In particular, the exchange rate could be affected by Ghana's oil imports. Since Ghana adopted a flexible exchange rate[3] in the mid-1980s, the Ghanaian currency witnessed remarkable depreciation and volatility in the years that followed. The government has attempted without success to manage a stable exchange rate. This is largely due to balance of trade deficits because of a continuous rise in imports, which oil is part of. The value of Ghana's oil imports increased from US$0.511 billion in 2002 to US$3.693 billion in 2014 (Bank of Ghana statistical bulletin). In 2014, the import of oil products constituted 33.8% of total imports.

[3] In 1982, the bilateral exchange rate of the Ghanaian currency against the US dollar was ȼ2.75 per US$1. Ghana agreed to reform its exchange rate policy, to implement a flexible exchange rate regime and devalue the local currency. By 1990, the cedi declined in value to ȼ345 per US$1, and further to ȼ1754 per US$1 in 1996. The cedi continued to depreciate at an alarming rate for the rest of the 19990s. By December 2000, the cedi suffered its highest annual depreciation, exchanging for the US dollar at ȼ7047 per US$1 representing a depreciation of 99% from the previous year. In 2007, the government redenominated the currency and new currency call the Ghana cedi (GHȼ) replaced the oil currency. The new currency was trading at GHȼ0.9704 per US$1 at the time of the redenomination. However, the new Ghana cedi fell steadily against the US dollar over the years. By 2015, the cedi fell to about GHȼ3.795 per US$1.

As it is generally known, the price of imported commodities can affect movements in the domestic currency. Considering the volume of Ghana's oil imports, and the volatilities in oil prices in the last four decades or so, the Ghanaian currency could be susceptible to oil price changes. Since the US dollar is the main invoicing and settlement currency in the world oil market, Ghanaian oil importers must sell their domestic currency (the Ghana cedi) in the foreign exchange market in order to obtain liquidity in US dollars to pay for their oil imports. As a result, movements in oil prices can have a destabilizing effect on the local currency.

The price of oil and petroleum products could also be important determinants of movements of the Ghana stock market. Here, we outline three possible reasons why the oil price and the Ghana stock market relationship could be significant. Firstly, the mining and manufacturing industries which rely heavily on oil for their operations constitute the second largest in terms of the number of listed companies on the Ghana stock market. Secondly, there are oil companies listed on the Ghana stock market e.g. Tullow Oil, Total Petroleum Ghana, and Ghana Oil, and some of these companies are foreign owned. As a result, oil price movements can have a direct effect on their share prices which may have some impact on the Ghana stock exchange index. Finally, as oil plays an important role in production activities in Ghana, oil price movements will be expected to have an impact on the Ghana stock market if the oil prices affect macroeconomic variables such as output and inflation. Inflationary pressures and economic downturns deteriorate consumer sentiments and slow down overall consumption and investment spending which can affect the stock market.

2.6: Overview of the Ghana Stock Market

The Ghana Stock Exchange (GSE) was established in July 1989 as a private company under the Ghana Company's Code 1963 (Act 179). Trading on the floor of the exchange commenced on the 12th of November 1990. However, in April 1994, the status of the company was changed to a public company under the Company's Code. Until the end of 2010, the principal index of the Ghana Stock Exchange was the GSE All-Share index which tracks price changes in listed equities on the exchange. In January 2011, the Ghana Stock Exchange introduced two new indices to replace the GSE All-Share index. The new indices were the GSE Composite index (GSE-CI) and the GSE Financial Stock Index (GSE-FSI).

The Ghana Stock Exchange also implemented some changes in its trading activities in 2011. One of these changes was the extension of the trading hours of the exchange. The new trading hours became 09:30 hours gmt to 15.00 hours gmt. This replaced the previous trading hours of 09.30 hours gmt to 13.00 hours gmt. The changes were made to afford dealers increased contact hours with their clients during the trading day, as well as offer non-resident Ghanaians in different time zones from Ghana greater opportunity to reach out to their local brokers. It was also expected to help improve liquidity of the exchange. The Ghana stock exchange also introduced a new method of calculating closing prices of equities on the stock exchange. From 4th January 2011, the closing prices of listed equities were calculated using the volume weighted average price of each equity for every given trading day. Until then, closing prices were based on the last transaction prices of listed equities.

The stock market index price used in this study is based on the GSE-ASI and the GSE-CI. The two indices which existed at different times comprised all listed stocks on the GSE and they measure the general performance of the stock exchange. In 1993, the number of listed companies on the GSE was 15, and as of 2011, there were 37 listings and two corporate bonds. Table 2.6.1 reports some summary statistics of the performance of the Ghana stock market, i.e. the number of listed companies, market capitalization (market value of listed shares), total value of traded shares, and the stock price index.

Table 2.6. 1: Performance indicators of the Ghana stock market (in USD millions)

Year	Number of listed companies	Market Value of Listed Shares/Market Capitalization (GH₵ million)	Total Value of Shares Traded (GH₵ million)	Stock Price Index	
				Index	% change
1993	15	10	0.3	132.88	NA
1994	17	199.9	7.2	298.10	124
1995	19	241.7	2.7	316.97	6
1996	21	290.9	2.8	360.76	14
1997	21	256.7	9.3	511.74	42
1998	21	322.5	13.3	868.35	70
1999	22	325.2	7	736.16	-15
2000	22	352.3	4.9	857.98	17
2001	22	205	9.1	955.95	11
2002	24	295.3	8.4	1395.31	46
2003	25	566.5	38.9	3553.42	154
2004	29	434.6	65.9	6798.60	91
2005	30	556.9	46.5	4778.07	-30
2006	32	701.8	47.6	5026.80	5
2007	32	2330.2	141	6595.63	31
2008	35	3453.3	348.2	10431.64	58
2009	35	3441.7	73.4	5572.34	-47
2010	35	4344.3	150	7369.21	32
2011	37	4804.2	393.9	7758.64	5

Source: World Bank Development Indicators and topforeignstocks.com

As it can be seen from table 2.6.1, the index performed well between 1993 and 2011 although its performance trend generally consists of both ups and downs. In 1994, the index posted an impressive return of 124% and was voted the best performing stock market among all emerging stock markets as a result. At the end of 2003, the

GSE was also ranked the best performing stock market in the world when it recorded its highest market gains of 154.67%. Yet, the GSE achieved another remarkable performance in 2008. In the mist of the 2008 global financial turmoil, the GSE index gained 58.8%, making it the best performing market in Africa and one of the best in the world during that year. However, the market crashed in 2009 when it posted its heaviest loss of 47% before rebounding in 2010 with a gain of 32%. The 2009 crash was believed to be the effects of the 2008 global financial crisis which started being felt at the close of 2008 and into 2009. In general, the Ghana stock exchange witnessed stronger growth since 2003 as new investors entered the market and raised the confidence of people towards investing in the market.

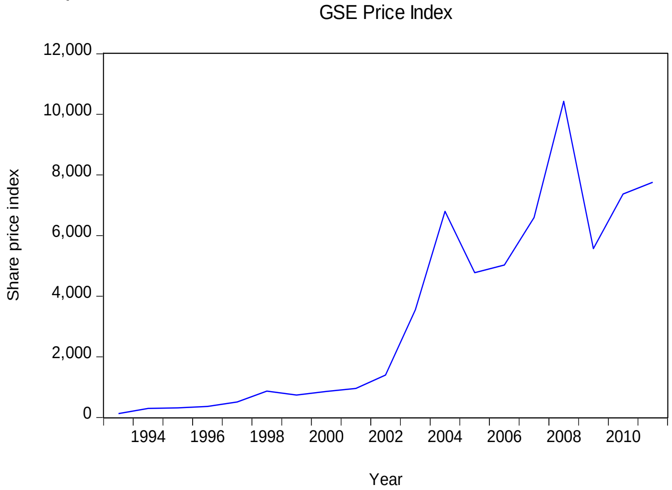
With regards to stock market capitalization, the capitalization of the Ghana stock market[4] has increased since 1993 (see table 2.6.1 and figure 2.6.1c). Market capitalization jumped from GH¢10 million in 1993 to GH¢199.9 million in 1994. From 2004, market capitalization continued to increase but at a steady state, rising to GH¢352.3 million in 2000 and GH¢556.9 million in 2005. Capitalization rose sharply again between 2006 and 2011 – it increased from GH¢701.8 million in 2006 to GH¢2330.2 million in 2007. By the close of 2011, market capitalization stood at GH¢ 4804.2 million. Since 2006, the Ghana Stock Exchange has been boosted by booms in sectors such as banking and consumer goods. The value of shares traded on the Ghana Stock Exchange has also increased substantially during the 1993 to 2011 period. The value of traded shares increased from GH¢0.3 million in 1993 to GH¢7.3

[4] The capitalization of the Ghana stock market reported in US dollars by the World Bank indicates that market capitalization declined between 1994 and 2004. This is due to the fact that the data was converted from local currency units to US dollars, and because the Ghanaian currency depreciated drastically during that period, the capitalization figures turn to be declining in the US dollar terms. The actual data reported in the local currency however, indicates that the capitalization of the Ghana stock market has been increasing since 1993 which is what we have reported in this study.

million in 1994. But the years between 1994 and 2005 experienced some ups and downs in the value of traded shares, although the value was generally trending on an upward trajectory (see figure 2.6.1d). Between 2006 and 2007 the value of shares traded increased from GH¢47.6 million to GH¢141 million representing a growth rate of 196%. The value of stocks traded further increased to GH¢348.2 million in 2008 representing an increase of 146%. 2009 was a particularly difficult year for the Ghana Stock Exchange – the value of shares traded on the exchange declined to GH¢73.4 million in that year representing a decrease of 78.9% from the previous year. This was a reflection of the major crash of the Ghana stock market index in that year. Investor confidence was low in that year as a result of the losses which affected trading activities. In 2010, trading activities rebounded however, as the stock market recovered sufficiently from the 2009 crash. This led to an increase in the value of shares traded on the exchange from GH¢ 73.4 million in 2009 to GH¢150 million in 2010. In 2011, the value of shares traded on the Ghana Stock Exchange reached an all-time high of GH¢393.9 million.

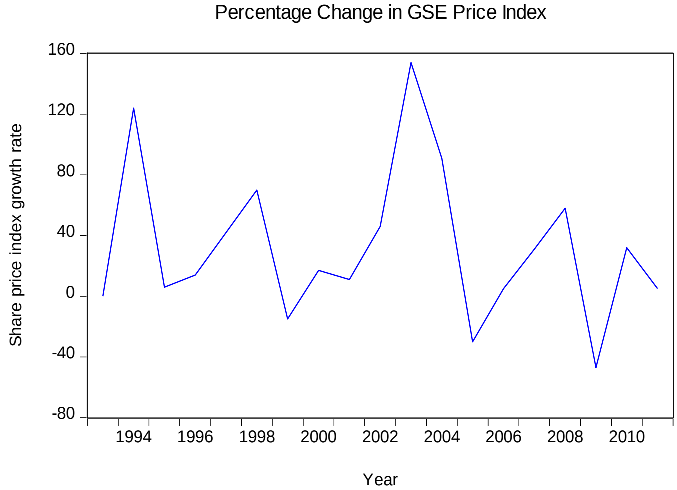
Figure 2.6. 1: Performance Indicators of the Ghana Stock Exchange (GSE), 1993-2011

a) The GSE Price Index



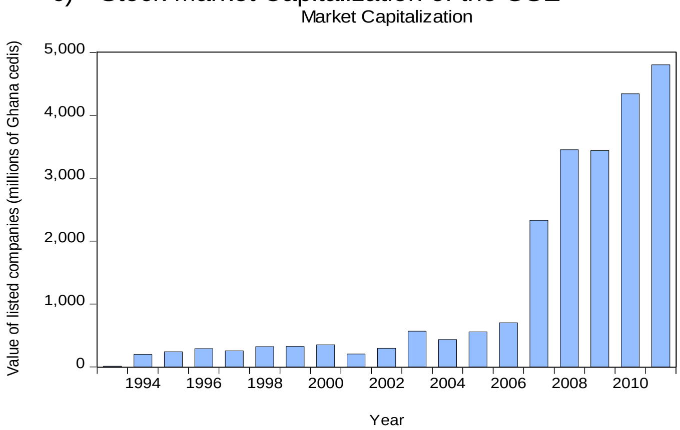
Source: topforeignstocks.com

b) Annual percentage change in the GSE Index



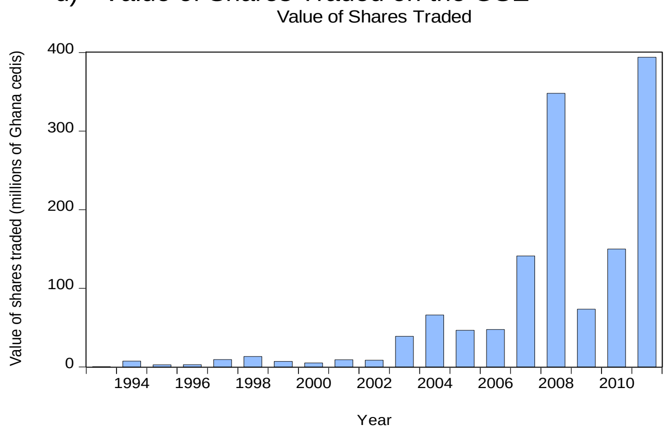
Source: topforeignstocks.com and author's calculations

c) Stock Market Capitalization of the GSE



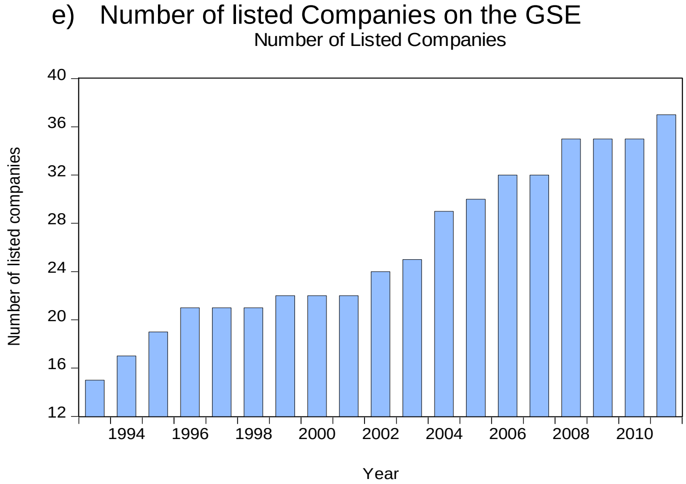
Source: World Bank Development Indicators

d) Value of Shares Traded on the GSE



Source: World Bank Development Indicators

e) Number of listed Companies on the GSE



Source: Knoema, World Bank Development Indicators

2.7: Summary

This chapter has made a statistical review of the structural changes that the Ghanaian economy has gone through, the importance of oil to the Ghanaian economy and the financial markets, and the stock market development in Ghana. It has been observed that the economy expanded rapidly since the year 2000. Amidst this economic growth is a substantial rise in the country's oil consumption. As a developing economy, oil and petroleum products form an important part of Ghana's energy mix – petroleum products accounted for over 52% of Ghana's energy consumption in 2014 with transport and industry being the main consumers of oil. Despite becoming an oil producer, significant amounts of refined petroleum products consumed in Ghana are still imported, and the evidence suggest that the import of refined petroleum products is still increasing annually.

Ghana's dependence on oil also suggests that oil prices could be important not only to the economy, but also to the financial markets such as the exchange rate and the stock market. In particular, oil prices may be relevant to the Ghana stock market because the companies listed on the Ghana Stock Exchange include oil companies. Mining and manufacturing companies are also listed on the exchange, many of which rely on oil for their operations. At the same time, the Ghana stock market has achieved an impressive growth since its establishment as revealed by the key performance indicators such as the share price index, market capitalization, and the number of listed companies. Given the importance of oil to the Ghanaian economy and the financial markets, it will be prudent to empirically investigate the relation between oil prices and economic growth; and oil prices and the financial markets (i.e. the exchange rate and the stock market) in Ghana. Such investigations are the main focus of this study as we attempt to disentangle these relationships.

Chapter 3: Literature Review

3.1: Introduction

The relationship between oil prices and economic downturns has been well established (e.g. see Hamilton, 1983, Rotemberg and Woodford, 1996, Hamilton 1996, Hamilton 2003, and Schubert and Turnovsky, 2011) since the oil price shock of the 1970s. Due to the attention that this topic attracted from researchers in recent decades, several theories have been proposed in the economics and finance literature that explain the relationship between oil prices and key macroeconomic variables such as GDP growth, stock market, and exchange rates. Several empirical studies have also been conducted to examine these relationships. The aim of this chapter is to review the existing literature, to discuss the various theories that underpin the relationship between oil prices, economic growth, exchange rates, and the stock market. The chapter will also discuss the empirical findings of previous research that examined the link between oil prices and these macroeconomic variables.

3.2: Review of Theoretical Literature

3.2.1 Oil prices and Economic Growth

There are different theories explaining the various channels by which oil prices affect output growth. One of the theories views the effects of oil price shocks as either demand driven or supply driven. According to the demand-side effects, an increase in oil prices would increase the general price level and, based on the Keynesian framework of rigid wages, lowers labour supply and reduces employment and output (see Pierce and Enzler 1974 and Solow 1980). From the supply-side perspective, the effects of oil price shocks often start from a production function that requires input factors including capital, labour, and oil (energy). In this regard, an exogenous increase in the price of oil reduces output directly by increasing the cost of production, thus lowering output (e.g. Rasche and Tatom, 1977 and Rotemberg and Woodford, 1996).

Another channel through which oil price shocks could affect economic activity is the income transfer and aggregate demand effect (see Fried and Schulze, 1975 and Dohner, 1981). This theory argues that an increase in oil prices transfers income from oil importing nations to oil exporting nations. Assuming that oil exporters do not spend their income on goods from oil importing nations, demand and output will fall in oil importing nations. Another explanation of how shocks to oil prices affect economic activity is the real balance effect suggested by Pierce and Enzler (1974). According to the real balance effect, an increase in the price of oil would lead to an increase in the demand for money. The failure of the monetary authorities to increase money supply to meet the growing demand for money raises interest rates, and retard economic growth.

Schubert and Turnovsky (2011) proposed a model to explain the oil price and output growth relationship from the perspective of a small developing economy. The model is based on a neoclassical growth model for a small country which imports oil, and only uses oil as an input in the production of goods and services. The model therefore, is somehow related to this study since our research is focused on Ghana which is a small developing economy that imports refined petroleum products.

Hence, we shall discuss the main ideas of the model here briefly (see Schubert and Turnovsky 2011 for a full version of the model).

In developing the model, Schubert and Turnovsky (2011) considered a small open economy which produces a tradable commodity. The model further made several key assumptions:

- The relative price of oil in the world market is exogenously determined and it remains constant over time.
- The economy is made up of a large number of agents who are identical, and each individual is endowed with a unit of time which is allocated to leisure and employment.
- Output is produced by each individual using capital K, labour L, and imported oil o. All three factors are 'cooperative' in production.
- The economy is able to borrow internationally because it has access to a world financial market.
- The economy faces restrictions in borrowing because its ability to borrow depends on the world capital market's assessment of the country's credit worthiness.

Given labour and capital, the demand for oil can be expressed as

$M_i = M_i(K_i, L_i, cop) M_{i,K} > 0, M_{iL} > 0, M_{iCOP} < 0$

(3.2.11)

where i represents each individual agent in the economy, and M_i, K_i, and L_i denote the quantities of imported oil, capital, and labour respectively used by each individual agent to produce a traded output, whilst cop is the relative price of oil

It can be noted from equation (3.2.11) that an increase in the relative price of oil reduces its demand. Also, because of the assumption that all the three factors are cooperative in production, oil usage increases with both capital and labour.

The economy reaches a steady-state when $\dot{K} = \dot{D} = \dot{v} = \dot{\lambda} = 0$, and is determined by the following set of equations:

$$\frac{\tilde{v}-1}{h} = t + \delta \qquad (3.2.12a)$$

$$\tilde{r} = r\left(\frac{\tilde{D}}{\tilde{v}\tilde{K}}\right) = \beta + t \qquad (3.2.12b)$$

$$\tilde{l} + \tilde{L} = 1 \qquad (3.2.12c)$$

$$\tilde{Y} = F(\tilde{K}, \tilde{L}, \tilde{M}) \qquad (3.2.12d)$$

$$\frac{\Phi\tilde{C}}{\tilde{l}} = F_L(\tilde{K}, \tilde{L}, \tilde{M}) \qquad (3.2.12e)$$

$$F_M(\tilde{K}, \tilde{L}, \tilde{M}) = cop \qquad (3.2.12f)$$

$$\frac{F_K(\tilde{K}, \tilde{L}, \tilde{M})}{\tilde{v}} + \frac{(\tilde{v}-1)^2}{2h\tilde{v}} - \delta = \beta + t \qquad (3.2.12g)$$

$$\beta\tilde{D} + \tilde{C} + cop\tilde{M} + \left(\frac{\tilde{v}^2-1}{2h}\right)\tilde{K} = F(\tilde{K}, \tilde{L}, \tilde{M}) \qquad (3.2.12h)$$

These equations determine the steady-state values of the eight variables, $\tilde{K}, \tilde{L}, \tilde{l}, \tilde{M}, \tilde{Y}, \tilde{D}, \tilde{v}$, and $\tilde{C}$. Due to the structure of the system (i.e. the recursive structure of the equations),the rate of growth of all aggregate variables, the market price of installed capacity in the long-run, $\tilde{v}$,the steady-state debt-equity ratio, $D/\tilde{v}\widetilde{K}$, and the long-run borrowing rate denoted as r, are all independent of the price of oil, cop.

Table 3.2.1 presents a summary of the long-run effects of an increase in the price of oil. Here, output is generated by the constant elasticity of substitution (CES) production function used to analyse the transitional dynamics:

$$Y = A[\alpha_1 L^{-\rho} + \alpha_2 M^{-\rho} + \alpha_3 K^{-\rho}]^{-1/\rho} \qquad (3.2.13)$$

$\alpha_1 + \alpha_2 + \alpha_3 = 1$, and $-1 \leq \rho < \infty$

The elasticity of substitution is denoted by $\sigma \equiv 1/(1+\rho)$, where ρ determines the degree of substitutability of the inputs, while α_2 parameterizes the degree of oil dependence.

Table 3.2. 1 Long-run effects of increase in oil price

$\frac{d\tilde{L}/\tilde{L}}{dcop/cop}$	$\left[\theta - (1+\theta)\tilde{I}\right]\frac{\tilde{S}_M}{\tilde{S}_L}(1-\mho)$
$\frac{d\tilde{Y}/\tilde{Y}}{dcop/cop} = \frac{d\widetilde{K}/\widetilde{K}}{dcop/cop} = \frac{d\tilde{B}/\tilde{B}}{dcop/cop}$	$\left[(1+\theta)\left(1-\tilde{I}\right)(1-\mho) - 1\right]\frac{\tilde{S}_M}{\tilde{S}_L} < 0$
$\frac{d\widetilde{M}/\widetilde{M}}{dcop/cop}$	$\frac{d\widetilde{K}/\widetilde{K}}{dcop/cop} - \mho = \left[(1+\theta)\left(1-\tilde{I}\right)(1-\mho) - 1\right]\frac{\tilde{S}_M}{\tilde{S}_L} - \mho < 0$
$\frac{d\tilde{C}/\tilde{C}}{dcop/cop}$	$\frac{d\widetilde{K}/\widetilde{K}}{dcop/cop} - \frac{\theta\left(1-\tilde{I}\right)(1-\mho)}{\tilde{I}}\frac{\tilde{S}_M}{S_L} = -\left[1 + \frac{\left(1-\tilde{I}\right)}{\tilde{I}}\left[\theta - (1+\theta)\tilde{I}\right](1-\mho)\right]\frac{\tilde{S}_M}{\tilde{S}_L} < 0$

(i) The condition $\theta < (1+)\tilde{l}$ is equivalent to $\tilde{q}\widetilde{K} > \tilde{B}$, i.e. the country's net wealth is positive.

(ii) $\tilde{S}_M$, $\tilde{S}_L$ denotes oil and labour's contributions respectively in GDP.

Equation (3.2.12g) shows that the long run equilibrium marginal product of capital is independent of the price of oil, whilst equation (3.2.12f) states that the equilibrium marginal product of oil increases with oil price. At the same time, the depreciation of capital stock means the marginal productivity of capital diminishes over time. This implies that the ratio of oil to labour, $\widetilde{M}/\tilde{L}$, declines. As it is established that capital and oil are cooperative in production, the $\widetilde{K}/\tilde{L}$ ratio also declines. Given that the long-run ratio of bonds, B to capital is independent of the price of oil, an increase in oil price,cop, reduces bond holdings, the stock of capital, and wealth as a whole by the same proportionate amount. Also, Row 2 of table 3.2.1 suggests that an increase in the price of oil leads to a decline in long-run output by a proportionate amount equal to the percentage increase in the oil price.

Overall, the expressions in table 3.2.1 suggest that for a small developing country that imports oil, the impact of an increase in the price of oil on the economy in the long-run is mainly determined by the conditions of its internal production environment. The country's access to external financial markets has little effect on how the economy responds to rising oil prices.

Besides the theories explaining the relationship between oil prices and output, there are also compelling theoretical arguments in support of the relationships between oil prices and other macro factors such as exchange rates and stock markets. The next section will discuss these theoretical linkages.

3.2.2: Oil Prices and Exchange Rates

The thought that there exist a relationship between oil prices and exchange rates has been in existence for some time now. Some of the early papers include the works of Krugman (1980) and Golub (1983). These papers, which presented seemingly related models, focused on the relationship between the international price of oil and the US dollar. In particular, Krugman (1980) noted that oil price movements affect exchange rates through changes in the current account. The logic here is that if rising oil prices lead to a worsening current account of an oil importing nation such as the US, then the US dollar exchange rate will fall (see Krugman 1980).

Similar to Krugman's (1980) theory, Chen and Chen (2007) also argued that rising oil price leads to a depreciation of the currencies of oil importing nations, and the mechanism by which oil prices affect exchange rates is through the terms of trade. International trade theory indicates that when the price of a domestic import rises, if the demand for that import is very inelastic (as is the case of oil), the demand for domestic currency will reduce, hence, driving down the value of the domestic currency. This is referred to as the terms of trade effect. Import costs have increased with no significant impact on export earnings. These unfavourable terms of trade impact on the oil importer puts downward pressure on that country's currency. In order for the home country to improve its competitiveness when oil price shock worsens terms of trade, the country would have to raise the nominal exchange rate. However, this would further lead to real exchange rate depreciation.

Dawson (2007) reasoned that in the case of energy-dependent developing open economies with floating exchange rates, international price of oil is of great relevance to the domestic economy. According to Dawson, since oil contracts, both in spot values and futures contracts are denominated in US dollars, domestic importers must sell their local currency in the foreign exchange market in order to obtain liquidity in US dollars. It follows therefore, that an increase in the world price of oil would put depreciating pressure on the domestic currency, whereas a decrease in the price of oil would allow for an appreciation of the domestic currency. This analysis is relevant to the case of Ghana since, as an oil dependent nation, Ghana has maintained a floating exchange rate since the mid-1980s when it adopted the IMF and World Bank's Structural Adjustment Program.

3.2.3: Oil Prices and Stock Markets

With regards to the link between oil prices and stock markets, there are also compelling theories that underpin this relationship. Some of the studies that examined this relationship have developed a theory based on the dividend valuation model (e.g. Jones and Kaul, 1996). Jones and Kaul (1996) proposed a model to test the rational reaction of stock prices to oil price changes using the dividend valuation model. In this model, they expressed the log of stock return in time t,RS_t, as:

$$RS_t \cong E_{t-1} + (E_t - E_{t-1}) \sum_{j=0}^{\infty} \rho^j \Delta C_{t+j} - (E_t - E_{t-1}) \sum_{j=1}^{\infty} \rho^j RS_{t+j}$$

(3.2.31)

where E_t represents the expectation at period t, C_t is the log expression of the real cash flow in time t, and ρ is a parameter with a value smaller than one. Equation (3.2.31) says that due to the time-variation of expected returns and unexpected returns, stock returns fluctuate over time. The unexpected return in time t changes either because of variations in present and expected future cash flows, or because of variations in expected future returns. The expected future returns and the expected future cash flows are given by the second term and last term respectively on the right hand side of (3.2.31). Equation (3.2.31) assumes that the stock market is rational, and given oil price shocks, it is possible to determine the stock market's reaction to new information. In view of this, Jones and Kaul specified a regression model to determine whether the effects of oil price shocks on the variations in expected returns can fully account for the response of stock prices to oil price shocks. The model is expressed as follows;

$$RS_t \cong E_{t-1} + (E_t - E_{t-1}) \sum_{j=0}^{\infty} \rho^j \Delta C_{t+j} - (E_t - E_{t-1}) \sum_{j=1}^{\infty} \rho^j RS_{t+j} + \sum_{s=0}^{k} \Phi_s COP_{t-s} + \eta_t \quad (3.2.32)$$

where COP_t is the percentage change in crude oil price in time t and Φ_s are the coeffients of oil price variables. To the extent that oil price shocks affect current and future cash flows, oil prices are relevant to stock prices. This view is justified by the assumption that the stock market is rational in equation (3.2.31). If indeed, stock prices respond rationally to oil price shocks, then the oil price variables' coefficients, Φ_s, should not be jointly significantly different from zero. If however, the stock market overreacts to oil shocks, then the joint insignificance of Φ_s should be rejected. If stock returns were constant, the first and third terms in (3.2.31) and (3.2.32) would disappear and any correlation between oil price shocks and stock returns would be a clear evidence of stock market inefficiency. Jones and Kaul (1996) argued that, owing to the increasing evidence that expected returns vary over time, it is natural to design a model based on (3.2.32) that allows expected returns to be influenced by oil shocks.

There are other transmission mechanisms by which oil prices can affect stock prices. According to financial economic science, the transmission mechanisms can be categorised into two main channels based on microeconomic and macroeconomic perspectives (e.g. see Basher and Sadorsky, 2006 and Muhtaseb and Al-Assaf, 2017). From the microeconomic perspective, oil prices can affect stock prices directly by impacting on future cash flows (Basher and Sadorsky, 2006). In the absence of complete substitution effects between the factors of production, increases in oil prices will increase the cost of production and the cost of doing business, hence, reduce profits. Rising oil prices can usually be passed on to consumers in the form of higher prices for final goods and services. However, this may result in a fall in demand for final goods and services, and once again reduce profit. Consequently, as profits decline, the share prices of the companies are expected to fall. From the macroeconomic perspective, changes in oil prices may affect stock prices through their effects on expected inflation rate and the expected real interest rate. For instance, rising oil prices puts upward pressure on expected domestic inflation which could cause the real interest rate to rise. This happens because central banks respond to inflationary pressures by raising interest rates (Basher and Sadorsky, 2006). As a result, the required rate of return or the discount rate, which is used in the stock pricing formula, will rise, causing a decrease in stock prices.

However, Basher and Sadorsky (2006) and Muhtaseb and Al-Assaf (2017) both noted that the overall response of aggregate stock price returns to oil price changes depends on whether a country is an oil importing or oil exporting country. For a net oil-importer, an increase in oil prices has a negative effect on stock prices (Huang et al, 1996). For a net oil-exporter however, a positive impact is expected through income and wealth effects. Higher oil prices leads to an immediate transfer of wealth from oil importing countries to oil exporting countries. Oil price rises also increase government revenues in oil exporting countries. This may increase government expenditure on infrastructure and government spending on domestic goods and services in these countries, and consequently lead to higher levels of economic activity and improve stock market returns (Bjornland, 2009).

3.3: Review of Empirical Literature

The aim of this section is to provide a broader picture of the empirical literature on the relationship between oil prices and macroeconomic fundamentals. Given the compelling theories explaining these relationships, testing the relationships is naturally based on empirical investigation. The evidence that there exist a relationship between oil prices and the macro economy began with the empirical work of Hamilton (1983), in which he investigated the relationship between the US dollar and international oil price movements. In his paper, Hamilton (1983) noted that seven out of eight recessions in the United States since World War 2 were preceded by dramatic oil price shocks. Since Hamilton (1983), the oil price literature has evolved through time due to the increased interest in this topic. In general, the literature can broadly be categorised into three main streams.

The first stream relates to the causes of oil price changes. That is, whether oil prices changes are due to demand-driven factors or supply driven factors. This line of research was pioneered by Hamilton (2009a, 2009b) and Kilian (2009). In particular, Hamilton (2009) classifies oil price shocks into demand-side and supply shocks, depending on whether the oil price change is related to changes in global oil production or changes in global oil demand respectively. According to this classification, the demand-side shocks are defined as oil price changes that are related to the performance of the economy or business cycles. In this respect, during economic booms, the demand for oil will increase leading to an increase in its price and vice versa. On the other hand, the supply-side shocks are defined as oil price changes that are related to disruptions in global oil supply mainly due to geopolitical events in the Middle East.

In Kilian's (2009) classification, the demand-side shocks are divided into aggregate demand shocks and precautionary demand shocks (or oil specific shocks). The former shocks are attributed to changes in global aggregate demand (similar to Hamilton 2009) whilst the latter shocks are related to the uncertainty about the future availability of oil. Kilian (2009) argues that wars and geopolitical events in the Middle East create expectations that there will be shortage of oil supply in the future as a result of such events, and this increases the precautionary demand for oil. According to Kilian (2009), the precautionary demand shocks are most related to geopolitical events than the actual disruption of oil supply (as suggested by Hamilton 2009 for the supply-side shocks). In principle, both Hamilton (2009a, 2009b) and Kilian (2009) argue that different oil price shocks will trigger different responses from the economy. The finding of Hamilton (2009a, 2009b) and Kilian 2009 are discussed later in this section.

The second stream of literature is related to the volatility spillover effects between oil prices and financial variables such as exchange rates and stock markets. For example, Gosh (2011), Zhang et al (2008), Ding and Vo (2012), and Narayan et al (2008) examined the volatility spillover effects between oil prices and exchange rates whilst Masih et al (2011), Arouri et al (2011), Arouri et al (2012), Chang et al (2013), and Malik and Hammoudeh (2007) examine the volatility spillover effects between oil prices and stock markets. Specifically, Gosh (2011) found evidence to suggest that oil price movements have significant effects on the volatility of the Indian currency. Also, Masih et al (2011) showed that oil price volatility has a significant spillover effect on the volatility of stock market returns in South Korea.

In recent times, some researchers argued that the relationship between oil prices and financial variables should be examined within a time-varying framework rather than the static frameworks adopted by the previous two streams of research in the literature. This led to the evolution of the third stream of research, and the studies in this category focused on the time-varying relationship between oil prices and financial variables. For the time varying relationship between oil price and exchange rates, examples of such studies include; Ding and Vo (2012), Beckmann and Czudaj (2013), Tiwari et al (2013), Uddin et al (2013), Tiwari et al (2013), and Reboredo and Rivera-Castro (2013). With regards to the time-varying relationship between oil price and stock markets, examples of these studies include; Antonakakis et al (2017), Boldanov et al 2015, Sadorsky (2014), Broadstock and Filis (2014), Antonakakis and Filis (2013), Ciner et al (2013), Chang et al (2013), and Broadstock et al (2012).

These papers argue that the nature of the relationship between oil prices and the financial variables change at different points in time. For example, Ding and Vo (2012) demonstrated that during normal times, the markets are calm and efficient in processing information. Hence, both the oil market and the US dollar exchange rate react to shocks almost instantaneously and therefore, are independent on each other. However, during turbulent times, there is a bidirectional volatility interaction between the two. Also, Reboredo and Rivera-Castro (2013) showed that oil prices have no effect on exchange rates and vice versa in the pre-crisis period. However, their study found evidence of contagion and negative interdependence between oil prices and exchange rates from the onset of the global financial crisis using the currencies of a range of developed and developing countries. Also, Ciner et al (2003) found that correlations between oil prices and the US stock market are stronger only during crisis periods. In particular, their evidence indicate that the correlation between oil prices and the US stock market is almost zero except during the first Gulf War and the 2008-2009 credit crunch when there was strong correlation between the two. They also indicated that correlation between oil prices and the UK pound sterling was weak until the 2008 financial crisis.

In general, different variables and approaches have been employed by various studies to examine the oil price effects. It is also worth noting that the hypotheses and methods used in the studies on this topic have been different. Whilst studies such as Hamilton (1996), Hooker (1997), Barsky and Kilian (2004), and Leduc and Sill (2004) investigated the relationship between oil prices and GDP, other studies focused on the relationship between the price of oil and other economic indicators such as inflation, unemployment, household income, and the external sector (e.g. trade balance, terms of trade, and current account). Examples of these studies include; Svensson (1984), Barsky and Kilian (2002), Kpodar and Djiofack (2009) and Dogrul and Soytas (2010). Yet, as mentioned above, some studies in the literature examined the link between oil prices and financial variables such as stock market prices and exchange rates. For this study, it is not feasible to examine all the different dimensions of the literature. However, this study is most closely related to the studies that examined relation between oil prices and GDP, and those that examine the relation between oil prices and financial variables.

Thus, this chapter will analyse some published studies in these dimensions of the literature for both developed and developing countries. This will consist of papers that empirically examined the relation between oil prices and economic growth and those that examined the relation between oil prices and financial variables; mainly exchange rates and stock markets.

3.3.1: Oil Prices and the Macro economy

Studies Related to Developed Countries

Hamilton (1996) employed the Granger causality test and the impulse response functions to investigate the relationship between oil prices and the economy using quarterly data on international crude oil prices and US macroeconomic variables including; the GDP growth rate, Treasury bills rate, inflation rate, and import price changes from 1948 to 1994. The study was divided into three sample periods; 1948-1973 (early subsample), 1973-1994 (late subsample), and 1948-1994 (full sample). A test for structural break in 1973 was conducted by a regression for the full sample period (1948:I-1994:*II*) of quarterly GDP growth, the net oil price increases, and the other macro variables using the Chow test to determine whether there was a change in parameters after the first oil shock. The Chow produced a statistic of 1.97, leading to a rejection of the null hypothesis of no relationship between oil prices and GDP beginning in 1973:IV. The regression results also revealed a highly significant negative relation from net oil price increases to GDP for the earlier subsample and the full sample periods. In the late sample however, the parameters relating GDP growth to oil prices are not statistically significant although the associated coefficients are negative. The impulse response functions also identify the primary effect of net oil price increases on GDP growth as negative for both the early and late subsample periods, even though the relation for the late subsample period is statistically insignificant. Hamilton (1996) noted that the structural change in the oil price and GDP growth relation appear to be caused by factors unrelated to oil prices, such as the slowdown in growth since 1973. Thus, the paper reaffirms Hamilton's conviction that there is a negative correlation between oil price shocks and economic recessions.

In a study to investigate the role of monetary policy in post war US business cycles, Bernanke, Gertler, and Watson (1997) conducted an experiment using monthly data of US macroeconomic indicators and world oil prices from January 1965 to December 1995. The study estimated a VAR system of equations which was then used to carry out simulations for three oil shocks, i.e. the oil price shocks of 1972-76, 1979-83, and 1988-92.

The simulation results for the 1972-76 oil shock suggest that the 1974-75 output declines were not a result of shocks to oil prices. Instead, the pattern of the output declines revealed that the main cause was shocks to the price of (non-oil) commodities which stimulated a sharp monetary policy response. The results for 1979-83 also reveal a similar pattern. The evidence suggests that if monetary policy response to oil price shocks is removed from the model, the economic recession produced by the 1979-83 oil price shock is only modest, not a serious decline in economic growth. Similarly, the result from the 1988-92 experiment shows that when the policy response to oil price shocks is being shut off in the model, output grows higher than otherwise would be. Thus, the study concluded that the economic cost of shocks to oil prices do not come from oil price changes themselves, but the resulting tightening of monetary policy. According to Bernanke Gertler and Watson (1997), this arises due to the central bank’s concern about rising inflation caused by oil price increases. The central bank therefore, targets inflation stabilization by tightening monetary policy.

In contributing to the literature, Leduc and Sill (2004) used VAR estimates and a general equilibrium model to examine the role of monetary policy to the recessionary consequences of oil price shocks. The study used quarterly macroeconomic data of the US, and spot prices of crude oil from 1972Q1 to 2000Q4, along with parameter values based on Orphanide's 1979:3-1995:4 episode parameter estimates. The study measured the role of the US Federal Reserve's interest rate policy to output response in the pre-1979 and post-1979 periods.

The result of Leduc and Sill (2004) show that the central bank is not able to use its interest rate policy to completely offset the negative consequences of oil price shocks on productivity. In contrast to the findings of Bernanke, Gertler, and Watson (1997), Leduc and Sill (2004) found that the real effects of oil price shocks on output decline greatly exceed the monetary policy effects. The recessionary consequences of oil price shocks are less severe when the central bank targets inflation stabilization following such shocks. However, the study also noted that since 1979, the Federal Reserve's monetary policy accounts for about 40 percent to the fall in output following a rise in oil prices. Thus, although the role of the central bank's monetary policy in augmenting the negative impact of oil price shocks on output is not as large as the real oil price effect, the impact of such policies is non-negligible.

Hooker (1997) and Segal (2011) also demonstrated that oil price changes are no longer relevant to the economy as they were in the period before the 1990s. Segal (2011) noted that oil price rises stopped having an impact on the macro economy sometime in the 1980s, because oil price shocks stopped passing through to core inflation from that time. Hooker (1997) also argued that the relationship between oil prices and real GDP broke down in the 1970s, and this break down according to Hooker, is due to oil price misspecification rather a weakened relationship (see

Hooker 1997). Zhang (2008) also used Granger causality test to examine the relation between oil prices and macroeconomic performance in Japan, and their results appear to be consistent with the findings of Hamilton (1983, 1996, and 2003). The findings of Zhang (2008) suggest that oil price increases have a significant negative effect on economic growth.

As noted earlier, Kilian (2009) and Hamilton (2009a, 2009b) suggest that the effect of oil price shocks on the economy depends on the cause of the oil price shock. In particular, the findings of Kilian (2009) show that oil price shocks caused by oil supply disruptions cause a temporary decline in real US GDP, whilst a positive aggregate oil demand shock will initially trigger a positive effect on the economy. They argue that the direct positive effect of aggregate demand shocks dominates the indirect negative effect of higher oil prices in the short term. However, that stimulus wears out over time and the adverse indirect effect dominates, making the macroeconomic effect of the aggregate oil demand shock negative with a delay. On the other hand, positive precautionary demand shocks have recessionary effects on the economy. Similar findings were also reported by Hamilton (2009a, 2009b) for the US economy. Appendix A1 presents the summary of the related studies that examined the relationship between oil prices and the economies of developed countries.

Studies Related to Developing Countries

Fofana et al (2009) examined various channels by which sustained oil price increase above $55 affect South Africa and its people using an economy and integrated approach. The approach identifies the impact of oil prices on various oil intensive industries, households, and transportation using input-output dataset and household survey dataset. The results indicate that oil price increases have a negative impact on the economy, with GDP growth declining and current account worsening. The paper categorised the impact of higher oil prices on households using three expenditure groups, i.e. lowest, median, and highest expenditure groups. It was revealed that the distributional impacts of rising transport fuel cost as a result of high oil prices is higher for the median expenditure group both in urban and rural areas. The paper also demonstrated that poor households in the rural areas witness increase in their living costs than their counterparts in the highest expenditure group when there are rises in transport fuel costs.

The evidence that higher oil prices have a growth-retarding effect is also reported by Rafiq et al (2009), Ozlale and Pekkurnaz (2010), Ahmed and Wadud (2011), Park et al (2011), and Guivarch et al (2009) for other developing countries. These papers found a negative and statistically significant effect of oil price shocks on output and the trade balance in Malaysia, South Africa, India, Thailand, South Korea, and Turkey.

This topic has also been researched on Ghana by Jumah and Pastuszyn (2007), Tweneboah and Adam (2008) and Cantah and Asmah (2015). Jumah and Pastuszyn (2007) used annual data from 1965 to 2004 to investigate the relationship between world oil prices and aggregate demand in Ghana through the interest rate channel. Using a cointegration and impulse response analysis, Jumah and Pastuszyn (2007) observed that oil prices negatively impacts output through its effect on the price level. They also noted that the central bank initially eases monetary policy in response to surges in oil prices in order to lessen any effect on output, but at the expense of inflation. Also, Tweneboah and Adam (2008) used quarterly data to investigate the short run and long run linkages between crude oil price and economic activity in Ghana between 1970:1 and 2006:4. Using the VECM model, their study reveals that oil price increases are followed by rises in the price level and a decline in output. Similar to Jumah and Pastuszyn (2007), Tweneboah and Adam (2008) argue that monetary policy has been used to lessen the negative consequences of oil price shocks on output growth, but at the cost of rising inflation. Most recently, Cantah and Asmah (2015) used annual data from 1967 to 2012 to examine the relationship between oil prices and economic growth in Ghana using autoregressive distributive lag (ARDL) approach to cointegration. Their study found that oil price increases had a negative effect on economic growth both in the short run and long run and this is reinforced by the government's fuel subsidies.

Similar studies have also been conducted for other African countries. As a case study, Kpodar and Djiofack (2009) investigated the distributional effects of changes in the prices of petroleum products on household income in Mali. The study used data from the household survey conducted in 2000-01, as well as data from eight sectors of the Malian economy in 2001. The study sampled 4,966 households, and 63 percent of them in rural areas. The household data included the characteristics of the household (average expenditure per capita, household size), and household expenditures; including the percentage of the expenditure spent on oil products. Also, parameter values were estimated and used to compute a general equilibrium model. The study then simulated the impact of a 34 percent rise in oil prices on household incomes in the general equilibrium model. Their findings show that richer households are affected by rising diesel prices whilst poorer households are affected by rising kerosene and gasoline prices. Overall, the joint effect of a 34 percent increase in the price of all petroleum products results in an average 3.16 percent fall in the incomes of households. Appendix A2 summarizes some of the main findings of the studies investigating the relationship between oil prices and the economies of developing countries.

From the forgoing discussions, it can be noticed that in general, international oil price shocks generally have a negative impact on economic growth in developing countries. However, for developed countries, the findings are conflicting. Whilst Hamilton (1996, 2003, 2009a, 2009b), Zhang (2008), and Kilian (2009) found strong evidence that oil price movements have a significant effect on economic performance, Bernanke, Gertler and Watson (1997) Leduc and Sill (2004), and Segal (2011) argued that a significant part of the oil price shock on the economy do not come from the oil price shock itself, but the tightening of monetary policy by the central bank as a result of the oil price shock. Yet, Hooker (1996, 1997) and Segal (2011) pointed out that the relationship between oil prices and economic growth broke down some time in the 1980s. These conflicting findings could be attributed to different sample periods used by the various studies. For example, the sample periods of Hamilton (1996) and Hamilton (2003) ended in 1973 and 1980 respectively whilst the data of Bernanke, Gertler and Watson (1997) and Leduc and Sill (2004) ended in 1995. Segal (2011) used a more recent data which ended in 2010.

Beside, Bernanke, Gertler and Watson (1997) used monthly data, and Hamilton (1996) and Hamilton (2003) used quarterly data whilst Segal (2011) used annual data. Therefore, the differences in data frequencies can also be a contributing factor to the different findings. Also, Hamilton (2009a, 2009b) and Kilian (2009) used a different approach by examining the underlying cause of the oil shock rather than general oil price movements as used by Bernanke, Gertler and Watson (1997), Leduc and Sill (2004), Segal (2011) and many others. All of these may have contributed to the conflicting results that have been reported in the literature.

3.3.2: Oil Prices and Exchange Rates

Studies Related to Developed Economies

Amano and van Norden (1998) used monthly observations of the US dollar real exchange rate and US real price of oil from 1972 to 1993 to study the relationship between the two variables. They tested the variables for cointegration, and found evidence of a long run relationship. The subsequent test for causality suggested that whilst oil prices Granger-causes the US dollar real exchange rate, the US dollar real exchange rate does not appear to Granger-cause the price of oil. The VECM regression also presented an outcome to suggest that a 1% increase in oil prices leads to 0.5% appreciation of the US dollar. This result was confirmed by Benassy-Quere et al (2007) as their paper also reported the same findings. Beckmann and Czudaj (2013) also examined the oil price and the US dollar relationship using the Markov-switching and the vector error correction models. Their results suggest that oil prices and the US dollar have a bidirectional relationship. Specifically, a real depreciation of the US dollar triggers an increase in the price of oil, whereas increases in oil prices lead to a depreciation of the US dollar.

Other studies examined the relationship between oil prices and the currencies of a group of developed countries. For example, Chaudhuri and Daniel (1998) used monthly data set from 16 OECD countries to examine the influence of oil prices on the volatility of the currencies in the sample over the post-Britton Woods period. They concluded that oil prices and exchange rates are strongly cointegrated, and that the non-stationarity in the real price of oil was the cause of the non-stationarity of the US dollar exchange rate over the period. Also, Chen and Chen (2007) supported the argument that oil prices are negatively related to the exchange rate. Using monthly panel data of G7 countries from 1972 to 2005, they tested and found evidence of cointegration between oil prices and the exchange rates of all of the G7 countries. The estimated cointegration coefficients from the OLS regressions revealed that a rise in oil prices depreciates the real exchange rate in the long run. This result is consistent with the findings of Lizardo and Mollick (2010) and Beckmann and Czudaj (2013).

Another group of studies distinguished between oil exporting and oil importing countries in examining the relation between oil prices and exchange rates. This is done to address the question of whether crude oil prices affect the currencies of oil exporting countries and oil importing countries differently. Some of these studies include; Aziz and Baker (2011), Reboredo (2012), Jiang and Gu (2016), and Yang et al (2017). However, some of the findings of these papers appear to be conflicting. Using pooled mean group estimator, Aziz and Baker (2011) noted that increases in real oil prices lead to a real depreciation of the exchange rates of oil importing countries, whilst oil prices and the exchange rates of oil exporting countries have no relationship. Contrary to these findings, Yang et al (2017) found that the degree of interdependence between oil prices and exchange rates are greater for oil exporting countries than for oil importing countries when they examined this relationship using the wavelet coherence framework. The results of Yang et al (2017) are consistent with the findings of Reboredo (2012) who suggested that the co-movement between oil prices and exchange rates is more intense for oil exporting countries and less intense for oil importing countries.

On the other hand, the findings of Jiang and Gu (2016) suggest that the oil price-exchange rate relationship is not dependent on the status of a country as either an oil exporter or oil importer. Their study used the multifractal detrended-cross correlation analysis (MF-DCCA) and found some evidence that the cross-correlations between oil prices and exchange rates are significantly asymmetric; cross-correlation persistence is greater when there is a negative shock to the oil market than when there is a positive shock. This result however, does not differ for both oil exporting countries and oil importing countries.

Yet, other papers used a time-varying approach to examine the oil price-exchange rate relationship (e.g. Ciner et al, 2013, Reboredo, 2012, Reboredo and Rivera-Castro, 2013, and Turhan et al, 2014). Using the wavelet analysis, Reboredo and Rivera-Castro (2013) examined the time-varying correlations between crude oil prices and the US dollar between 2000 and 2011 using daily data. Their study reveals that oil prices had no effect on the dollar and vice versa before the 2008 financial crisis. However, the oil price effect on the exchange rate became apparent from the onset of the 2008 crisis, with evidence of negative interdependence between the two. This evidence was also demonstrated by Reboredo (2012). Using the DCC model, Turhan et al (2014) showed that correlations between oil prices and the exchange rates of developed countries in the G20 group were stronger during the 2003 Iraq invasion. During the 2008 financial crisis, correlations between oil prices and exchange rates also became stronger for all currencies in the G20 countries. Appendix A3 provides a summary of the main findings of the studies that examined the link between oil prices and exchange rates of developed countries.

Studies related to developing countries

Huang and Guo (2007) investigated the role of oil price shocks on China's exchange rate using monthly data of the RMB exchange rate, world oil prices, the consumer price index, and the real GDP of China. The exchange rate used in the study is the pegged RMB rate against a basket of the currencies of China's main trading partners including the US, Japan, South Korea, the UK, Singapore, Malaysia, Russia, Australia, Canada and the European Monetary Union (EMU) currency (the euro). Johansen cointegration test revealed no evidence of a cointegration relationship between the variables. However, using a four-dimensional structural VAR model, their result suggests that a real oil price hike leads to a slight real RMB appreciation against the basket of currencies included in the sample in the long run. They attributed this result to the rigorous energy regulations by the Chinese government and China's lesser depends on imported oil than its trading partners included in the RMB pegged basket of currencies.

Ghosh (2010) examined the asymmetric effects of oil price shocks on exchange rate in India using daily data from July 2 2007 to November 28 2008. Employing the GARCH and EGARCH models, Ghosh (2010) reveals that from the mean equation of the EGARCH (1, 1) model, an increase in the oil price return leads to a depreciation of the Indian currency against the US dollar. From the variance equation, the asymmetric term is statistically insignificant, suggesting that shocks to exchange rates have symmetric effects. That is, positive and negative shocks to the price of oil have similar effects on exchange rate volatility.

Dogan et al (2012) used monthly data from 2001 to 2011 to estimate a long run relationship between the price of oil and the Turkish exchange rate. Using the Kejriwal Perron test approach, they identified two structural breaks in April 2004 and December 2007. Their findings revealed that in the two structural breaks that occurred during the sample period, the 1 percent rise in the real price of oil led to a real exchange rate decline of -0.73 percent for the first structural breaks period, and, the 1 percent increase in real price of oil led to a -0.78 percent real exchange rate decline in the second period.

Selmi et al (2012) used quarterly data from 1972 to 2010 to examine the relationship between oil prices and exchange rates in Morocco and Tunisia. The study used GARCH specifications taking into account several effects including; asymmetrical, symmetrical, linear, non-linear, power, threshold, etc. In all the effects estimated, the paper found that the real price of oil negatively and significantly affects real exchange rates in both countries. The asymmetrical nature for the relationship for Morocco in particular is significant. The parameter estimate for asymmetry is positive for Morocco indicating that good news has more impact on conditional volatility than bad news. This suggests that the Moroccan currency responds more to oil price increases than to a fall in oil prices. Appendix A4 summarizes the major results of the studies that examined the relationship between oil prices and the exchange rates of developing countries.

From the discussions above, it can be stated that that opinions are divided about the relation between oil prices and exchange rates for both developed and developing countries. Whilst papers such as Amanao and Norden (1996), Benassy-Quere et al (2007) and Huang and Guo (2007) showed that oil price increases lead to currency appreciation for various countries, other papers including Chen and Chen (2007), Lizardo and Mollick (2010), Ghosh (2010), Dogan et al (2012), Selmi et al (2012), and Beckmann and Czudaj (2013) demonstrated that positive shocks to oil prices lead to depreciation of currencies for both developed and developing countries. The differences in results between these papers can be attributed to various reasons. For instance, Chen and Chen (2007) and Lizardo and Mollick (2010) used panel data from a group of countries in their papers whilst Amano and Norden (1996), Benassy-Quere et al (2007), and Huang and Guo (2007) studied individual countries. Also, Ghosh (2010) and Selmi et al (2012) used GARCH specifications, whereas Beckmann and Czudaj (2013) used Markov-switching model. On the other hand, Amano and Norden (1996), Benassy-Quere et al (2007), and Huang and Guo (2007) used cointegration, VAR, and VECM.

It is also worthwhile noting that studies such as Ghosh (2010) and Selmi et al (2012) examined the relation between oil prices and the exchange rates of developing countries vis-à-vis the US dollar. Hence, the results that oil price increases have a depreciating effect on the currencies of India, Morocco, and Tunisia which was found in those studies can also imply an appreciation of the US dollar. Their results therefore, should be in line with Amano and Norden (1996) and Benassy-Quere et al (2007).

There are also notable differences in the results of the papers that examined the relationship between oil prices and the exchange rates of oil exporting countries and oil importing countries. Yang et al (2017) and Reboredo (2012) both noted that oil price movements exert great effect on the currencies of oil exporting countries whilst their effects on the currencies of oil importing countries are insignificant. However, the results of Aziz and Baker (2011) are contrary. Their study found oil price increases to be associated with depreciation of the currencies of oil importing countries whilst such shocks have no effect on the currencies of oil exporting countries. Meanwhile, Jiang and Gu (2016) demonstrated that the oil price-exchange rate relationship does not really depend on whether a country is an oil exporter or oil importer. Note however, that the methods of estimations employed by these studies are significantly different and this could possibly account for the conflicting results. In particular, Aziz and Baker (2011) used the pooled mean group method whilst Yang et al (2017) and Reboredo (2012) used the wavelet coherence analysis, correlations, and copula models. Jiang and Gu (2016) meanwhile used the multifractal detrended cross-correlation analysis. The sample periods also vary across some of the studies (see appendix A3).

3.3.3: Oil Price and Stock Markets

Studies related to developed countries

As mentioned previously, the seminal work of Jones and Kaul (1996) laid the foundation for the research on the relationship between oil prices and stock markets. In their study, Jones and Kaul (1996) used quarterly data to test the rational reaction of stock prices to oil price shocks using the dividend valuation model in four developed countries namely; The United States, Canada, The United Kingdom, and Japan over the post-war period of 1970 to 1991. For all four countries, they showed that stock prices react to oil price shocks. In order to measure how these markets react, they introduced real cash flows and expected returns in their model. After the inclusion of these variables, the effects of oil price shocks for the US and Canada were eliminated, which implies that in both the US and Canada, the effects of oil price shocks on stock prices can be sufficiently accounted for by current and future cash flows only. However, the inclusion of cash flow variables have completely no effect on the significance of oil price shocks on stock prices in the UK and Japan. They concluded that the US and Canadian stock markets rationally react to oil price shocks, whereas the UK and Japanese stocks overreact to oil price shocks within the framework of the rational assert pricing model.

Several other papers have examined the relationship between oil prices and stock market prices since the pioneering work of Jones and Kaul (1996). However, the question of whether oil prices affect stock market prices is inconclusive. Evangelia (2001) used monthly data from 1989:1 to 1999:6 to examine the dynamic relationship among oil prices, stock market, economic activity, and employment in Greece. The study found no evidence of cointegration between oil prices and all three variables, and as a result, the variables were modelled within a short-run VAR context. The VAR results show that oil price shocks have a significantly negative impact on stock market returns. Specifically, the variance decompositions revealed that in the first month, about 1.9% of real stock return variability is attributed to oil price changes. In the long run, approximately 12.5% are attributable to oil price changes. Similar results are also reported by Filis (2010) for Greece. In support of this view, Driesprong et al (2008), Al-rjoub and Am (2005) and Lee and Zeng (2011) demonstrated that oil price movements have a significantly negative effect on stock market prices in several developed countries.

In contrast to these findings, Apergies and Miller (2009) argue that the linkage between oil markets and stock markets is very weak. They used monthly data of world oil prices and the stock market prices of eight developed countries namely;

Australia, Canada, France, Germany, Italy, Japan, United Kingdom, and the United States, to investigate whether structural oil market shocks affect stock prices in the countries covered in their study. Cointegration test revealed that oil prices and stock market returns do not have a long run relationship for each country. In the subsequent VAR model, they find that the significant effects that exist prove very small, which suggest that international stock market returns do not show any significant response to world oil price shocks.

Also, it is often argued that oil price increases turn to improve the macroeconomic conditions of net-oil exporting countries leading to a rise in their stock market prices, whilst the reverse holds for net oil-importing countries. Hence, some papers in the literature distinguished between the oil price effects on the stock markets of net oil-exporting countries and net oil-importing countries. Examples of such studies include; Filis et al (2011), Talukdar and Sunyaeva (2012), Wang et al (2013), and Boldanov et al (2015). Some of the findings of these papers appear to be consistent whilst others are conflicting. For example, the evidence of Filis et al (2011) suggest that correlations between oil prices and stock market prices do not differ for oil exporting countries and oil importing countries, whereas Talukdar and Sunyaeva (2012) showed that oil price shocks have a negative effect on the real stock market returns of net oil-importing countries compared to the positive effects for net oil-exporting countries. The findings of Boldanov et al (2015) also suggest that correlations between oil prices and stock markets are different for oil exporting countries and oil importing countries. In most part, they found correlations to be positive for oil importing counties, and negative for oil exporting countries during crises periods such as wars in the Middle East. Yet, Wang et al (2013) noted that oil price shocks have a strong explanatory power on the variability of stock returns in oil exporting countries than oil importing countries.

As mentioned earlier, some papers also examined the oil price-stock market relationship within time-varying frameworks due to the growing evidence that the relationship between oil prices and the stock market varies over time. Within this category, examples of papers include; Filis et al (2011), Ciner et al (2013), Antonakakis and Filis (2013), Boldanov et al (2015), and Antonakakis et al (2017). All of these papers have concluded that the relation between oil prices and stock market prices of a range of developed countries is not constant, and it changes over time. Using a DCC-GARCH model, Ciner et al (2013) found that the correlation between oil prices and the UK stock market was positive in the 1990s, but this relationship became negative in the decade after. Their results also suggest that the relation between oil prices and the US stock market is stronger only during crises periods such as the Gulf war 1 and 2008 financial crisis. Filis et al (2011) also used the DCC-GARCH model to examine the dynamic correlations between oil prices and the stock market prices of a group of major oil exporting and oil importing countries. Their results show that oil price shocks caused by global business cycle's fluctuations are associated with positive effects on the stock market, whilst oil price shocks caused by world turmoil such as wars, turn to have negative effects on the stock market. However, the findings of Boldanov et al (2015) show that oil shocks caused by global business cycle's fluctuations (aggregate demand) and world turmoil such as wars in the Middle East (precautionary demand) are both associated with positive oil price effects on stock markets. They also indicated that oil shocks due to disruptions in oil supply (supply-side) cause negative oil price effects on stock markets.

Appendix A5 provides a summary of the main findings of the studies investigating the relationship between oil prices and stock markets of developed countries.

Studies Related to Developing Countries

Using daily, weekly, and monthly data, Basher and Sadorsky (2006) examined the linkage between oil price risk and a group of 21 emerging stock returns by employing the international multi-factor model. The OLS estimates from the multi-factor model reveal that the pricing of emerging markets stock returns is significantly influenced by oil price risk. Oil price risk is positive and statistically significant at the 10 percent significance level. They also found an asymmetric conditional relationship in the model; while increases in oil prices have a positive impact on excess stock market returns in emerging markets for daily and monthly data, decreases in oil prices have positive and significant impacts on emerging markets returns for weekly and monthly data.

Nandha and Hammoudeh (2007) also used the international multifactor model to study the correlation between domestic beta risk and stock index returns when oil and exchange rate sensitivities are present. The study was conducted for fifteen countries in the Asia-Pacific region. It used weekly data from May 4th 1994 to June 30th 2004 for domestic stock returns, World Market Index (used as a benchmark), and oil prices measured in US dollar and local currencies. The findings show that when oil prices are measured in local currency, the stock markets of thirteen out of the fifteen countries show important sensitivity to domestic risk in the presence of changes in oil prices. When oil prices are measured in US dollars, sensitivity is non-existent in any of the countries, except Sri Lanka. This finding suggests that the sensitivity of individual country stocks to changes in oil prices will depend on whether the oil price used in the study is measured in domestic currency or in US dollars.

Using a simple bivariate regression model, Driesprong et al (2008) investigated the predictive power of oil price shocks on stock market returns in a large group of developed and emerging countries. Using monthly price data from 1973 to 2003, they demonstrated that oil prices have a negative impact on emerging stock returns, although the effect is less pronounced compared to developed markets. They found that on average, a decrease in the current month's oil price indicates an increase in next month's stock market return. They also noted that the little effect of oil price shocks on emerging markets does not mean there is no predictability, but that the data for some of the emerging stock markets were simply not enough to confirm predictability.

Nedal A. Al-Fayoumi (2009) examined the relationship between oil price changes and stock market returns in Turkey, Tunisia, and Jordan within the VECM context. Monthly data from December 1997 to March 2008 was used to test for a long run relationship. The test revealed the existence of a cointegrating relationship, and the result from the subsequent VECM regression showed that oil price changes have no effect on stock market returns in the three countries (Turkey, Tunisia, and Jordan). They noted that stock market returns are rather influenced by local macroeconomic variables.

In contributing to the literature, Masih et al (2011) reviewed the volatility of oil prices and the fluctuations in stock prices in South Korea. The data consists of monthly observations from May 1988 to January 2005 on the Korean stock market index, industrial production, interest rates, and oil prices to adequately capture the Asian financial crises in 1997. Using a VAR regression, the evidence shows that oil prices significantly affect the stock market – the stock index price initially increases, and then later decrease, recovering to its previous equilibrium level in response to oil price shocks and oil price volatility. Vector Error Correction Model (VECM) estimates also indicates a negative effect of oil prices on the Korean stock market index. Appendix A6 summarizes the main findings of the studies that examined the relationship between oil prices and emerging stock markets.

It can be noted that the oil price effect on the stock market is not conclusive for both the developed market and the emerging markets. In some studies, oil price movements have significant negative effects on stock market prices whilst in other studies, the effects are not significant. Some of these differences could be due to different estimation methods, types of data, sample periods, or the countries being investigated. For example, Papatertrou (2001) and Masih et al (2011) found significant negative effects of oil shocks on stock market index price in Greece and South Korea respectively whilst papers such as Apergies and Miller (2009), Nedal A. Al-Fayoumi (2009), Driesprong et al (2008) found no relationship between oil prices and stock market prices. However, Papatertrou (2001) used a relatively shorter sample period from 1989 to 1999 whilst the other papers used more extended and recent sample periods in their studies. The findings of Masih et al (2011) may also differ because of their country under investigation (Korea). In contrast, Basher and Sadorsky (2006) found a positive relationship between oil prices and 21 emerging stock market returns which contradicts all the above papers. Perhaps, this could be due to their use of the international multi factor model which is different from the estimation methods used by all the other papers.

Further, the papers that distinguished between oil price effects on the stock markets of oil exporting countries and oil importing countries also have some notable differences in terms of results. Talukdar and Sunyaeva (2012) found evidence that oil price shocks have a negative effect on the stock markets of oil importing countries and a positive effect on the stock markets of oil exporting countries, whilst Boldanov et al (2015) found the opposite results for most part of their study. Yet, Filis et al (2011) noted that the oil price effects on the stock market do not differ for both oil importing countries and oil exporting countries. Note that Talukdar and Sunyaeva (2012) used a cointegration and impulse response approach whilst Filis et al (2011) and Boldanove et al (2015) used the DCC-GARCH and Diag-BEKK approaches respectively, and this could explain the differences in their results.

Similarly, for the studies that examined the time-varying relations between oil prices and stock market prices, some conflicting results are reported across the different studies. Most notably, Filis et al (2011), show that oil price shocks caused by global aggregate demand shocks are associated with positive effects on the stock market, whilst oil price shocks caused by precautionary demand turn to have negative effects on the stock market. In contrast, Boldanov et al (2015) show that oil shocks caused by global aggregate demand and precautionary demand shocks are both associated with positive oil price effects on stock markets. They also indicated that oil shocks due to disruptions in oil supply (supply-side) cause negative oil price effects on stock markets whilst such evidence were not reported in Filis et al (2011). Again, this result could possibly be due to the fact that Filis et al (2011) used the DCC-GARCH framework whilst Boldanov et al (2015) used the Diag-BEKK approach. The sample periods for the two papers are also different.

Summary

From this literature review, it can be noted that the link between oil prices and macro-economic variables has been examined extensively in the world. The broad nature of the literature allows for several key points to be noted. Firstly, whilst existing theories posit a link between oil prices and macroeconomic fundamentals, they provided general considerations about how oil prices affect the macro economy. As a result, several different approaches have been adopted to investigate the influence of oil prices on macroeconomic variables, as shown by the existing empirical literature.

Secondly, whilst the existing literature has significantly improved our understanding of the relationship between the price of oil and real economic activity, opinions in the literature have been divided. These varying opinions could mostly be due to the differences that exist among the studies in the literature in terms of methodologies, types of data, and national and regional characteristics. A significant feature of empirical research is that the findings of such investigations are often sensitive to the choice of countries, methodologies, sample periods, and the types of data. All of these factors are found in the literature, and may have influenced the results of the various studies. Thus, it is difficult to draw conclusions about the findings in the literature for both developed and developing countries because of the various factors.

Finally, it is worthwhile noting that despite the presence of a large body of empirical literature investigating the link between oil prices and macroeconomic fundamentals, there is a shortage of literature that distinguished between treating oil price as exogenous for small countries. Most studies in the existing literature treated crude oil prices as endogenous even for small countries like Ghana. However, the treatment of crude oil prices may be important for those countries because economic activities in such countries are not likely to affect world oil prices in a significant way compared to economic activities in developed countries. On the other hand, world oil price movements can influence economic activities in those countries. The literature has also been silent about the macroeconomic effects of domestic oil price movements. For some developing countries like Ghana where the government provides subsidies on petroleum products, domestic and world oil prices may have different effects on macroeconomic activities.

This study therefore, intends to build on the existing literature in two folds; firstly, the study will investigate the relationship between oil prices and economic growth in Ghana using both domestic and international crude oil prices. This will also include models that treat the international crude oil prices as exogenous and models that treat them as endogenous. Secondly, the study shall examine the shock and volatility spillover effects of domestic and international crude oil prices on the exchange rate and the stock market in Ghana. Again, models that treat the international crude oil price as exogenous and models that treat them as endogenous shall be considered. The aim of treating the international crude oil price as both exogenous and endogenous is to determine whether the crude oil price-macro economy relationship in Ghana is related to the treatment of the crude oil price. To the best of our knowledge, this study will be the first to carry out such studies on Ghana.

Chapter 4: Oil Prices and the macro economy: evidence from Ghana

4.1. Introduction

The aim of this chapter is to empirically investigate the macroeconomic effects of oil price shocks in Ghana. The effects of oil price movements on the economy have received great attention since the seminal work of Hamilton (1982). Despite the large body of literature that exists on this topic, there has been no consensus as to whether oil prices have a significant impact on GDP growth. Whilst Hamilton and many others argue that oil price shocks have a sufficiently large impact on economic growth, other papers found relatively weak evidence to support this view. Most studies in the literature that studied this topic used aggregate GDP as a measure of economic growth. However, for countries that produce some oil, it is also interesting to examine how oil price movements affect non-oil GDP. This is important because the response of the oil sector to oil price shocks will be particular to that sector, and not consistent with the response of the rest of the economy. In particular, for an oil producing country like Ghana that still imports refined petroleum products, increases in oil prices will benefit the oil sector whilst households and firms suffer, as such shocks lead to rises in the cost of production and increase in the costs of goods and services. To this end, this study sheds more light into the topic by examining the impact of both domestic and world crude oil price shocks on the non-oil GDP growth of Ghana. For comparative purposes, this study will also examine the oil price effects using total GDP in order to determine whether the oil price effect on non-oil GDP and total GDP are different. This is important given that Ghana only became an oil producer in 2011.

Ghana is a small open economy with a GDP of about 0.05% of total world GDP (IMF estimates 2016). As a result, economic activities in Ghana are not likely to drive world oil prices. However, world oil prices are expected to affect economic activities in Ghana since Ghana has been a traditional oil importer for several years. In this study, the international crude oil price is therefore, treated as an exogenous variable in some of our investigations. Some previous literature though, including that on small open economies, treated crude oil price as endogenous (e.g. Chang and Wong, 2003, Jumah and Pastuszyn, 2007, Adam and Tweneboah, 2008, Rafiq et al, 2009, Dawson, 2007, Masih et al, 2011, and Al-Fayoumi 2009). Hence, following previous studies, other models of our investigations will treat crude oil prices as endogenous (for comparative purposes).

It is also worthwhile noting that when examining the oil price-macro economy relationship, the choice of oil price variables can be difficult. As noted by Cunado and Gracia (2005), national oil prices have been influenced by high and varying taxes on petroleum products, price-controls, subsidies (particularly for developing countries such as the petroleum product subsidies in Ghana), and exchange rate fluctuations. As a result, this study will use both world oil price and domestic oil price variables in order to determine whether the two oil price variables have different effects on the economy. To explore the various oil price effects, this study employs three different classes of models. In the first class, the crude oil price is treated as an exogenous variable, whilst the second class treats the crude oil price as endogenous. These two approaches to treating crude oil prices will enable us to compare the crude oil price effects for a small country depending on whether the crude oil prices are exogenous or endogenous. The third class of models examine the domestic oil price effects. The domestic oil prices are only treated as endogenous because they are affected by governmental policies such as subsidies and taxes as well as domestic economic conditions. These approaches to modelling oil price effects represent the contributions of this paper to the existing literature.

The rest of the chapter is organised as follows; section 4.2 discusses the description and justification of the choice of the variables. Section 4.3 discusses the research methodology whilst section 4.4 presents and analyses the results. Section 4.5 concludes the chapter.

4.2. Variable Description and Justification

From the literature review in the previous section, it can be stated that the relationship between oil prices and economic growth has been investigated extensively. Yet, the variables to include when modelling this relationship is still an open question. The number of macroeconomic variables to include in modelling the oil price effect varies across different studies. For example, Hamilton (1996) and Hooker (1996) used GDP growth, the Treasury bill rate, inflation, and import price changes in their oil price specifications to examine the effects of oil price shocks on the US economy. Park et al (2011) and Ahmed and Wadud (2011) also used several variables in their papers which include industrial production, the federal funds rate, money supply, domestic interest rates, and exchange rates to model the oil price effects on the Korean economy and the Malaysian economy respectively. Also, Rafiq et al (2009) included investment, interest rates, inflation rate, unemployment rate, trade balance, and budget deficit whilst Chang and Wong (2003) only included CPI inflation and unemployment in their models to investigate the macroeconomic effects of oil price shocks in Thailand and Singapore respectively. Yet, Hamilton (2003) and Oladosu (2009) examined the oil price and the macro economy relationship for the US without including any additional macroeconomic variable in the model. In those studies, the only variables in the models are GDP and the price of oil in a bivariate analysis.

For the case of Ghana, Tweneboah and Adam (2008) included CPI inflation, interest rates, and exchange rates in their specification to examine the oil price effect on economic growth. In this study, we shall employ two specifications to model the oil price-macro economy relationship for Ghana. The first specification follows

Tweneboah and Adam (2008) where the model consists of oil prices and the GDP growth rate, as well as CPI inflation, interest rates, and exchange rates. The second specification follows Hamilton (2003) and Oladosu (2009) and uses only the oil price and GDP growth rate in a bivariate analysis. Thus, the variables we are using in this chapter include; the non-oil GDP growth rate and total GDP growth rate of Ghana, the Bank of Ghana's nominal interest rates, the Ghana cedi exchange rate vis-à-vis the US dollar, and inflation in the Ghanaian economy measured by the consumer price index (CPI). For oil prices, we use both the domestic price of oil in Ghana and the world oil price proxied by the UK Brent crude oil price.

Oil prices

Oil is an indispensable commodity that has affected our economic lives in modern times. Because oil is a vital source of energy, a fuel for transport, and an important raw material for many production processes, its price affects economic activities in all nations – oil importers and oil exporters alike. Traditional economic theory posits that oil price increases tend to boost economic growth in oil exporting countries due to the increase in the oil revenue; whilst for oil importing countries, the consequences of oil price increases are a negative growth of the economy. As we noted in chapter 1 and chapter 2, oil is an important part of Ghana's energy mix, and petroleum products consumption accounts for a significant percentage of Ghana's total energy consumption. Besides, Ghana still imports large amounts of refined petroleum products to meet local demands. Thus, examining the consequences of oil price movements on macroeconomic variables is important. Understanding the causes of oil price movements and their effects on the economy will help policy makers and portfolio managers in planning and decision making. As mentioned above, this study will examine the oil price effects using both world oil price and domestic oil price variables to differentiate the effects of the two oil price variables.

Gross Domestic Product (GDP)

In the wider literature, GDP growth is the most commonly used indicator of economic growth. This is mostly so because the aggregate condition of the economy is largely captured by GDP growth. GDP figures are also more reliable because the calculation of GDP data follows the requirements of international standards. In this study, we will use both total GDP and non-oil GDP to examine the oil price-macro economy relationship in Ghana. As noted earlier, oil became part of the Ghanaian economy in 2011, but before then, Ghana was mainly an oil importer. Thus, using both proxies of economic growth will help to determine whether the oil price effect is different for the two economic growth variables. This is especially important in the case of Ghana since the country still imports significant amounts of refined petroleum products (see chapter 2).

Interest rates

In Ghana, the Bank of Ghana uses short term interest rates as its operating target to influence the deposit and lending rates and eventually the overall level of prices and economic activity. In the early 2000s, it became difficult for Ghana to achieve its quantitative targets. At the same time, the authorities became increasingly concerned about rising inflation. This compelled the Bank of Ghana to replace monetary targeting with inflation targeting since 2002. In the oil price literature, Bernanke, Gertler and Watson (1997) and many others included interest rates in their oil price specifications to examine the role of monetary policy in the oil price-macro economy relationship. In this paper, the role of monetary policy is not our main concern. The inclusion of interest rates in this paper is motivated by the fact that it is an important macroeconomic variable and it was also included in a similar study on Ghana by a previous paper.

CPI Inflation

Inflation as measured by the consumer price index (CPI) is a sustained increase in the general price level of goods and services in an economy over a period of time. High oil prices can be inflationary as they may result in a rise in the general price level. As it is commonly known, higher inflation has a potential negative effect on growth. For example, higher inflation may lead to a misallocation of investment resources towards less productive uses, hence, lowering the productivity growth rate (Jung and Marshall 1986). Also, because inflation lowers real money balances, it distorts the price system. This reduces the efficiency of the factors of production and leads to a consequent decline in output growth. Higher prices of consumer goods and services may also dampen aggregate demand for goods and services which lowers output. For the case of Ghana, persistent and higher inflation has been a major problem for several decades as the government has often been unable to achieve a sustained and acceptable level of inflation. Thus, it is important to include CPI inflation in this study since it is an important variable that can affect the output growth rate.

Exchange rate

Exchange rate movements have an impact on the economy through their effect on merchandise trade (i.e. imports and exports). According to the traditional view, a depreciation of the domestic currency may stimulate economic growth by increasing the prices of foreign goods relative to home goods (e.g. see Kandil and Mirzaie

2003). Currency depreciation diverts spending from foreign goods to domestic goods by increasing the international competitiveness of domestic industries. On the other hand, a stronger currency can impede economic growth by making imports cheaper and reducing export competitiveness. This analogy is based on the fact that net exports (defined as exports minus imports) is a determinant of GDP growth and, the higher the value of net exports, the higher a nation’s GDP and vice versa.

The mechanism explained above is typically a demand-side channel. Kandil and Mirzaie (2003) noted that supply-side channels further complicate the effect of currency appreciation/depreciation on output and prices. From the supply-side perspective, output is produced using a combination of labour, capital, energy, and imported intermediate goods in a production function. This will be the case for a semi industrialized country where inputs for manufacturing cannot be produced domestically and are largely imported. In such a scenario, currency depreciation increases the input cost of firms. Hence, the negative effect from the higher cost of imported raw materials may dominate the extra growth in output created by lower relative prices of domestically produced goods. The net outcome of exchange rate depreciation on output therefore, will be determined by the combined effects of the demand-side and supply-side channels. Usually, the final effect will depend on the magnitudes of demand and supply curve shifts as a result of currency depreciation (Kandil and Mirzaie 2003).

Since Ghana adopted a managed-floating exchange rate regime in 1983 as part of the structural adjustment and economic recovery programs, the Ghana cedi has depreciated extensively. Hence, we have been motivated to include the exchange rates in this study because of its likely influence on output growth rate and the fact that it has also been included by previous papers.

Following Tweneboah and Adam (2008), we shall estimate a VAR based on the following variables;

$$VAR1 = f(LRNOGDP/LRGDP, LCOP, LCPI, LIR, LEXR) \quad (4.2.1)$$

where LRNOGDP, LRGDP LCOP, LCPI, and LIR and LEXR represent the logarithms of real non-oil GDP, real GDP, world crude oil prices, CPI inflation, interest rates, and exchange rates respectively. At least, some of these variables have also been included by other papers such as Hamilton (1996), Hooker (1996), Chang and Wong (2003), Jumah and Pastuszyn (2007), Rafiq et al (2009), Park et al (2011), Bernanke, Gertler and Watson (1997), Leduc and Sill (2004), and Ahmed and Wadud (2011) to examine the oil price- macro economy relationship.

In our second specification, the only variables in the model are the non-oil GDP growth rate and crude oil prices, and this model follows Hamilton (2003) and Oladosu (2009) who examined the oil price-macro economy relationship using US data. Thus, the model will be based on the following variables;

$$VAR2 = f(LRNOGDP/LRGDP, LCOP) \quad (4.2.2)$$

The purpose of using this specification is to determine whether the exclusion of other macroeconomic variables in the model affects the oil price and GDP relationship. This model will also add novelty to our work since most of the papers that studied the oil price and macro economy relationship for both developed and developing countries have often included other macroeconomic variables such as interest rates, inflation, exchange rates, etc. in their models.

Another aspect of this paper examines the relation between domestic oil prices and GDP growth rate in Ghana. In doing so, we used the prices of diesel, petrol, and kerosene as proxies of domestic oil prices. Here, we shall also estimate two specifications similar to the world crude oil price models by replacing crude oil prices in equations (4.2.1) and (4.2.2) with domestic oil prices. Hence, the domestic oil price specifications will be;

$$VAR3 = f(LRNOGDP/LRGDP, LDOP, LCPI, LIR, LEXR) \quad (4.2.3)$$

and

$$VAR4 = f(LRNOGDP/LRGD, LDOP) \quad (4.2.4)$$

where LDOP is the logarithm of domestic oil prices. All the models are re-estimated with the conventionally measured GDP (total GDP) replacing the non-oil GDP as the measure of economic growth for comparison purposes.

These two streams of research will provide a basis to compare the macroeconomic effects of international crude oil prices and domestic oil prices in Ghana. Petroleum products pricing in Ghana have been influenced by government regulations, subsidies, and tax policies for several decades. As a result, domestic oil prices in Ghana do not usually adjust automatically to changes in world crude oil prices. Hence, the crude oil price effect on economic growth may differ from the domestic oil price effect in Ghana. To check this possibility, we first conduct a covariance analysis to examine the correlation coefficient between world oil prices and domestic oil prices. Correlation tests involving the prices of diesel, petrol, kerosene, and crude oil are shown in tables 4.2.1 and 4.2.2 below. The tests are conducted using logs of the variables in levels and differences. The tests in levels are shown in table 4.2.1 whilst the tests in differences are shown in table 4.2.2

Table 4.2. 1: Covariance Analysis in log levels

Correlation t-Statistic Probability	LDIESEL	LKEROSINE	LPETROL	LCOP
LDIESEL	1.000000 ----- -----			
LKEROSINE	0.968288 {21.92406} (0.0000)	1.000000 ----- -----		
LPETROL	0.998499 {103.1248} (0.0000)	0.974268 {24.45209} (0.0000)	1.000000 ----- -----	
LCOP	0.805925 {7.700774} (0.0000)	0.679449 {5.238418} (0.0000)	0.803445 {7.633741} (0.0000)	1.000000 ----- -----

Note: t-statistics are in curly brackets, probability values are in parenthesis. Correlation coefficient between 0-0.19 implies very weak correlation, 0.20-0.39 implies weak correlation, 0.40-0.59 implies moderate correlation, 0.60-0.79 implies strong correlation, and 0.80-1.00 implies very strong correlation

Table 4.2. 2: Covariance analysis in log differences

Correlation t-Statistic Probability	DLDIESEL	DLKEROSE NE	DLPETROL	DLCOP
DLDIESEL	1.000000 ----- -----			
DLKEROSENE	0.880363 {10.33448} (0.0000)	1.000000 ----- -----		
DLPETROL	0.826915 {8.187520} (0.0000)	0.832604 {8.369759} (0.0000)	1.000000 ----- -----	
DLCOP	0.119568 {0.670534} (0.5075)	0.091258 {0.510234} (0.6135)	0.179864 {1.018040} (0.3165)	1.000000 ----- -----

Note: t-statistics are in curly brackets, probability values are in parenthesis. Correlation coefficient between 0-0.19 implies very weak correlation, 0.20-0.39 implies weak correlation, 0.40-0.59 implies moderate correlation, 0.60-0.79 implies strong correlation, and 0.80-1.00 implies very strong correlation

From table 4.2.1, all the correlations are high and their t-statistics are significant at the 5% level. This means the correlations are significantly different from zero. The correlations between crude oil prices and the domestic oil prices (i.e. diesel and petrol) are around 80% and their t-statistics are also significant. However, the high and significant correlation between the crude oil price and domestic oil prices in levels could reflect exaggerated correlation due to spurious correlation since all the series included are trended. Correlations between the domestic oil prices are also high and significant for the series in differences as shown in table 4.2.2. However, the correlations between crude oil prices and the domestic oil prices are very low for the series in differences, which implies they are insignificantly different from zero. Note that variables in difference are unlikely to exhibit spurious correlation. The series are also used in our modelling in differenced format. Hence, we can conclude that the correlation between the world oil prices and the domestic oil prices is not sufficiently high to automatically assume that domestic oil prices are a good approximation of world oil prices (although the correlations for the series in levels appear to be very high). In other words, the dependence of the domestic oil prices on world oil prices is not extremely strong. Therefore, it is prudent to examine the macroeconomic effects of domestic oil price shocks in Ghana to ascertain how the effects of such shocks differ from the world crude oil price shocks.

4.3. Econometric Methodology

This chapter presents the econometric techniques that will be employed to address the research questions in the first paper of this study. These techniques include unit root testing, cointegration testing, VAR modelling, and dynamic forecasting. These methods shall be explained briefly in the section below.

4.3.1: Testing for Integration

Most macroeconomic time series data such as income, consumption, stock prices, etc. often share a long run relationship. Other common features of these variables are that they evolve over time such that their mean and variance are not constant, and they often exhibit trending behaviour. When a data series exhibits these features, the series is said to be non-stationary.

Unit-root non-stationarity is defined by reference to an autoregressive representation of the series in question, say $y_t = d_t + \sum_{i=1}^{i=p} y_{t-i} + u_t$ where d_t is deterministic and u_t is a white noise disturbance. This representation can be expressed by using a lag polynomial: $\varphi(L)y_t = d_t + u_t$. If the lag polynomial has a unit root then we have $(1-L)\tilde{\varphi}(L)y_t = d_t + u_t$, i.e. $y_t = y_{t-1} + \left(\tilde{\varphi}(L)\right)^{-1}(d_t + u_t)$, so that each value in the series is formed by adding some combination of deterministic terms and random shocks to the preceding value. Consequently, any random shock is persistent in the sense of contributing to all successive values of the series. Such series are called “integrated” because their values contain the addition (“integration”) of shocks. Note that where a lag polynomial has a single unit root then first differencing produces a stationary series: $y_t - y_{t-1} = \left(\tilde{\varphi}(L)\right)^{-1}(d_t + u_t)$. Such series are called "integrated of order one", usually abbreviated to $I(1)$.

Non-stationarity is a major problem in time series analysis because as noted by Brooks (2008 chapter 7) if the non-stationarity is due to a unit root in the autoregression lag polynomial then the persistence of shocks to such a non-stationary series will be indefinite, and never die away. Also, the use of non-stationary data can lead to spurious regression; a situation where a regression model looks good under standard measures, with significant coefficient estimates and high R^2, but is valueless in reality (Brooks 2008 chapter 7) because it does not represent any valid feature of the processes generating the data. Specifically, various standard estimation statistics indicate that two independently generated series appear to be correlated. For example, if X_t and Y_t are non-stationary time series data $(X, Y \sim I(1))$, a spurious relationship may exist between the two variables unless $\hat{\mu}_t = Y_t - \hat{\beta} X_t$, i.e. a linear combination of the two variables, is stationary or $\hat{\mu}_t \sim I(0)$. Hence, we first need to find out whether the data series are $I(0)$or $I(1)$. This is done through unit root testing.

4.3.2. Unit Root Testing

The non-stationarity of time series is often self-evident from a plot of the series. However, it is not always easy to determine the actual form of non-stationarity from just a visual inspection. Therefore, some kind of formal hypothesis testing procedures have been suggested to determine whether the true data generating process for a series contains one or more unit roots. Some of the commonly known testing procedures include the Augmented Dickey-Fuller (ADF) test originally developed by Dickey and Fuller (1979), the Phillips-Perron (PP) test developed by Phillips and Perron (1988), and the Lee-Strazicich (2003) test. These tests are employed in this study.

The Augmented Dickey-Fuller (ADF) Test

The ADF test evolved from the original DF test which was developed by Dickey and Fuller (Dickey and Fuller, 1979). The main objective of the test is to examine the null hypothesis that a series contains a unit root. In a more general form, the Augmented Dickey-Fuller test can be expressed as stated in Enders (2010) as:

$$\Delta y_t = a_0 + \Upsilon y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \qquad (4.3.1)$$

where $\Upsilon = -(1 - \sum_{i-1}^{p} a_i)$ and $\beta_i = -\sum_{j-i}^{p} a_j$.

Equation (4.3.1) also includes deterministic components where a_0 represents the coefficient on the intercept or drift term while t denotes the linear time trend. The appropriate test statistics and critical values to use differ depending on the deterministic components included in the regression. The τ, τ_μ, and τ_τ statistics are used respectively for models without intercept or trend, models with intercept only, and models with both intercept and trend. For example, assuming no intercept or trend, the test statistic is expressed as;

$$\tau = \frac{\Upsilon - 0}{SE(\Upsilon)}$$

These statistics are used to test the null hypothesis of a unit root. The coefficient of interest is Υ. If $\sum a_i = 1$, it implies that $\Upsilon = 0$ and the series has a unit root. Therefore, the hypotheses of interest are;

H_0: Series contains a unit root ($\Upsilon = 0$)

H_1: Series is stationary ($\Upsilon < 0$)

The null hypothesis of a unit root is rejected in favour of the stationary alternative if the test statistic is more negative than the critical value.

However, a problem arises as to how to determine the optimal number of lags of the dependent variable. Two simple rules of thumb have been suggested. Firstly, the frequency of the data can be used to decide the appropriate number of lags. For example, if the data are monthly, choose 12 lags, if the data are quarterly, choose 4 lags, if the data are yearly, choose 1 lag, and so on. Secondly, an information criterion can be used to decide, by choosing the number of lags that minimizes the value of an information criterion. There are various information criterions, including the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the Hannan-Quinn Information Criterion (HQC).

The AIC and BIC have widely been used in the literature to select the optimum lag values. However, Ng and Perron (2001) outlined two problems associated with the AIC and BIC as well as other traditional lag selection procedures. Firstly, they noted that when the autoregressive polynomial is close to but less than one, the AIC and BIC tend to have low power. Secondly, they argued that the traditional tests suffer from size distortions when the first differenced series of the polynomial has a large root. In particular, the AIC and BIC tend to select lag values that are generally too small for a unit root test to have a good size. The end result is that they over-reject the unit root hypothesis. As a result, Ng and Perron (2001) proposed modified AIC and BIC statistics to overcome these problems (see Ng and Perron 2001). In general, they concluded that the modified information criteria offer more desirable properties in power and size than the traditional AIC and BIC tests. Also, Zhang and Siegmund (2007) demonstrated that when selecting the appropriate lag for a model, the modified information criteria are consistent in selecting the correct model and perform better than the standard BIC. Thus, the modified versions of the AIC and BIC will be used in this study.

Phillips-Perron (PP) Test

The theory underpinning the ADF test is that the error terms ε_t are identically and independently distributed. As a result, when using the ADF methodology, additional lagged difference terms must be added to take care of possible serial correlation in the error terms (Gujarati and Porta 2009, chapter 21). Phillips and Perron (1988) developed a generalized version of the ADF test that accounts for serial correlation of the error terms without the addition of lagged difference terms. As a result, the PP test is only a modification of the ADF test that allows serially correlated residuals. The PP test equation can be expressed as

$$\Delta y_{t-1} = \alpha_0 + \gamma y_{t-1} + \varepsilon_t \qquad (4.3.2)$$

The asymptotic distributions of the PP test and the ADF test are both the same, and therefore, often offer similar conclusions. Gujarati and Porter (2009, chapter 21) noted that when performing unit root tests, it is always important to conduct the ADF test as well as the PP test for comparison purposes.

However, the traditional unit root tests have been challenged by Perron (1989), who argues that the standard ADF and PP tests are biased towards the non-rejection of the null hypothesis in the presence of structural breaks. Perron argues that the persistence of shocks in most macroeconomic series is not characterized by a unit root, but rather arises only from large and infrequent shocks. According to Perron, fluctuations are stationary around a deterministic trend function which may have breaks. The presence of structural breaks in unit root testing has been widely acknowledged in the applied econometrics literature. As a result, some unit root testing procedures that allow for structural breaks to be exogenously or endogenously determined have been proposed. The most notable among these procedures include Perron (1989), Zivot and Andrews (1992), Lumsdaine and Papell (1997), and Lee and Stracizich (2003).

The Zivot and Andrews, Lumdanune and Papell, and other similar tests assume no break under the null of a unit root. Thus, the alternative hypothesis is stationarity with the possibility of structural breaks. However, Lee and Stracizich argued that allowing for breaks under the null is important, if not the test statistic for a unit root will diverge as the size of the break increases under the null hypothesis. Also, there is evidence suggesting that assuming no break under the null in endogenous break tests could lead to significant rejections of the null hypothesis of a unit root when the data actually contains a unit root with structural breaks. The Lee and Stracizich test however, allows for structural breaks in both the null and alternative hypotheses. Thus, using the Lee and Stracizich test, the rejection of the null hypothesis unambiguously implies trend stationarity. This important feature of the Lee and Stracizich test makes it different from the other tests. In this study, we employ the

Lee and Stracizich test as it is more recent and also provides a remedy to the limitations that characterize the other test procedures.

Lee and Strazicich Test

Lee and Strazicich proposed a two-break minimum Lagrange multiplier (LM) unit root test in which the null hypothesis implies a series contains a unit root with two structural breaks, whilst the alternate hypothesis assumes stationarity around a trend with a structural break. The test allows the break dates to be endogenously determined. We will briefly explain the model as described in Lee and Strazicich (2003) as follows;

Consider the data generating process

$$y_t = \delta' Z_t + e_t, \qquad e_t = \beta e_{t-1} + \varepsilon_t \qquad (4.3.3)$$

where Z_t is a vector of exogenous variables and $\varepsilon_t \sim$ iid $N(0, \sigma^2)$. Two models can be considered as; Model A and Model C. Model A allows for two shifts in level and is explained as $Z_t = [1, t, D_{1t}, D_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{Bj} + 1$, $j = 1,2$ and 0 otherwise. T_{Bj} denotes the break date. Model C allows for two changes in level and trend and is expressed as $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $DT_{jt} = t - T_{Bj}$ for $t \geq T_{Bj} + 1$, $j = 1,2$, and 0 otherwise. The null hypothesis in the data generating process is $\beta = 1$ and the alternative is $\beta < 1$. For instance, in both models, depending on the value of β, the following models can be considered under the null and alternate hypotheses

Null: $$y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + y_{t-1} + \upsilon_t, \qquad (4.3.4a)$$

Alternative: $$y_t = \mu_1 + \Upsilon t + d_1 D_{1t} + d_2 D_{2t} + \upsilon_{2t} \qquad (4.3.4b)$$

where υ_{1t} and υ_{2t} are stationary error terms, $B_{jt} = 1$ for $t = T_{Bj} + 1,\ j = 1{,}2,$ and 0 otherwise, and $d = (d_1, d_2)'$.

Lee and Strazicich obtain the two-break LM unit root test statistic from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t, \qquad (4.3.5)$$

where $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}, t = 2, \dots, T$; $\tilde{\delta}$ are coefficients in regressing Δy_t on ΔZ_t; $\tilde{\psi}_x$ is denoted by $y_1 - Z_1 \tilde{\delta}$ and y_1 and Z_1 represent the first observations of y_t and Z_t respectively. The null hypothesis of the unit root is given by $\phi = 0$, and the LM test statistics are given by

$$\tilde{\rho} = T\tilde{\phi}, \qquad (4.3.6a)$$

$$\tilde{\tau} = t\text{-statistic} \qquad (4.3.6b)$$

The break dates (T_{Bj}) in the two-break LM unit root test are determined endogenously as follows:

$$LM_\rho = inf\, \tilde{\rho}(\lambda), \qquad (4.3.7a)$$

$$LM_\tau = inf\, \tilde{\tau}(\lambda) \qquad (4.3.7b)$$

The break dates are determined to be where the test statistic is minimized (see Lee and Strazicich). Critical values for both models are provided by Lee and Stazicich (2003), and these critical values shall be considered in this study to test for the non-stationarity of our variables using the Lee and Strazicich unit test. This test is available in the RATS software program.

4.3.3: Cointegration

In most cases, when variables are integrated of the same order, e.g. $I(1)$ processes, a linear combination of the variables will also be $I(1)$. However, it is possible that a linear combination of *I*(1) variables such as X_t and Y_t will have u_t which will be *I*(0). In such circumstance, X_t and Y_t are said to be cointegrated (Mills and Markellos, 2008). Thus, a set of variables are said to be cointegrated if a linear combination of them is stationary. If the cointegration condition is met, they move together in the long run, such that they do not drift apart arbitrarily from each other in the course of time.

In this study, the variables will be tested to determine whether a long run relationship exists between them if the evidence of non-stationarity is established. The most commonly used method of testing for the existence of cointegration between variables, based on Granger's Representation Theorem, is Johansen's (1995) cointegration test. The Johansen's cointegration test is based on a VAR model and it is used to examine the long run relationships that exist between variables. The Johansen approach does not require the choice of dependent and exogenous variables since all variables entering the VAR system are treated as endogenous. The Johansen technique can be expressed in general form as follows;

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots + \beta_k y_{t-k} + u_t \qquad (4.3.8)$$

where y_t is a vector containing n variables, all of which are integrated of order one and the subscript t denotes the time period. β_k is an (*n*x*n*) matrix of coefficients where *k* is the maximum lag included in the model, and u_t is an (*n*x1) vector of error terms. The VAR can be turned into a vector error correction model (VECM) assuming cointegration of order *r.* Brooks (2008) shows how to rewrite equation (4.3.8) into a VECM form as;

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \ldots + \Gamma_{k-1} \Delta y_{t-(k-1)} + u_t$$

(4.3.9)

Equivalently, equation (4.3.9) can be written more compactly as:

$$\Delta Y_t = \delta + \sum_{i=1}^{p} \Gamma \Delta Y_{t-i} + \Pi Y_{t-i} + v_t \qquad (4.3.10)$$

where $\Pi = (\sum_{i=1}^{k} \beta_i) - I_g$ represents the long run relationships among the variables included in the model, Y_t is a vector containing both endogenous and exogenous variables, and $\Gamma_i = (\sum_{j=1}^{i} \beta_j) - I_g$ represents the short run dynamics of the model. Π describes the error correction mechanism and has two parts; α and β'. α is a vector representing the speed of the short run adjustment to the long run equilibrium, whilst β' is a cointegrating vector with long run coefficients in the matrix. In general, equation 4.3.10 has two channels of causation. The first channel is through the coefficients of the exogenous lagged variables, and the second channel is through the error correction term (ECT). The error correction term captures the adjustment of the system towards its long run equilibrium.

The issue of finding the appropriate (optimal) lag length is very important in the Johansen test because setting the value of the lag length is affected by the omission of variables that might affect the behaviour of the model (Asteriou and Hall, 2011). The lag length of the VAR model can be selected using the sequential log likelihood ratio (LR) test as in Lütkepohl (2005). Alternatively, the optimal lag length can be selected by choosing the model that minimizes the AIC or the BIC criterion. The model should also pass all the diagnostic checks including autocorrelation, heteroscedasticity, and normality of the residuals.

Two test statistics have been suggested for cointegration under Johansen's approach. These are the trace and maximum eigenvalues tests, and they are formulated as

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} \ln(1-\widehat{\lambda_i}) \qquad (4.3.11)$$

and

$$\lambda_{max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \qquad (4.3.12)$$

where r is the number of cointegrating vectors under the null hypothesis, $\hat{\lambda}_i$ is the estimated value for the ith ordered eigenvalue from the Π matrix, and T is the sample size. The first statistic, which is λ_{trace} is a joint test where the null is that the number of cointegrating vectors is less than or equal to r against an unspecified or general alternative that there are more than r. It starts with p eigenvalues, and then the largest is successively removed. λ_{trace} = 0 when all the λ_i = 0 for all i = 1… g. The second statistic, which is λ_{max} conducts separate tests on each eigenvalue and its null hypothesis is that the number of cointegrating vectors is r against an alternative of r + 1. Johansen-Juselius (1990) provide critical values for both statistics; and the critical values depend on the value of $g - r$, the number of non-stationary components, and whether constants are included in each of the equations

(Brooks, 2008). If the test statistic is greater than the critical value from Johansen's tables, reject the null hypothesis that there are r cointegrating vectors in favor of the alternative there are more than r cointegrating vectors (for λ_{trace}) or r + 1 (for λ_{max}). The testing is conducted in sequence so that the hypotheses for λ_{max} are

$\mathrm{H}_0 : r = 0$ versus $\mathrm{H}_1 : 0 < r \leq g$

$\mathrm{H}_0 : r = 1$ versus $\mathrm{H}_1 : 1 < r \leq g$

$\mathrm{H}_0 : r = 2$ versus $\mathrm{H}_1 : 2 < r \leq g$

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$\mathrm{H}_0 : r = g - 1$ versus $\mathrm{H}_1 : r = g$

The first test involves a null hypothesis of no cointegrating vectors. If this null is not rejected, it would be concluded that there are no cointegrating vectors and the testing would be completed. However, if the null of no cointegration is rejected, the null that there is one cointegrating vector (r = 1) would be tested and so on. Thus, the value of r is increased continuously until the null is no longer rejected.

4.3.4: The VAR and VECM models

In dealing with a set of economic variables, the value of one variable is often related not only to its previous values in time, but also it depends on past values of other variables (Luetkepohl 2005). A VAR of order p can be expressed as follows:

$$\Delta Y_t = \delta + \sum_{i=1}^{p} \Gamma \Delta Y_{t-i} + v_t \qquad (4.3.13)$$

where ΔY_t is a vector containing both the dependent and independent variables and δ is a vector of constants. Γ is a vector with a matrix of short run coefficients. Also, v_t is a vector of white noise error terms whilst p is the order of the autoregression. The expression in equation (4.3.13) is a differenced VAR that contains the differences of variables that are assumed to be I(1).

VAR models were traditionally designed for variables that are stationary with no time trends (Luetkepohl 2011). However, researchers have shown that stochastic trends can also be captured in VAR models since the discovery of the significance of stochastic trends in macroeconomic variables and the development of the concept of cointegration (see Engle and Granger 1987, and Johansen 1995). It may be desirable to separate the short run dynamics from the long run relations of the data generating process of a set of variables if there are trends or long run relationships among the variables. Often, the most suitable model that separates short run and long run components of the generation process is the vector error correction model (VECM) as described in equation (4.3.10). The VECM is a transformation of the VAR model expressed in equation (4.3.13) by adding an error correction term in equation

(4.3.13). In principle, the VAR model is a VECM where no cointegration has been found. That is, $r = 0$.

Standard reduced form VARs treat all variables as endogenous (see Enders 2004). Hence, Johansen's cointegration approach, and the models expressed in equations 4.3.12 and 4.3.13 are suitable for our investigations where the international crude oil price is treated as an endogenous variable, and where the domestic oil price and macro economy relationship are examined. This is because all variables in those models are treated as endogenous. However, for the models where the crude oil price is treated as exogenous, the standard reduced form VARs are not appropriate and other models may be suitable. To treat crude oil prices as exogenous, we shall employ three methods; 1) structural VAR analysis, 2) scenario-based dynamic forecasting from a reduced form VAR in which the oil price is included as exogenous, and 3) the ARDL framework. The structural VAR and the ARDL models are explained in detail in section 4.4.4. The scenario-based forecasting procedure is not used in the existing literature for oil price effects. As noted in chapter 1, the scenario-based forecasting is also a novelty of our work since this paper is the first to use this method to investigate oil price effects. The exogeneity of oil prices in the VAR allows us to use scenario forecasting as is common place for example, in simulating the consequences of exogenous policy interventions.

Under the assumption of stationarity, the estimated VAR model allows us to decompose the historical fluctuations of oil prices into orthogonal components which correspond to oil supply and oil demand shocks (Baumeister and Kilian 2012). As indicated in Baumeister and Kilian (2012), we can let

$$y_t = \sum_{i=0}^{\infty} \Theta_i \, w_{t-i} \approx \sum_{i=0}^{n-1} \Theta_i \, w_{t-i}, \qquad (4.3.14)$$

where y_t denotes the current observations of the data, Θ_i represent the matrix of the impulse responses at lag $i = 0,1,2,,,$ and w_t is the vector of uncorrelated structural shocks. Θ_i and w_t can be estimated consistently in practice. Baumeister and Kilian (2012) noted that the reduced-form forecast corresponds to the expected change in oil prices conditional on the expectation that all future shocks are zero. Any departures from this benchmark can be corrected by putting pre-identified sequences of future structural shocks into the structural moving average representation of the VAR model, and the dependent variable can then be projected into the future. Such sequences of future shocks are known as forecast scenarios, and they may either be purely hypothetical, or based on sequences of past structural shocks (Baumeister and Kilian 2012).

By analogy to equation (4.3.14), a structural moving average representation of the VAR can be written as:

$$y_{t+h} = \sum_{i=0}^{\infty} \Theta_i \, w_{t+h-i} = \sum_{i=0}^{h-1} \Theta_i \, w_{t+h-i} + \underbrace{\sum_{i=h}^{\infty} \Theta_i \, w_{t-i}}_{y_t}, \qquad (4.3.15)$$

where y_{t+h} is the dependent variable h periods into the future. Setting all structural shocks in (4.3.15) to zero produces the reduced-form or unconditional VAR forecast. Also, putting a sequence of nonzero future structural shocks into the model yields a conditional forecast.

From the structural model obtained, it is expedient to normalize all conditional forecasts relative to the baseline forecast by setting all future structural shocks to zero. This will remove the dependence of the forecast scenario on y_t. The plot of this normalized conditional forecast denotes the downward or upward adjustments of the baseline forecast that would be necessary if a given hypothetical scenario were to occur. That is to say, for a given sequence of future structural shocks $\{w_{t+1}^{scenario}, \dots, w_{t+h}^{scenario}\}$, the revision required in the baseline forecast of $y_{t+h}, h = 1,2, \dots$, if the scenario were to come true would be:

$$y_{t+h}^{revision} = \sum_{i=0}^{h-1} \Theta_i \, w_{t+h-1}^{scenario} - \sum_{i=0}^{h-1} \Theta_i \, w_{t+h-1}^{baseline} = \sum_{i=0}^{h-1} \Theta_i \, w_{t+h-1}^{scenario}$$

(4.3.16)

Formally, this approach is analogous to the construction of standard impulse response functions. The main difference between the two is that impulse responses involve a one-time structural shock $w_t^{scenario} \neq 0$ followed by

$w_{t+i}^{scenario} = 0 \; \forall \; i > 0$, whilst forecast scenarios tend to comprise sequences of nonzero structural shocks that extend over several periods.

4.4. Results and analysis

The aim of this study is to examine the macroeconomic effects of domestic and international crude oil price movements in Ghana. The data are annual time series from 1971 to 2014, making a total of 43 observations (for the domestic oil prices, data are only available from 1982). This time period was chosen for three main reasons. Firstly, the period captures the effects of fundamental changes made to stabilize and regulate the Ghanaian economy. In 1985, under the guidance of the IMF, Ghana developed and implemented the Structural Adjustment and Economic Recovery programmes, aimed at rescuing the country from economic collapse (see chapter 2). Secondly, data was available during this period for all the variables in this study. Finally, significant fluctuations in world oil prices also occurred during this period.

4.4.1. Data definitions

The set of macroeconomic variables to be studied include real non-oil GDP/total GDP, domestic oil prices, international crude oil prices, and the inflation rate. As a measure of the government's monetary policy, we also include the Bank of Ghana's nominal interest rate. Nominal data on GDP were collected from World Bank development indicators (see table 5). The data have been divided by the consumer price index to derive real GDP. Nominal data were also collected for international crude oil prices and Bank of Ghana's interest rates. Oil price data were obtained from BP (2014) while interest rates were obtained from Data Stream. The consumer price index (CPI) was taken from the World Bank development indicators and this is used to obtain the rate of inflation by taking the log differences of the CPI. The domestic oil price data were all obtained from the Bank of Ghana's statistical bulletin.

All the data and variables are defined in table 4.4.1. The variables to be used in the analysis have been expressed in their logarithmic form. They will be referred to as LRNOGDP, LRGDP LCOP, LDIESEL, LKEROSENE, LPETROL, LCPI, LEXR and LIR (see table 4.4.1), where LRNOGDP is the log of real non-oil GDP, LRGDP is the log of real GDP, LCOP is the log of crude oil price, LDIESEL is the log of diesel price, LKEROSENE is the log of kerosene price, LPETROL is the log of petrol price, LCPI is the log of the consumer price index which will be differenced to obtain the inflation rate, LEXR is the log of the Ghana cedi exchange rate vis-à-vis the US dollar, and LIR is the log of the Bank of Ghana's nominal interest rate.

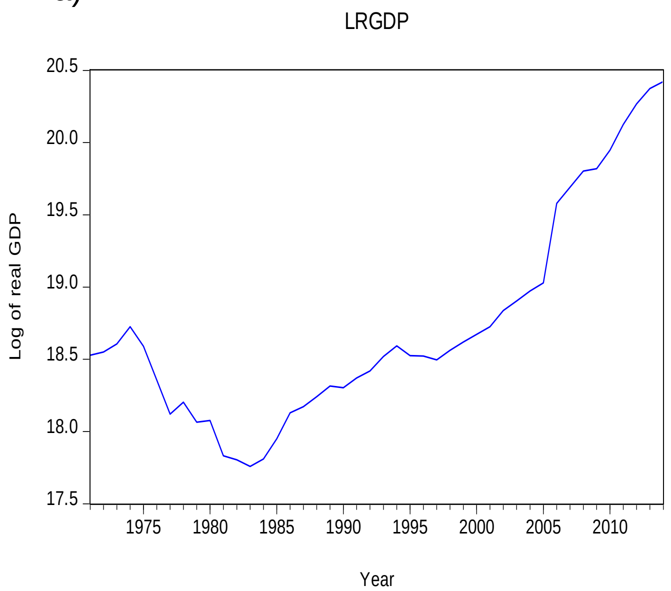
Table 4.4. 1: Variable definitions and data sources

Variable	Description	Source
	Data obtained from sources	
GDP	Gross domestic product	World Bank Development Indicators
NONGDP	Non-oil GDP	World Bank Development Indicators
EXR	Ghana cedi exchange rate	IMF International Financial Statistics
COP	International Crude Oil Price (UK Brent)	British Petroleum (2014)
DIESEL	Domestic price of diesel	Bank of Ghana's website
KEROSENE	Domestic price of kerosene	Bank of Ghana's website
PETROL	Domestic price of petrol	Bank of Ghana's website
CPI	Consumer price index	World Bank Development Indicators
IR	Bank of Ghana nominal interest rates	Kingston University Data stream
Computed Variables		
RNOGDP	Real Non-Oil GDP	NOGDP/CPI
LRNOGDP	Log of real non-oil GDP	LN(RNOGDP)
RGDP	Real GDP	LN(GDP/CPI)
LRGDP	Log of real GDP	LN(RGDP)
LCPI	Log of Consumer price index	LN(CPI)
LDIESEL	Log of domestic price of diesel	LN(DIESEL)
LKEROSENE	Log of domestic price of kerosene	LN(KEROSENE)
LPETROL	Log of domestic price of petrol	LN(PETROL)
LEXR	Log of exchange rate	LN(EXR)
LCOP	Log of international crude oil prices (UK Brent Crude Oil Price)	LN(COP)
LIR	Log of interest rates(Bank of Ghana's nominal interest rates)	LN(IR)
INF	Inflation rate	LCPI-LCPI(-1)

The graphs in figures 4.4.1 to 4.4.7 illustrate developments in the respective data series during the sample period. There were a series of potential structural shocks in real GDP, the CPI inflation rate, and the nominal short-term interest rate between 1974 and1984.

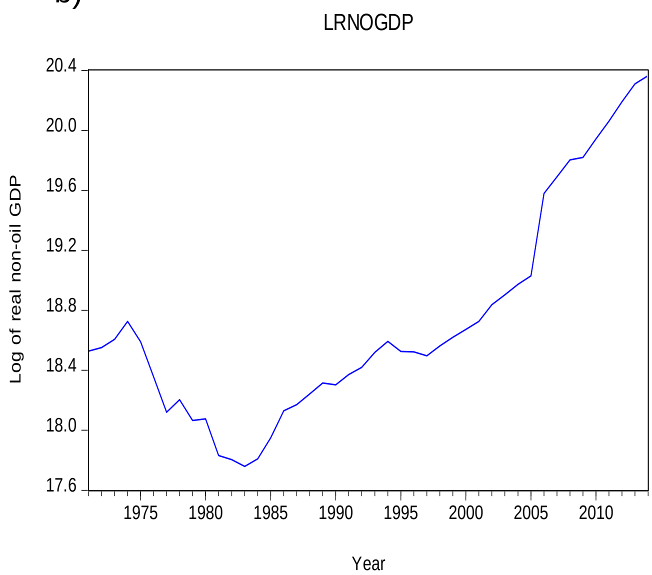
Figure 4.4. 1: Log of real GDP and real Non-oil GDP of Ghana

a)



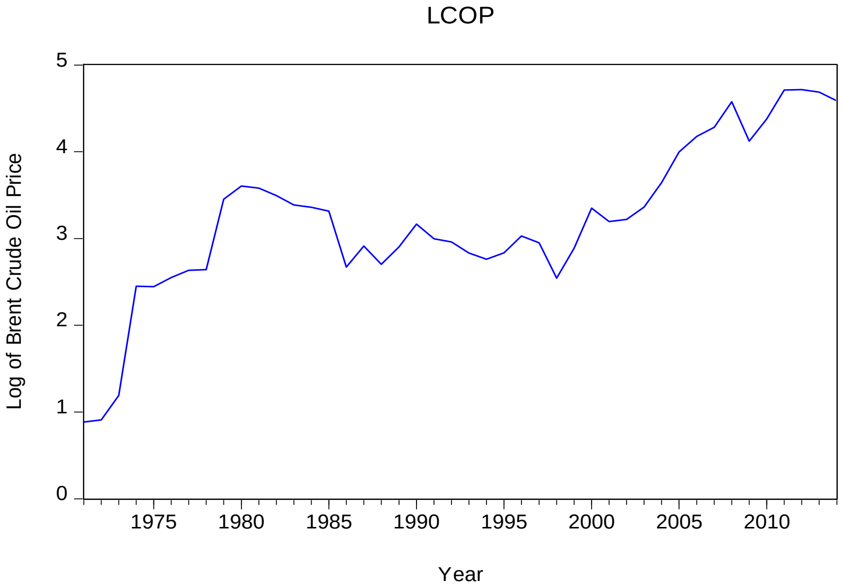
Source: Author’s calculations using World Bank series for Nominal GDP (current LCU) (World Bank 2014, Series Code: “NY.GDP.MKTP.CN”) and Consumer price index (2010=100) (World Bank 2014, Series Code: “FP.CPI.TOTL”)

b)



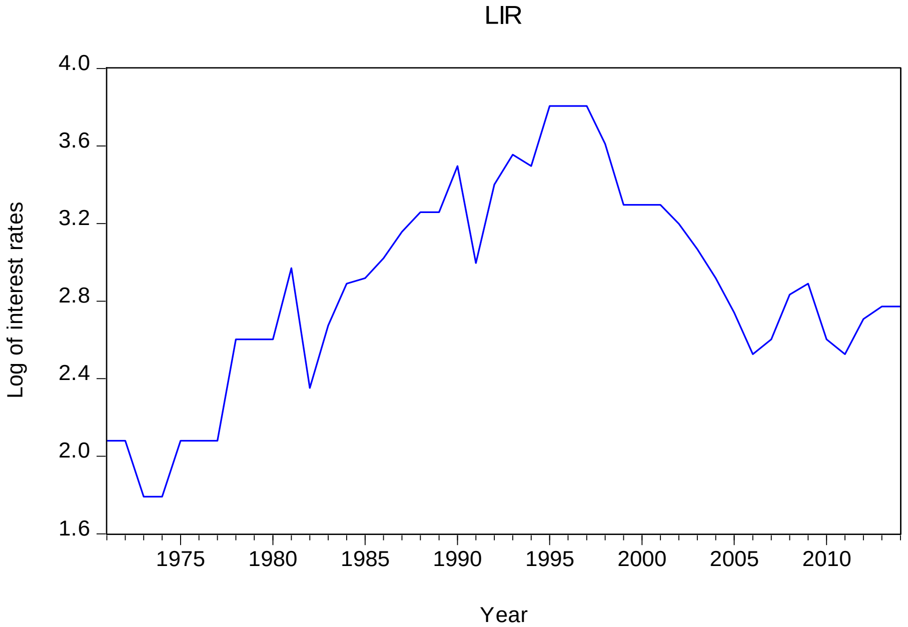
Source: Author’s calculations using World Bank series for Nominal GDP (current LCU) (World Bank 2014, Series Code: “NY.GDP.MKTP.CN”) and Consumer price index (2010=100) (World Bank 2014, Series Code: “FP.CPI.TOTL”)

Figure 4.4. 2: Log of Brent Crude Oil Price (UK)



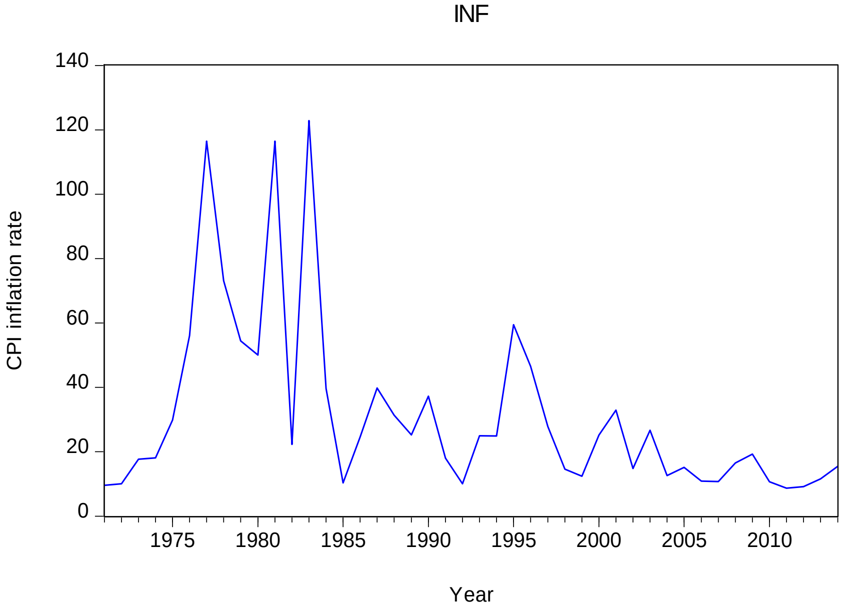
Source: British Petroleum oil price series (BP-Statistical_Review_of_world_energy_2014_workbook)

Figure 4.4. 3: Log of Bank of Ghana Short Term Nominal Interest Rates



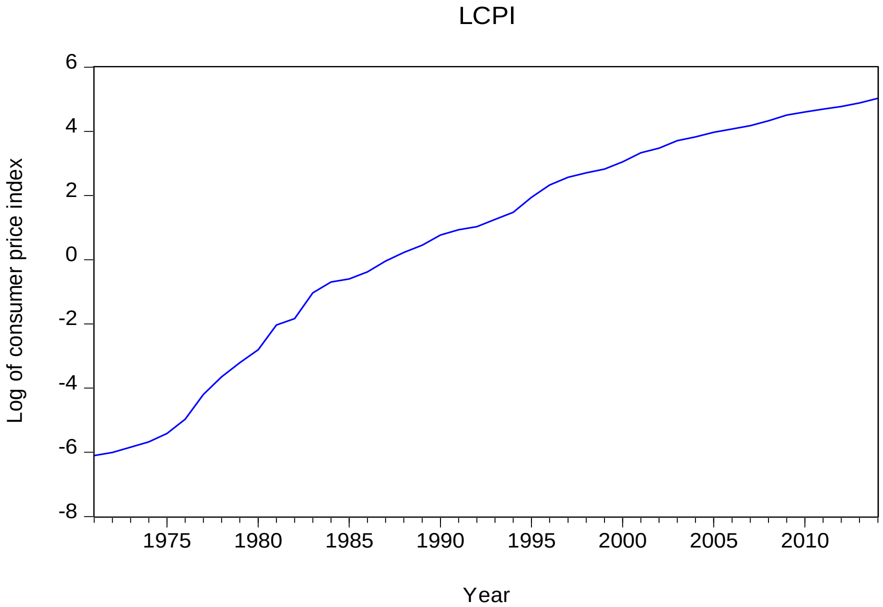
Source: Kingston University data stream (GSS 2014, Series Code: GHY60…)

Figure 4.4. 4: Ghana's CPI inflation rate



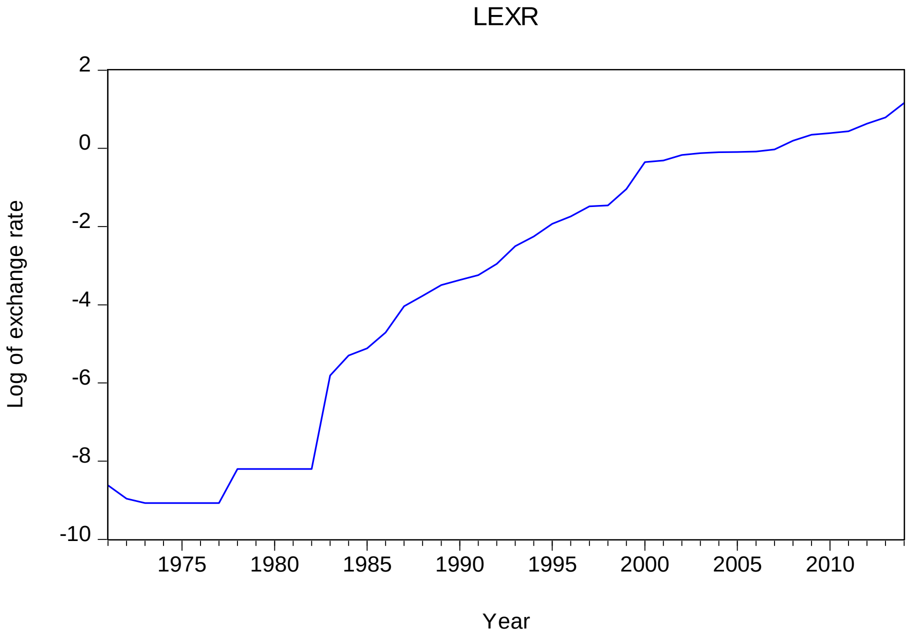
Source: IMF International Financial Statistics series for CPI inflation (IMF 2014, Series Code: "64---XZF---CPI%CHG. OVER CORRESPONDING PERIOD OF PREVIOUS YEAR")

Figure 4.4. 5: Log of the Consumer Price Index CPI



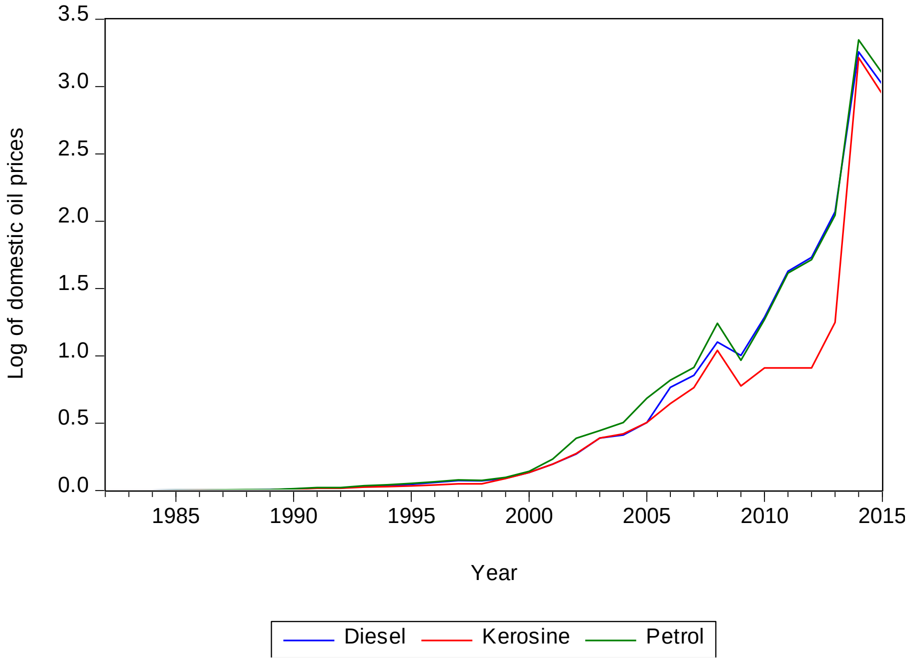
Source: World Bank series for Consumer Price Index (2010=100) (World Bank 2014, Series Code: "FP.CPI.TOTL")

Figure 4.4. 6: Log of Ghana cedi exchange rate



Source: IMF International Financial Statistics series for GH₵/US$ (IMF 2017, Series Code: “AE---ZF---)

Figure 4.4. 7: Log of Diesel, Kerosene, and Petrol Prices



Source: Bank of Ghana Statistical Bulletin (available online at www.bog.gov.gh)

As we can see from the graphs in figure 4.4.1, there is no noticeable difference between total GDP and non-oil GDP for the entire sample period. By visual inspection, the two variables have the same trend and their structural breaks occurring on the same dates. In the 1970s, military coups and counter coups in Ghana created macroeconomic uncertainty and this affected GDP growth and some key macroeconomic indicators such as nominal interest rates and the inflation rate. The political instability might have caused the possible structural breaks and the decline in GDP which was witnessed from the mid-1970s to the mid-1980s. The inflation rate was also highly volatile during that period. But Ghana's adoption of the structural adjustment and economic recovery programs from the IMF and the World Bank brought some steady growth to the economy as we can see from the trend in LRGDP and LRNOGDP. However, nominal interest rates continued to trend upwards (with a possible structural break occurring in 1991) because of investors' perceived risk to invest in Ghana due to the military regime that was still in place at the time.

In 1992, Ghana returned to democratic governance and this created new opportunities and a conducive business environment in the country for investors from both home and abroad. Perhaps, this explains the decline in interest rates from around 1995. Inflation rate volatility also reduced from the mid-1980s reflecting the impact of the structural adjustment programs – although possible structural breaks continued to occur. It is important to note that the monetary authorities in Ghana have been unable to manage a balance between economic growth and inflation targets for several decades. In particular, inflation stabilization has been a major problem facing the government. In most cases, the government's monetary policies designed to stabilize inflation has been ineffective, and this helps to explain why the inflation rate is erratic.

A structural break in oil prices occurred in 1973 and this reflects the oil shock in that year. This was the first oil shock which was a consequence of the Gulf oil producing states cutting back oil supply in the wake of the Arab-Israeli war in 1973. This shock was then followed by the 1979 and 1981 shocks. The 1979 shock was due to the political turmoil in Iran caused by the Islamic revolution in that year, whilst the 1981 shock was caused by the Iran-Iraq war. The graph also shows structural shocks in oil prices in 1986, 1990, 1998, 2003, and 2008. The 1986 shock was an oil price collapse caused by a supply glut in the 1980s. The glut started from the beginning of the 1980s as a result of slowed economic activities in developed countries. After 1980, reduced demand and increased production caused a serious surplus of crude oil on the world market. This led to a six-year decline in oil prices, which ended by falling more than half in 1986 alone. The oil price shock of 1990 occurred in response to the invasion of Kuwait by Iraq on 2 August 1990. The oil supply uncertainty created by the war pushed up oil prices from $17 per barrel in July to $36 per barrel in October of that year. The 1998 shock was due to the 1997 Asia/Pacific economic recession which was not noticed by international financial institutions until several months into 1998. Indeed, the decline in the Asia/Pacific oil demand resulting from the 1997 crisis became visible in 1998. Another cause of this shock could have been due to the warmer weather during the first quarter of 1998 in the United States which reduced oil demand. On the supply side, OPEC's decision to raise production quotas in November 1997 and the UN's decision to permit Iraqi oil exports have contributed to a supply glut which drove down prices. The 2003 shock was mainly due to oil supply shortages and supply uncertainty created by the US-led invasion of Iraq in that year, whilst the 2008 shock was a reflection of the sharp decline in oil prices caused by the global financial crisis. There also appears to be a decline in oil prices in 2014. This is reflecting the collapse of oil prices in the final quarter of 2014 due to the discovery of shale oil from the United States which propelled a decline in US oil demand.

The Ghana cedi exchange rate (as depicted in figure 4.4.6) also experienced structural shocks in 1978 and 1983. Before 1978, Ghana had maintained a fixed exchange rate regime for over a decade in which the cedi was pegged to the US dollar. In 1978, the authorities decided to float the currency for the first time. High inflation followed, leading to a sudden rise (depreciation) of the cedi exchange rate. This caused the exchange rate shock in 1978. After the shock, the authorities re-pegged the cedi at ₵2.80=$1.00. This exchange rate remained as the official cedi rate for the next five years. By 1983, Ghana was faced with several economic challenges including trade deficits and balance of payment problems. The World Bank and the IMF viewed the pressure on the external sector to be caused by overvaluation of the domestic currency. Hence, as part of the economic recovery program, Ghana agreed to adopt a flexible exchange rate regime and devalue the cedi. This led to a spike in the cedi exchange rate in 1983, and since then, the cedi has been depreciating alarmingly. Thus, the exchange rate shock in 1983 represents the effect of the exchange rate reform in that year.

As the graphs in figures 4.4.1 to 4.4.7 suggest, all the series show a visual trend (except inflation rate which does not show a trend by visual inspection). This implies the series are likely to be non-stationary and will need to be differenced to induce stationarity. Hence, in order to obtain a meaningful regression analysis, we will start by testing the variables in order to establish whether they contain a unit root (i.e. testing for non-stationarity). If all the variables in the model are found to be $I(1)$, we shall test for cointegration and estimate VAR/VECMs using differenced series.

4.4.2: Unit Root Test Results

The first step in understanding the relationship amongst the variables is to determine the order of integration of each variable included in the model. To do so, two commonly used unit root test procedures have been applied. These tests are the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. In order to analyse the data series, we used the Eviews 8 software package. The null hypotheses are examined using the MacKinnon (1996) critical values in both tests. In selecting the optimal lag length for the ADF test, we use the BIC criterion proposed by Ng and Perron (2001). The optimal lag length varies across the series as it can be seen in panel (a) of table 4.4.2. The table reports the results of the ADF and PP tests. The ADF test results are shown in panel (a) while the PP test results are reported in panel (b).

It is evident that for the model with an intercept only, the null hypothesis of a unit root cannot be rejected for LRNOGDP, LRGDP, LCOP, LIR, and LEXR in their levels for the ADF test. The test statistics for these variables are less than the critical values at the 5% level of significance. On the other hand, the test statistics for LCPI, LDIESEL, LKEROSENE, and LPETROL are higher than the critical values at the 5% level of significance, suggesting that these variables are stationary in levels. In first differences, all the variables become stationary at the 5% level of significance. For the model with an intercept and trend, only LEXR, LDIESE, and LKEROSENE are stationary in levels – the null hypothesis of a unit root cannot be rejected for the rest of the series at any significance level. In first differences, the unit root null is rejected for all the series.

Table 4.4. 2: ADF and PP unit root test results

Panel (a): ADF test								
	Intercept only				**Intercept and trend**			
	Data in levels		Data in first differences		Data in levels		Data in first differences	
	t-statistic	Lag	t-statistic	Lag	t-statistic	Lag	t-statistic	Lag
LRNOGDP	1.88	0	-4.54***	0	-1.02	0	-5.59***	0
LRGDP	1.98	0	-4.48***	0	-0.94	0	-5.58***	0
LCOP	-2.23	0	-6.23***	0	-2.50	0	-6.27***	0
LIR	-1.81	0	-7.77***	0	-1.47	0	-7.97***	0
LCPI	-3.68**	0	-2.41	1	0.01	0	-5.29***	0
LEXR	-1.35	0	-23.52***	0	-11.02***	0	-6.12***	9
LDIESEL	-4.10***	0	-4.73***	0	-4.13**	0	-5.63***	0
LKEROSENE	-3.36**	0	-5.55**	0	-3.91**	0	-5.93***	0
LPETROL	-3.73***	0	-5.22***	0	-3.20	0	-6.06***	0

Panel (b): PP test				
	Intercept only		**Intercept and trend**	
	Data in levels	Data in first differences	Data in levels	Data in first differences
	t-statistic	t-statistic	t-statistic	t-statistic
LRNOGDP	1.36	-4.54***	-1.04	-5.52***
LRGDP	1.68	-4.42***	-0.94	-5.52***
LCOP	-2.23	-6.23***	-2.49	-6.27***
LIR	-1.74	-7.75***	-1.31	-8.02***
LCPI	-3.10**	-3.97***	-0.23	-5.25***
LEXR	-1.56	-24.90***	-7.72***	-26.19***
LDIESEL	-4.10***	-4.71***	-4.46***	-5.75***
LKEROSENE	-3.37**	-5.65***	-3.88**	-6.15***
LPETROL	-3.73***	-5.24***	-3.28	-6.22***

Note: * indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Panel (b) of table 4.4.2 shows the results of the PP test. These results confirm the conclusions from the ADF test. In the model with intercept only, the null hypothesis of a unit root cannot be rejected for LRNOGDP, LRGDP, LCOP, LIR, and LEXR in their levels at any level of significance whilst the other variables are stationary. In their first differences, the null is rejected for all the series at any level of significance. Similarly, the unit root null cannot be rejected for LEXR, LDIESEL, and LKEROSENE in their levels in the model with intercept and trend, whilst in first differences, all the series are stationary. In general, except for the domestic oil prices (LDIESEL, LKEROSENE, and LPETROL) all the series are judged to be $I(1)$ either from the ADF test or the PP test, or in most cases both. LDIESEL, LKEROSENE, and LPETROL appear to be $I(0)$ from both the ADF and PP tests. However, the graphs in figure 4.4.7 suggest that these series are not $I(0)$ as they clearly do not have constant means. The same applies to LCPI as we can see from the graph in figure 4.4.5. Further, to conclude that price series are I(0) means we believe that prices are converging to a constant and will not increase in the future. We consider this implausible in a growing inflationary country such as Ghana and believe that the unit root test results for these series may be incorrect due to their known weaknesses (especially in smaller samples). As a result, we treat LCPI, LDIESEL, LKEROSENE, and LPETROL as I(1). If this is not the case, it may become apparent in our cointegration analysis.

Nevertheless, as Perron (1989) suggested, the ADF and PP tests may be unreliable when the variables under investigation include structural shocks such as political and economic events. Such shocks are likely to create structural breaks in the series. These breaks may bias unit root tests that do not recognise the possibility of their existence towards under-rejection of the unit root null hypothesis. In order to take into account any possible structural breaks, we proceed to conduct the Lee-Strazicich LM unit root test with two structural breaks.

Lee and Strazicich Unit Root test results

In the original Lee-Strazicich test, two structural break models are considered; model A and model C. Model A allows for two shifts in the level whilst model C allows for two changes in level and trend. This study assumes model C since some of the series exhibit trending behaviour. For a description of model C and its null and alternate hypothesis, see section 4.3.2 above (under Lee and Strazicich). The optimal lags are determined at each combination of two break points, following the general-to-specific procedure described by Lee and Strazicich (2003). Starting from a maximum of five lags, the optimal lag is determined endogenously in the testing procedure. After determining the optimal lags, the breakpoints are determined by examining each possible combination of two break dates over the $[0.1T, 0.9T]$ trimmed sample. The results are reported in table 4.4.3

Table 4.4. 3: Lee-Stracizich LM Unit Root tests with two structural breaks

	Intercept only			Intercept and trend		
Series	Lag	$\hat{T}_B$	t-statistic	Lag	$\hat{T}_B$	t-statistic
LRNOGDP	4	1979 1989	-1.46	5	1979 2004	-5.50
LRGDP	2	1981 2010	-3.15	2	1981 1992	-4.47
LCOP	5	1986 2008	-2.78	0	1980 1997	-4.08
LCPI	5	1981 1984	-2.72	4	1990 1995	-4.86
LIR	5	1981 1990	-2.28	0	1997 2007	-5.93**
LEXR	5	1980 1999	-3.33	5	1981 1994	-6.52**
LDIESEL	0	1989 1992	-0.16	4	1991 2007	-5.05
LKEROSENE	3	1997 2010	-1.00	4	1991 2007	-5.91**
LPETROL	0	1989 2008	-0.60	3	1991 2007	-5.40

Note: critical values are drawn from Lee and Stracizich (2003) critical values

*** denotes significance at 1% level

** denotes significance at 5% level

* denotes significance at 10% level

The results in table 4.4.3 suggests that the null hypothesis of a unit root cannot be rejected for LRNOGDP, LRGDP, LCOP, LCPI, LDIESEL, and LPETROL for both the intercept only and intercept and trend models as their t-statistics are less than the Lee and Stracizich critical values. This suggests that these series contain a unit root in both models. LIR, LEXR and LKEROSENE also contain a unit root for the model with intercept only as their t-statistics suggest. However, if we consider the model with intercept and trend, these series are stationary in levels since the unit root null can be rejected at the 5% significance level.

The results here support some of the ADF and PP tests results as both tests appear to suggest that some of the series contain a unit root either from the model with intercept only, or the model with intercept and trend. The notable difference between the Lee and Stracizich test results and the traditional ADF and PP tests results is that the domestic oil price variables (namely; LDIESEL, LKEROSENE, and LPETROL) which were found to be I(0) under the ADF and PP tests, are I(1) in the Lee and Stracizich test where structural breaks in the series have been accounted for. As we noted earlier, Perron (1989) and several others have highlighted the importance of allowing for structural breaks in unit root testing. In general, some series are unambiguously I(1) whilst for other series, they could be I(1) or I(0). However, the graphs in table 4.4.7 show that all the series are rising through time and therefore, are likely to be nonstationary. For these series to be I(0), one have to believe that the prices will not rise in the future which is not realistic. Besides, the short sample size of the domestic oil price variables may reduce the reliability of inferences from unit root tests. Thus, we can assume that the domestic oil prices and all the other series contain a unit root, and therefore are all I(1). The consequences of treating variables as I(0) when they are actually I(1) is a spurious regression.

However, there is no spurious regression when variables are assumed to be I(1) even if they are actually I(0). The evidence that structural breaks are present in the variables is shown in Table 5.3, and the break dates vary across the series.

4.4.3. Selection of Optimal Lag Lengths in the VAR

The next step is to determine the optimal lag length for the VAR system. Unnecessarily long lag lengths will reduce estimation precision by limiting the degrees of freedom in the data but excessive truncation of the lag length can lead to omitted variable bias and autocorrelation. In the lag selection, the optimal lag length is determined using a VAR system which is developed to investigate the dynamic relationship between the variables.

To perform this step, five different criteria are used to determine the lag length of the VAR. These include; the likelihood ratio (LR) test, the final prediction error (FPE), the Akaike information criterion (AIC), the Schwarz information criterion (SC), and the Hannan-Quinn information criterion (HQ). These testing procedures have been explained by Luektepohl (1995). The likelihood ratio test statistic is expressed as:

$$\lambda LR = 2[Llnl(\tilde{\delta}) - lnl(\tilde{\delta}_r)]$$

where $\tilde{\delta}$ is the unrestricted maximum likelihood estimator for a parameter δ derived from maximizing the likelihood function over the full possible parameter space, whilst $\tilde{\delta}_r$ is the restricted maximum likelihood estimator over that part of the parameter space which satisfies the restrictions of interest. Essentially, the unrestricted model includes one more lag than the restricted model in the tests. A statistic exceeding the critical value indicates the need for the extra lag specified in the unrestricted model.

Luektepohl (1995) also expressed the order testing procedures based on minimizing some objective function. The final prediction error is defined as follows:

$$FPE(m) = \left[\frac{T+Km+1}{T-Km-1}\right]^{K} det\tilde{\Sigma}_u(m).$$

where m denotes the lag order of the VAR, T is the total sample size of the data, K is the number of endogenous variables in the VAR, and $det\tilde{\Sigma}_u(m)$ is the determinant of the residuals of the system VAR. The estimate $\hat{p}(FPE)$ of p is chosen such that

$$FPE[\hat{p}(FPE)] = min\{FPE(m)|m = 0,1,\dots,M\}.$$

The lag order minimizing the FPE values is chosen as an estimate for p.

The Akaike information criterion is expressed as:

$$AIC(m) = ln\left|\tilde{\Sigma}_u(m)\right| + \frac{2mK^2}{T}$$

The estimator $\hat{p}(AIC)$ is chosen for p such that this criterion is minimized.

The Schwarz criterion is defined as follows:

$$SC(m) = ln\left|\tilde{\Sigma}_u(m)\right| + \frac{lnT}{T}mK^2$$

Similarly, the estimate $\hat{p}(SC)$ is chosen as to minimize the value of the criterion.

Finally, the Hannan-Quinn criterion is expressed as:

$$HQ(m) = ln\left|\tilde{\Sigma}_u(m)\right| + \frac{2lnlnT}{T}mK^2$$

Again, the estimate $\hat{p}(HQ)$ is the order that minimizes $HQ(m)$ for $m = 0,1,\dots,M$.

Selecting the optimal lag length from these criteria involves two stages. Firstly, choose the smallest lag length from among those suggested. Secondly, apply an autocorrelation test to the residuals, and increase the lag length incrementally until the null of no serial correlation is accepted. The smallest lag length with a differenced VAR free from autocorrelation is therefore, chosen.

The next section discusses the estimation of the models to be used and the analysis of the results of the macroeconomic effects of both world crude oil price and domestic oil price shocks in Ghana.

4.4.4 Model Estimations and Presentation of Results

In this section, we will examine the results of the oil price effects where world crude oil prices are treated as an exogenous variable in some models, and endogenous in other models. The exogenous crude oil price models include structural VAR analysis, forecast scenarios where the crude oil price is included in the VAR as an exogenous variable, and the ARDL model. The endogenous crude oil price models employ standard reduced form VARs where all the variables including crude oil prices are treated as endogenous. For the domestic oil price models, we only estimated standard reduced form VARs to examine the domestic oil price effects on the non-oil GDP and GDP growth rate. Because the domestic oil prices are influenced by government policies and domestic economic conditions, the domestic oil prices do not need to be treated as exogenous.

4.4.4.1 Exogenous Crude Oil Price Models

Structural VAR Analysis

In treating crude oil prices as exogenous, a structural VAR with an identification scheme that makes oil price exogenous could be appropriate. For example, Ahmed and Wadud (2011, page 8065) and Park et al (2011, page 8187) used the following identification for Malaysia and Korea, respectively:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & a_{52} & a_{53} & 0 & 1 & a_{56} & 0 \\ a_{61} & 0 & a_{63} & 0 & a_{65} & 1 & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{COP} \\ u_{ip} \\ u_{cpi} \\ u_{ff} \\ u_{m} \\ u_{IR} \\ u_{exc} \end{bmatrix} = \begin{bmatrix} \varepsilon_{COP} \\ \varepsilon_{ip} \\ \varepsilon_{cpi} \\ \varepsilon_{ff} \\ \varepsilon_{m} \\ \varepsilon_{IR} \\ \varepsilon_{exc} \end{bmatrix} \qquad (4.4.1)$$

where the ε_x are structural shocks and the u_x are the resulting reduced form disturbances. COP represents international crude oil price, ip represent industrial production, cpi represents the consumer price index, ff represent the US federal funds rate, m represents the money supply, r represents the domestic interest rate, and exc represents the domestic exchange rate. In this identification strategy, the coefficient matrix *A* is a block-diagonal and the leading 4x4 block is lower triangular, so that A^{-1} will be similarly block-diagonal with a lower triangular leading block. Consequently, the international crude oil price is represented as exogenous because only ε_{COP} has immediate effect on u_{COP}. This identification strategy is based on a modified Kim and Roubini (2000) model that accounts for external shocks emanating from oil price changes.

Following Ahmed and Wadud (2011) and Park et al (2011), we develop and investigate a 5-variable SVAR model to investigate the oil price-macro economy relationship for Ghana in which the crude oil price is treated as exogenous. We can express an SVAR in the following form:

$$Ay_t = \overset{\delta}{A}_1 y_{t-1} + \cdots + \overset{\delta}{A}_p y_{t-p} + \overset{s}{C} x_t + Bu_t \qquad (4.4.2)$$

where A, all of the $\overset{\delta}{A}_i$, and $\overset{s}{C}$ are the structural coefficients, and the u_t are the unobserved structural innovations with $E(u_t u_t') = I_k$

Assuming that A is invertible, we have

$$\begin{aligned} y_t &= A^{-1}\overset{\delta}{A}_1 y_{t-1} + \cdots + A^{-1}\overset{\delta}{A}_p y_{t-p} + A^{-1}\overset{s}{C} x_t + A^{-1}Bu_t \\ &= A_1 y_{t-1} + \cdots + A_p y_{t-p} + Cx_t + \epsilon_t \end{aligned} \qquad (4.4.3)$$

where, the reduced-form lag matrices are $A_i = A^{-1}\overset{\delta}{A}_i$ and $C = A^{-1}\overset{s}{C}$. Also, the reduced-form error structure is given by

$$\begin{aligned} &\epsilon_t = A^{-1}Bu_t = Su_t \\ &E(\epsilon_t \epsilon_t') = \Sigma_\epsilon = A^{-1}BB'^{A^{-1}\prime} = SS' \end{aligned} \qquad (4.4.4)$$

where $S = A^{-1}B$

From equation (4.4.4), we can write the A-B short run restrictions model as:

$$\begin{aligned} &\epsilon_t = A^{-1}Bu_t \\ &A\,\epsilon_t = Bu_t \\ &\Sigma_\epsilon = A^{-1}BB'A^{-1}B' \end{aligned} \qquad (4.4.5)$$

The relationships expressed in (4.4.4) and (4.4.5) can be used to estimate the responses of macroeconomic variables to shocks to other variables. The impulse responses of the endogenous variables to structural shocks are defined using matrix A, whilst matrix B contains the structural parameters of the model.

In our model, the data vector of the macroeconomic variables (expressed in logarithm form) includes the following;

$[\Delta LCOP_t, \Delta LRNOGDP_t, \Delta LCPI_t, \Delta LIR_t, \Delta LEXR_t]$

where LCOP is the log of the world crude oil price, LRNOGDP is the log of the real non-oil GDP of Ghana, LCPI is the log of the consumer price index, LIR is the log of the interest rate, and LEXR is the log of the Ghana currency exchange rate expressed as a unit of the Ghana cedi per the quoted units in US dollars. In the model, LCOP, LRNOGDP, LCPI, LIR, and LEXR are denoted by the numbers 1, 2, 3, 4, and 5 respectively. Using the identification scheme of Ahmed and Wadud (2011) and Park et al (2011), the SVAR can be presented as:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & 0 & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} u_{COP} \\ u_{RNOGDP} \\ u_{CPI} \\ u_{IR} \\ u_{EXR} \end{bmatrix} = \begin{bmatrix} \varepsilon_{COP} \\ \varepsilon_{RNOGDP} \\ \varepsilon_{CPI} \\ \varepsilon_{IR} \\ \varepsilon_{EXR} \end{bmatrix} \tag{4.4.6}$$

where the ε's are structural shocks and the u's are the resulting reduced form disturbances. COP represents international oil price, $RNOGDP$ represent real non-oil GDP, CPI represents the consumer price index, IR represents the domestic interest rate, and EXR represents the domestic exchange rate. Row (1) in the SVAR system depicts crude oil prices as exogenous to all the domestic variables. Row (2) shows a contemporaneous response of non-oil GDP to crude oil prices. We assume an inverse relationship between oil prices and GDP such that an increase in oil prices will raise energy input prices which can adversely affect output. GDP meanwhile, is exogenous to CPI, interest rates, and exchange rates in the short run. Whilst these variables will eventually influence GDP, such influence can only happen after the current time period (i.e. a one-period lagged effect). In row (3), CPI is assumed to respond contemporaneously to crude oil prices and non-oil GDP. The international oil price is an external shock that can affect domestic prices whilst the GDP effect represents the responses to changes in prices due to domestic aggregate demand or output changes.

In row (4), interest rates respond to international oil prices and CPI. It is assumed that the monetary authorities will take actions in response to inflationary pressures by tightening monetary policies. Therefore, interest rates will respond to factors related to inflationary pressures such as oil prices and CPI. Row (5) depicts that exchange rates respond contemporaneously to all the current variables. Because the exchange rate is a forward-looking asset price, it can be assumed that all the variables in this equation have a contemporaneous effect on the exchange rates. The dynamic effects of oil price shocks on real non-oil GDP, CPI, interest rates, and exchange rates are determined by the parameter estimates of a_{21}, a_{31}, a_{41}, and a_{51} respectively.

The identifying restrictions stated above are commonly referred to as short run restrictions. Blanchard and Quah (1989) proposed an alternative identification method using restrictions based on the long run[5] properties of the accumulated impulse responses. These long run restrictions can be written as:

$$
\begin{aligned}
&(I - A_1 - A_2 - \cdots - A_p)^{-1} \epsilon_t = \Psi \epsilon_t = F u_t \\
&\Sigma_\epsilon = \Psi^{-1} F F' \Psi^{-1\prime}
\end{aligned}
\qquad (4.4.7)
$$

[5] Long run in this context does not mean there is cointegration between level variables as it does in the Johansen's procedure. Long run here refers to the accumulated impulse responses in the long run.

where $\Psi = (I - A_1 - A_2 - \cdots - A_p)^{-1}$ is the long run multiplier. Thus, the elements of this F matrix are used in identifying the long run restrictions. Using the F matrix, our long run SVAR can be expressed as:

$$\begin{bmatrix} f_{11} & 0 & 0 & 0 & 0 \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} \\ f_{31} & f_{32} & f_{33} & 0 & f_{35} \\ f_{41} & f_{42} & f_{43} & f_{44} & 0 \\ f_{51} & f_{52} & f_{53} & f_{54} & f_{55} \end{bmatrix} \begin{bmatrix} u_{COP} \\ u_{RNOGDP} \\ u_{CPI} \\ u_{IR} \\ u_{EXR} \end{bmatrix} = \begin{bmatrix} \varepsilon_{COP} \\ \varepsilon_{RNOGDP} \\ \varepsilon_{CPI} \\ \varepsilon_{IR} \\ \varepsilon_{EXR} \end{bmatrix} \tag{4.4.8}$$

In the long run model, some of the restrictions that were imposed in the short run model have been relaxed. For example, the CPI, interest rates, and exchange rates are all assumed to have an effect on the GDP. These variables are assumed not to affect real economic activity instantaneously, but they will do so with a one-period lag. Evidence also suggests that exchange rates will feed through to CPI, but such pass-through will likely occur slowly over time (e.g. see Goldberg and Knetter, 1996). Hence exchange rates are also allowed to affect CPI in this long run model. Here, the oil price effects on the real non-oil GDP, CPI, interest rates, and exchange rates are determined by the coefficients of f_{21}, f_{31}, f_{41}, and f_{51} respectively.

Unfortunately, there is an issue with initial values and convergence cannot be achieved when estimating the SVAR model with the above long run restrictions. This could be due to the sample size because the long run model requires large parameters to be estimated and the sample size may be too small for such as a model – our sample size is relatively small because we are using annual data. However, if we reduce the number of parameters by restricting the long run effects of CPI, interest rates, and exchange rates on non-oil GDP to zero, our target parameter estimates which are the long run effects of crude oil prices on the non-oil GDP and the other economic variables will be estimated. Also, the long run output results of the estimated model show that the structural VAR model is “just-identified” implying that the model is properly identified. Hence, although the extra parameters we included in the long run model have not been estimated, the parameters that have been estimated by the model are still sufficient for the purpose of this paper.

Another issue to consider is the ordering of the variables in the impulse response analysis. In Cholesky factorizations, variables are ordered by placing them in the decreasing order of exogeneity such that the most exogenous variables are placed first, then the second, and so on until the last variable for which all the other variables have effect on it. This also means that variables that are not expected to have any predictive value for other variables should be put last. The ordering that we adopted in the impulse response analysis of the SVAR system follows this rule. The most exogenous variable is the crude oil price, hence, the crude oil price is placed first. The second most exogenous variable is the real non-oil GDP because the other domestic variables are unlikely to have an instantaneous effect on GDP in the short term whilst the world oil price can affect GDP. CPI is assumed to respond directly to the price of oil and GDP growth but it is also assumed to be exogenous to monetary policy and the exchange rate in the short run. The next variable is the interest rate which is assumed to be affected by CPI inflation, GDP growth, and the price of oil. It is assumed that the monetary authorities will take action in response to inflationary pressures or a decline in output. Hence, factors related to inflation such as oil prices and the CPI, as well as output growth will be expected to affect interest rates. On the other hand interest rates are assumed to be exogenous to exchange rates in the short run because the monetary authorities will not take immediate action to exchange rate shocks. Finally, there are no restrictive assumptions with regards to the exchange rates. The exchange rates are assumed to be affected by all the current variables. Perhaps, the explanations given in our identification strategy helps to explain this ordering in detail. This ordering strategy is also used in Park et al (2011) where oil price is placed first as the most exogenous variable whilst the exchange rate is placed last.

In tables 4.4.4 and 4.4.5, we report the short run and long run estimated coefficients, standard errors, and probability values of the structural VAR model. The results of the short run restrictions are reported in table 4.4.4 whilst the results of the long run restrictions are reported in table 4.4.5. At the bottom of table 4.4.4, we reported the likelihood ratio test of the over-identifying restrictions. Our identifying restrictions are not rejected at any conventional level of significance.

Table 4.4. 4: Contemporaneous Coefficients in the short term structural model

	Coefficient	Std. Error	z-Statistic	Prob.
a_{21}	0.017333	0.059404	0.291782	0.7705
a_{31}	0.046133	0.060305	0.764994	0.4443
a_{41}	0.081695	0.087628	0.932294	0.3512
a_{51}	0.224572	0.138215	1.624803	0.1042
a_{32}	0.830302	0.156485	5.305943	0.0000
a_{52}	-0.790983	0.456002	-1.734604	0.0828
a_{43}	-0.752613	0.173319	-4.342353	0.0000
a_{53}	-1.117835	0.394355	-2.834592	0.0046
a_{54}	-0.251946	0.239662	-1.051253	0.2931
Log likelihood	44.28213			
LR test for over-identification:				
Chi-square(1)	0.026143		Probability	0.8716

Table 4.4. 5: Contemporaneous Coefficients in the long term structural model

	Coefficient	Std. Error	z-Statistic	Prob.
f_{11}	0.349260	0.038107	9.165150	0.0000
f_{21}	-0.026283	0.031681	-0.829611	0.4068
f_{31}	0.019467	0.052942	0.367696	0.7131
f_{41}	-0.044855	0.028416	-1.578521	0.1144
f_{51}	-0.262030	0.066158	-3.960665	0.0001
f_{22}	0.204471	0.022310	9.165150	0.0000
f_{32}	-0.309748	0.040696	-7.611202	0.0000
f_{42}	-0.093353	0.026072	-3.580593	0.0003
f_{52}	-0.128362	0.057995	-2.213338	0.0269
f_{33}	0.146929	0.016031	9.165150	0.0000
f_{43}	0.060362	0.023079	2.615509	0.0089
f_{53}	0.127950	0.054519	2.346889	0.0189
f_{44}	0.143347	0.015640	9.165150	0.0000
f_{54}	0.013404	0.052681	0.254441	0.7992
f_{55}	0.341281	0.037237	9.165150	0.0000
Log likelihood	44.29520			

Structural VAR model is just-identified

From the results in table 4.4.4, the coefficient of a_{21} is positive and statistically insignificant. This suggests that the response of the non-oil GDP to oil price shocks is insignificant in the short run. The positive sign also indicates that oil price increases turn to promote economic growth. The only significant relationships in the model are the effect of non-oil GDP on the consumer price index, and the effect of the consumer price index on interest rates and exchange rates. The effect of crude oil price shocks on the exchange rate is also insignificant as the z-statistic of a_{51} (1.624803) is not significant. The long run dynamic effects in table 4.4.5 indicate that the oil price effect on non-oil GDP is still insignificant even in the long run as indicated by the z-statistic of f_{21}. Note that 1 lag has been used in the SVAR model because a lag order of 1 was chosen by the likelihood ratio test (**see appendix B1**), and using 1 lag produces no serial correlation. The model is also free from heteroscedasticity, but the normality test reveals that the Jarque-Bera statistic for the joint test is very high suggesting that the model has not passed the normality test (although the test statistic for some of the individual components indicate that the residuals of the model are normally distributed[6]). The autocorrelation, heteroscedasticity, and normality tests are reported in **appendices B2, B3, and B4** respectively**.**

We also estimated the dynamic impulse response functions for the identification scheme in our model. We use the structural decomposition method which shows the impulse response of each variable from shocks to the underlying fundamental shocks. The graphs of the impulse response functions for the short run SVAR model are presented in figure 4.4.8 whilst the impulse response graphs for the long run SVAR model are presented in figure 4.4.9. In both figures, shock 1 represents shocks to crude oil prices.

---

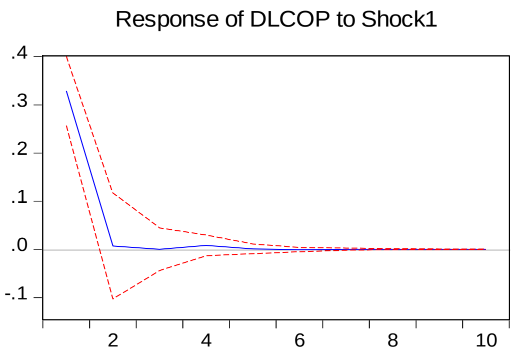
[6] When residuals are non-normally distributed, this implies that hypotheses tests on the coefficients do not follow normal distribution. Hence hypotheses tests on the coefficients do not use the critical values from the normal distribution and other critical values would be appropriate. Because our test statistic for the oil price in the non-oil GDP equation is very small, it is very unlikely that the appropriate critical values from the normal distribution would be so small as to cause the null hypothesis to be rejected. Hence, we are confident that the coefficients obtained from the models are not significantly different from zero. However, any hypotheses tests of interest are borderline using conventional critical values based on the normality assumption, we will be cautious in interpreting our results.

Also, as it is commonly known, tests of normality turn to have low power when the sample size is small. Because the data we used are annual, the size of the samples we used is relatively small than they otherwise would be if quarterly or monthly data was used. Hence, the rejection of the null hypothesis of normality in the models could also be due to the sample size of our data. Besides, Mills (lecture notes 2008) noted that with non-normality, OLS remains BLUE although hypotheses tests on coefficients do not follow normal distribution. In addition, the Central Limit Theorem suggests that the coefficients to a normal distribution in large samples even when the residuals are not normal (although some of our samples are not very large)

Figure 4.4. 8: Structural Impulse response functions for short run restrictions

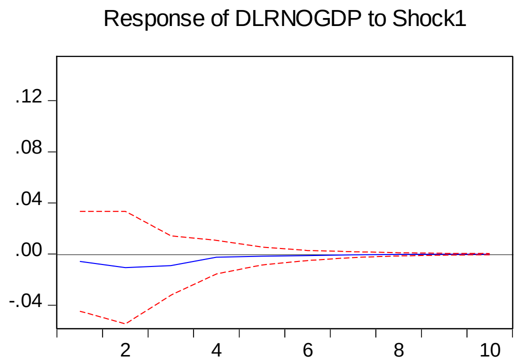
a) Response of DLCOP to DLCOP

Response to Structural VAR Innovations ± 2 S.E.



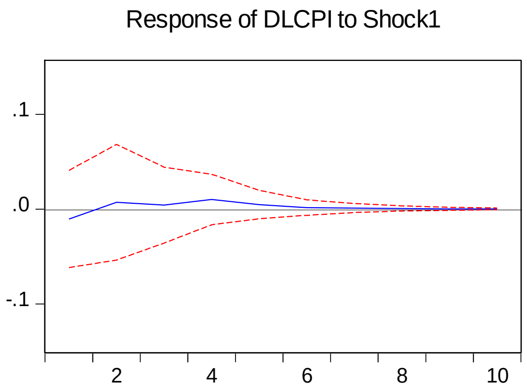
b) Response of DLRNOGDP to DLCOP

Response to Structural VAR Innovations ± 2 S.E.



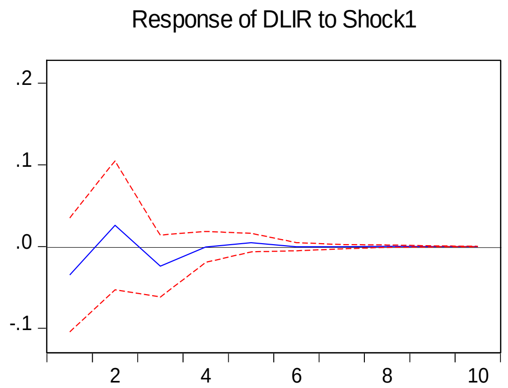
c) Response of DLCPI to DLCOP

Response to Structural VAR Innovations ± 2 S.E.



d) Response of DLIR to DLCOP

Response to Structural VAR Innovations ± 2 S.E.



e) Response of DLEXR to DLCOP

Response to Structural VAR Innovations ± 2 S.E.

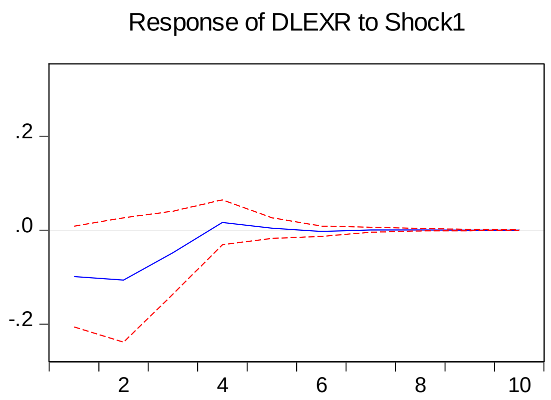
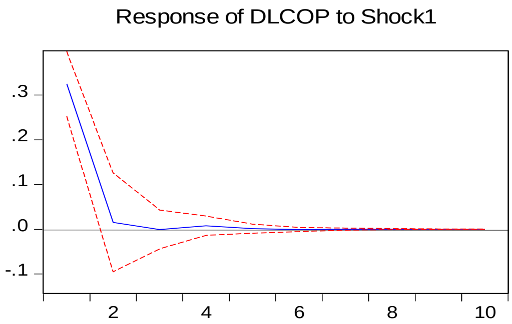
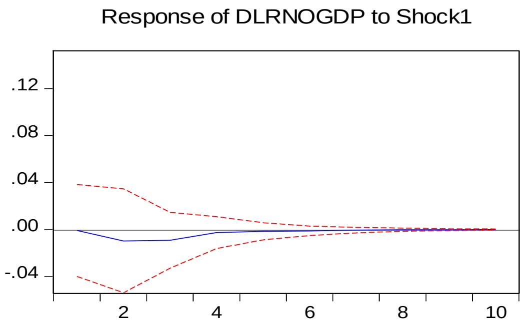


Figure 4.4. 9: Structural Impulse response functions for long run restrictions

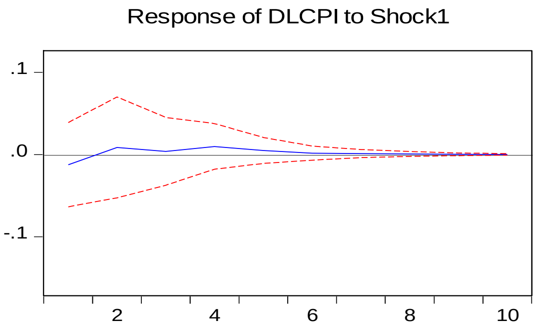
a) Response of DLCOP to DLCOP
Response to Structural VAR Innovations ± 2 S.E.



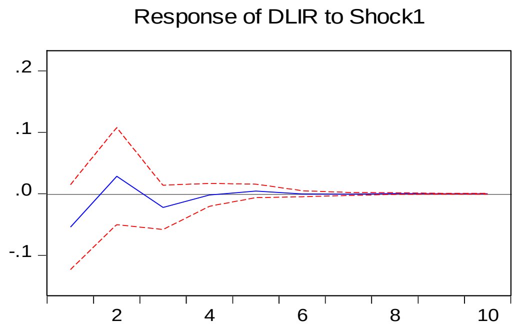
b) Response of DLRNOGDP to DLCOP
Response to Structural VAR Innovations ± 2 S.E.



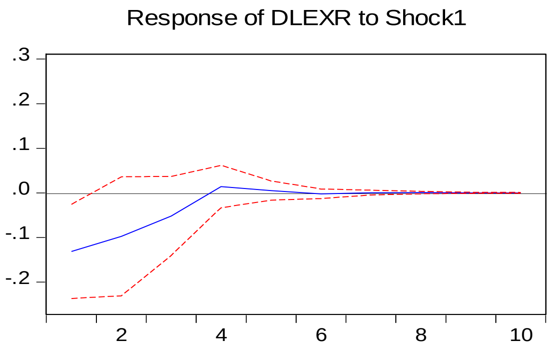
c) Response of DLCPI to DCLOP
Response to Structural VAR Innovations ± 2 S.E.



d) Response of DLIR to DLCOP
Response to Structural VAR Innovations ± 2 S.E.



e) Response of DLEXR to DLCOP
Response to Structural VAR Innovations ± 2 S.E.



The point estimates (impulse response) from the graph in figure 4.4.8b show that the response of non-oil GDP growth rate to crude oil price shocks is initially negative but close to zero. This effect increases slowly for about two years before declining, achieving equilibrium after about four years. However, the effect of the shock appears to be insignificant because zero lies between the confidence intervals. Also, the impulse response from the graph in figure 4.4.8e show that the initial effects of crude oil price shocks is a depreciation of the exchange rate. The exchange rate will however, return to equilibrium after 3 years. This result is not also highly significant since the value zero is within the confidence intervals. Hence, these graphs are consistent with the coefficients. The long run impulse response functions (reported in figure 4.4.9) are similar to the short run impulse response graphs. The difference however, is that in the long run, the initial response of the non-oil GDP to crude oil price shocks is actually zero, becoming negative after one year before declining to almost zero after four years. In both graphs, the oil price effects are not significantly different from zero which is consistent with the coefficient estimates. If we replicate this for the Cholseky decomposition, the graphs we obtain are identical in shape to the graphs reported above. The Cholesky decomposition graphs for the short run and long run restrictions are presented in **appendices B5 and B6** respectively. We also tried various possible ordering of the responses of the variables in the model to confirm that the results of the impulse response graphs are not related to the ordering of the variables. The shapes of the graphs from all the possible ordering we performed are also identical to the impulse response functions we reported above, and this confirms the robustness of the results. We also estimated the SVAR models with total GDP and the other variables using the same short run and long run specifications. The results of these models are reported in **appendices B7 and B8** in other to save space. The results suggest that the effect of crude oil price shocks on GDP is insignificant both in the short run and in the long run. This implies the crude oil price effect on non-oil GDP and GDP is qualitatively the same.

In the next section, we shall evaluate the second exogenous crude oil price model using forecast scenarios in a reduced form VAR where crude oil prices are included as an exogenous variable.

Dynamic Forecasting Using Scenarios

In this methodology, we shall estimate a five-variable VAR and a two-variable VAR, and these VARs will then be used to conduct some scenario forecasting. The variables included in the five-variable VAR follows the work of Tweneboah and Adam (2008) whilst the two-variable VAR follows Hamilton (2003) and Oladosu (2009). The five-variable model uses the same variables as in the SVAR model above whilst the two-variable model only consist of the non-oil GDP and the price of crude oil. In both specifications, the crude oil prices are included as exogenous in the VAR models.

All the variables included in the models have been tested for non-stationarity (see section 4.4.2), and the results suggest that all the variables can be considered as I(1) and are not integrated of order 2. As a result, all the data will be analysed in first differences (the difference of the log of prices being the inflation rate, is one of these variables). Including all variables in first differences ensures that they are stationary and that there is no issue of spurious regression. The general estimation equation for the VAR model is expressed as

$$\Delta Y_t = \delta + \sum_{i=1}^{p} A\Delta Y_{t-i} + B\Delta X_t + v_t \tag{4.4.9}$$

where $\Delta Y_t$is a vector of endogenous variables in first differences whilst ΔX_t is a vector of first-differenced exogenous variables, here simply the international price of oil. δ is a vector of constants that allow for trend growth in the levels of the variables whilst A and B are matrices of short run coefficients. Also, v_t is a vector of error terms whilst p is the lag order of the autoregression. For the five-variable model, we estimate a VAR in which the endogenous variables (expressed in logarithm form) are

$$LY_t = [LRNOGDP, LCPI, LIR, LEXR]'_t \qquad (4.4.10)$$

where $LRNOGDP$ is the log of the real non-oil GDP, $LCPI$ is the log of the consumer price index, LIR is the log of the Bank of Ghana' nominal interest rate, and $LEXR$ is the log of the domestic exchange rate against the US dollar. Also, the exogenous variable in the VARs can be expressed as:

$$\Delta X_t = [\Delta LCOP]_t \qquad (4.4.11)$$

where $LCOP$ is the log of the Brent crude oil price. See section 4.2 for the description and justification of the choice of these variables.

All the variables' levels are in logarithm form, and because the series are all found to be $I(1)$ (see section 4.4.2), their first differences have been taken so that the model is expressed in terms of stationary variables, reducing the risk of "spurious regression".

Starting with the five-variable model, the lag selection results of the various information criteria show that the LR, FPE, and AIC all selected lag 1 (**see appendix B9**). Based on the lag selection results, lag 1 was used to estimate the VAR model, and using this lag, the model is free from autocorrelation and heteroscedasticity. For the normality test, the Jarque-Bera statistic for the joint test is very high indicating a rejection of the null hypothesis of normality of the residuals (even though the Jarque-Bera statistic for some of the individual components in the normality test suggests that the residuals are normally distributed). The explanations given in footnote 6 for the normality test also apply to this model (**see footnote 6**). The diagnostic tests are reported in **appendices B10, B11, and B12**. As in the SVAR system, the ordering of the variables follows the Cholesky decomposition where the variables are placed in a decreasing order of exogeneity. Hence, in the set of endogenous variables, the real non-oil GDP is placed first, followed by the CPI, the interest rates, and the exchange rates.

The result of the estimated five-variable VAR model is presented in table 4.4.6. The first column in table 4.4.6 is the DLRNOGDP equation. It is a regression of non-oil GDP growth rate on:

- a constant;
- one lagged values of itself, the growth rates of the consumer price index, the exchange rate, and the interest rate;
- the current rate of growth of the oil price.

Table 4.4. 6: Estimated Results of the Basic Five-Variable VAR

	DLRNOGDP	DLCPI	DLIR	DLEXR
DLRNOGDP(-1)	0.197134	-0.420716	0.409826	-0.323384
	(0.21106)	(0.27390)	(0.37290)	(0.59284)
	[0.93403]	[-1.53601]	[1.09903]	[-0.54548]
DLCPI(-1)	-0.112930	0.357062	0.325126	0.423061
	(0.16128)	(0.20931)	(0.28496)	(0.45302)
	[-0.70020]	[1.70594]	[1.14097]	[0.93386]
DLEXR(-1)	0.002034	0.004197	0.028156	0.036944
	(0.01361)	(0.01767)	(0.02405)	(0.03824)
	[0.14943]	[0.23757]	[1.17050]	[0.96606]
DLIR(-1)	-0.048845	-0.191007	-0.315546	-1.007563
	(0.09867)	(0.12804)	(0.17432)	(0.27714)
	[-0.49505]	[-1.49172]	[-1.81011]	[-3.63554]
C	0.066876	0.192720	-0.071946	0.192446
	(0.05161)	(0.06698)	(0.09119)	(0.14497)
	[1.29579]	[2.87739]	[-0.78901]	[1.32751]
DLCOP	-0.019596	-0.027785	-0.101607	-0.363357
	(0.06502)	(0.08438)	(0.11487)	(0.18263)
	[-0.30140]	[-0.32930]	[-0.88452]	[-1.98963]
R-squared	0.133722	0.303847	0.323101	0.158230
Adj. R-squared	0.013406	0.207159	0.229087	0.041317
Sum sq. resids	0.589342	0.992555	4.649828	1.839702
S.E. equation	0.127948	0.166045	0.359391	0.226059
F-statistic	1.111422	3.142549	3.436745	1.353402

Standard errors in ( ) & t-statistics in [ ]

The t-statistics reported in the first column are all statistically insignificant. This suggests that the lagged values of the inflation rate (as measured by the consumer price index), and the rates of change of exchange rate, interest rate, and oil price have insignificant effect on the non-oil GDP growth rate in Ghana. Although the coefficient of crude oil price has the expected negative sign, the overall fit of the estimated equation to the data is low. However, the crude oil price effect on the exchange rate is non-trivial. The t-statistic of -1.98963 is very close to -2 suggesting that the effects of crude oil price shocks on the Ghanaian currency is almost significant at the 5% level (and is insignificant at the 10% level).

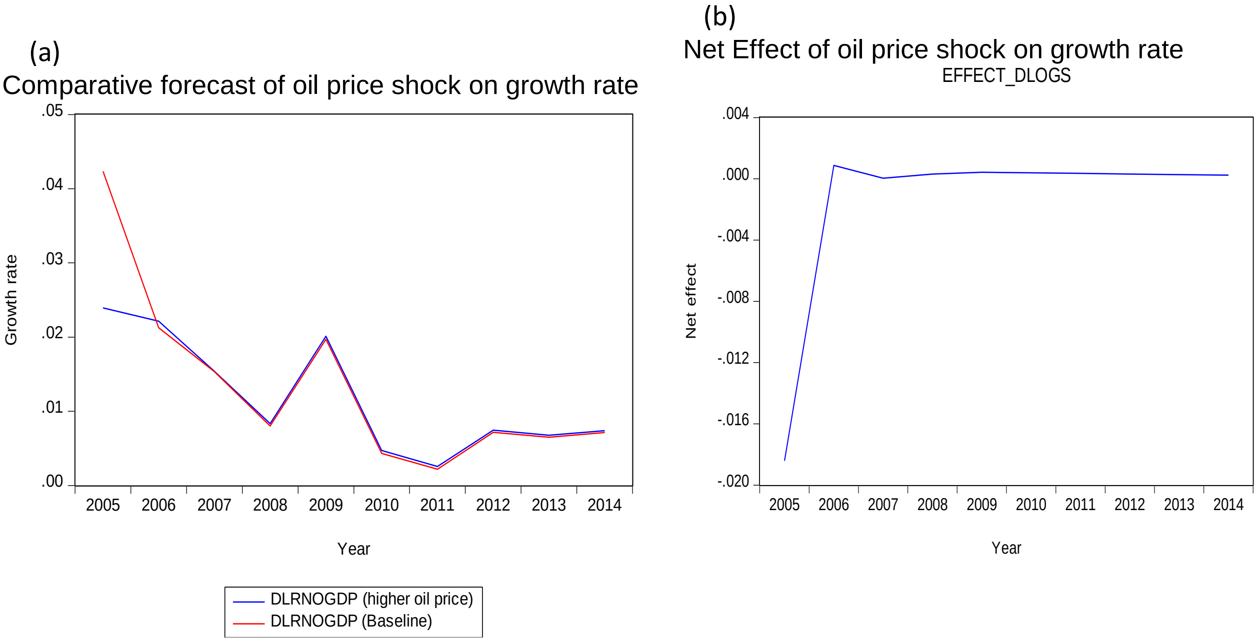
The failure of oil price shocks to significantly affect Ghana's GDP growth challenges the assumption of traditional economic theory. The theory suggests that for an established oil importing nation such as Ghana, oil price shocks have a significantly negative impact on the GDP growth rate. The evidence is also not consistent with the findings of some papers in the literature such as Fofana et al (2009), Rafiq et al (2009), Ozlale and Pekkurnaz (2010), Ahmed and Wadud (2011), Park et al (2011), and Guivarch et al (2009). These papers found a negative and statistically significant effect of oil price shocks on output and the trade balance in Malaysia, South Africa, India, Thailand, South Korea, and Turkey. Hamilton (1983), (1996) and (2003) also established a strong negative relationship between oil price shocks and the US GDP growth rate.

However, there are other papers in the literature whose results are also puzzling and appear to be consistent with our findings (e.g. Bernanke Gertler and Watson, 1997, Basky and Kilian, 2004, and Leduc and Sill, 2004). These papers did not find any evidence of significant relationship between oil prices and economic growth

To explore the dynamic response of non-oil GDP growth to a change in the rate of growth of the oil price based on the estimated VAR, this paper employs a scenario-based forecasting exercise. Because LCOP is exogenous, it is not appropriate to employ standard impulse response function analysis. Therefore, to determine the response of non-oil GDP growth to oil price shocks, we analyse the multiplier effects of DLCOP through a dynamic forecasting exercise. To perform this exercise, we convert the reduced form VAR into an Eviews model object, for which scenario simulations can be computed. We then create two scenarios: a baseline scenario and high oil price scenario, and solve the model for each one. The high oil price scenario has DLCOP=1 whilst the baseline scenario has DLCOP=0 for all years in the forecast period. Because of the linearity of the VAR, the choice of 1 for the high oil price scenario and 0 for the baseline scenario does not restrict the generality of the results. The baseline means no growth in oil prices (a zero rate of change) each period, whereas the high oil price scenario means a 100% (doubling) of the oil price in the first period. The estimation period starts from 1971 to 2014. However, we shall first conduct a scenario forecast to cover the final ten years of our sample period (i.e. 2005 to2014) to examine the response of the Ghanaian economy to oil price shocks during this period. We will then conduct a second forecast exercise into the future to cover the period from 2015 to 2024.

The graphs in figures 4.4.10a and 4.4.10b show the results of the dynamic forecasting exercise for the forecast period between 2005 and 2014. Figure 4.4.10a compares the predicted non-oil GDP growth rates for the two scenarios and figure 4.4.10b shows the implied net effect of the oil price shock. Both graphs suggest that the estimated effect of oil price shock on non-oil GDP growth rate is negative and very temporary. The graphs predict that the effect of a onetime oil price shock is transitory, becoming almost zero after about one and half years (although it reduces growth in the first year by almost 2 percentage points). This is not surprising from an economic perspective. The information from these graphs also supports the commonly held view that oil price shocks have a stagflationary effect on the economy of an oil importing country (e.g., see Hamilton 1996 and Hamilton 2003).

Figure 4.4. 10: The impact of higher oil price on non-oil GDP growth rate, 2005 to 2014



We can determine the multiplier effect of the oil price shock by examining the graphs in figure 4.4.10a above for higher oil price and baseline. The multiplier effect is the ratio of change in response variable divided by the change in the causal variable. In the simulation exercise, the causal variable is the log of oil price whilst the response variable is the log of real non-oil GDP. In figure 4.4.10a (comparative forecast of oil price shocks on growth rates), the gap between higher oil price and baseline are the multiplier effects. As we can see, the multiplier effects are negative and have been declining since 2005. This is illustrated in table 4.4.7. From table 4.4.7, the multiplier effect for 2005 was -0.019596. This declined to almost zero by 2010. It is important to note that the multiplier effects are negative because they are the ratios of negative response to higher oil price shocks.

Table 4.4. 7: Multiplier Effects of higher oil prices, 2005 to 2014

Year	Multiplier Effect
2005	-0.019596
2006	0.003499
2007	-0.001203
2008	-0.001022
2009	-0.000185
2010	-0.000131
2011	-7.95E-05
2012	-3.27E-05
2013	-1.64E-05
2014	-8.50E-06

Because the higher oil price and the baseline are different series, it is important to formally test the two series to determine whether they are statistically the same or different. To do so, we use three procedures which include some tests and statistics to determine whether the two series are generally different. Firstly, we calculate the correlation coefficient between the two series and test if this correlation is significantly different from zero. Secondly, we calculate the Mean Absolute Percentage Error (MAPE) to indicate the average difference of the two series in percentage terms. The MAPE is a measure of predicting forecasting accuracy in statistics, and it is usually expressed as a percentage. In our scenario forecast, the MAPE can be calculated using:

$$PE = 100(baseline - higher\ oil\ price)/baseline$$

$$APE = Absolute\ value\ of\ PE$$

$MAPE = Mean\ of\ APE$

where PE denotes the percentage error, APE denotes the absolute percentage error, and MAPE is the mean absolute percentage error.

However, both the correlation coefficient and the MAPE do not indicate whether the two series are significantly different from zero. Hence, the third procedure is to use a t-test to test whether the average difference between the two series is significantly different from zero. The information in table 4.4.8 and figure 4.4.11 show the results of these tests. Table 4.4.8a shows the correlation coefficient, table 4.4.8b show the absolute prediction error for each year, whilst table 4.4.8c presents the results of the t-test.

Table 4.4. 8: Tests for the difference between the baseline and the higher oil price scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	HIGH_OIL_PRICE
BASELINE	1.000000	

HIGH_OIL_PRICE	0.822735	1.000000
t-statistic	4.093850	-----
Probability	0.0035	-----

b) Average prediction errors, 2005-2014

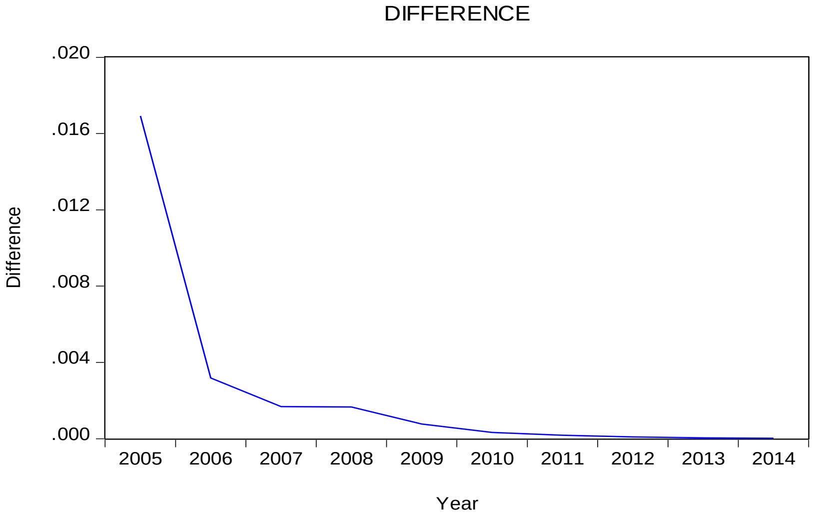
Year	APE
2005	24.6946
2006	5.87493
2007	3.45440
2008	3.84749
2009	1.42775
2010	0.75350
2011	0.44907
2012	0.21370
2013	0.10362
2014	0.05079

MAPE=4.087

c) t-test results

Test of Hypothesis: Mean = 0.000000		
Sample Mean = 0.002490		
Sample Std. Dev. = 0.005174		
Method	Value	Probability
t-statistic	1.521989	0.1623

Figure 4.4. 11: Difference between baseline and higher oil price scenarios



From table 4.4.8a, the two series have a high positive correlation of 82% which is significantly different from zero at the 5% level (t-statistic = 4.094). This indicates that the two series are very similar. The MAPE calculated for the two series is 4.087% (see table 4.4.8). Hence, the average difference between the two series for each year is around 4%. Also the result from the t-test reported in table 4.4.8c indicates that the average difference between the two series is insignificantly different from zero at the 5% level.

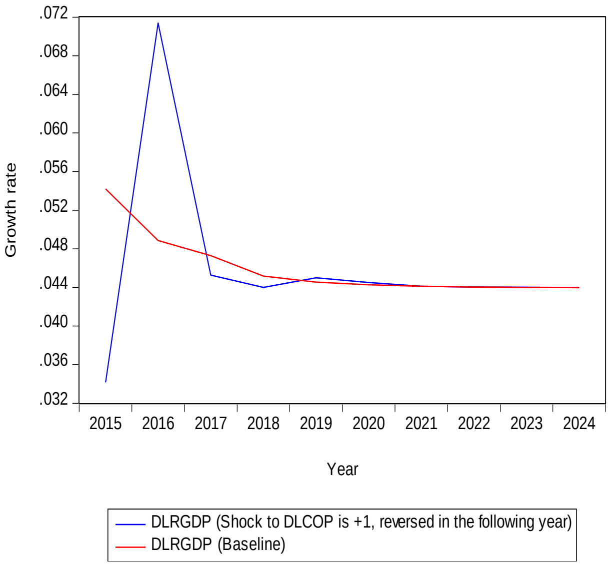
These tests and statistics suggest that the two series are not significantly different on average. This implies on average, the different forecasting assumptions do not produce different forecasts. However, the APE series and the graph of the difference (see figure 4.4.11) both show one very large difference in 2005 (APE=24.69) compared with smaller differences for other years. Hence, whilst the series are not significantly different in general, we cannot discount the likelihood that there is a significant difference in 2005.

The forecasting exercise performed assumes a higher oil price within the last 10 years of our sample, and the effect of the higher oil price is analysed for that period.

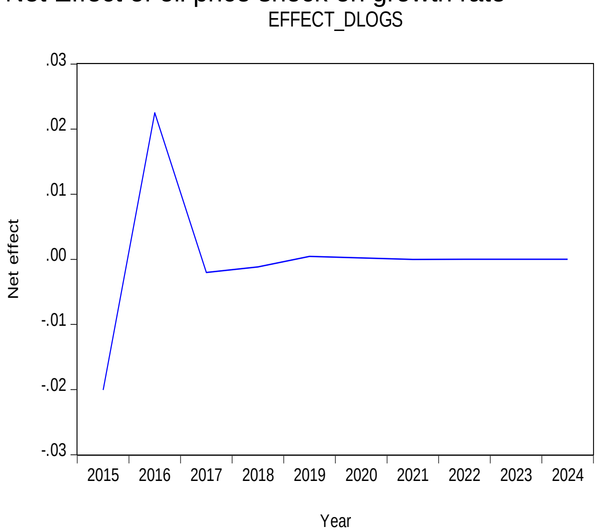
We can also forecast the oil price effect for the period between 2015 and 2024. We assume an oil price shock using scenarios where DLCOP=1 is the higher oil price (oil price shock) scenario, and DLCOP=0 is the baseline scenario. Here, the shock is temporary, and it will reverse in the following year. Hence, DLCOP is 1 in 2015 and zero the following years, whilst DLCOP is zero for all years in the baseline scenario. This forecast has produced the graphs in figures 4.4.12a and 4.4.12b below.

Figure 4.4. 12: The impact of higher oil price on non-oil GDP growth rate, 2015 to 2024

(a)
Comparative forecast of oil price shock on growth rate



(b)
Net Effect of oil price shock on growth rate



The graphs for the comparative forecast and net effect predict that a temporarily high oil price produces an immediate drop in the non-oil GDP growth rate. As the graphs indicate, the baseline will become higher than the non-oil GDP growth rate in the first year. The initial effect is to reduce output by about 2%. However, the effect immediately declines, becoming positive after about a year before declining to almost zero after two years. Note that the high oil price effect is larger for this forecast period than the 2005 to 2014 forecast period. From these graphs, we can also determine the multiplier effects. The gap between the shock to oil price and the baseline are the multiplier effects. These effects are shown in table 4.4.9 below. The multiplier effect for 2015 is -0.020052, declining to almost zero by 2020.

Table 4.4. 9: Multiplier Effects of higher oil prices, 2015 to 2024

Year	Multiplier Effect
2015	-0.020052
2016	0.022511
2017	-0.002015
2018	-0.001161
2019	0.000541
2020	0.000231
2021	-4.90E-06
2022	6.40E-06
2023	1.49E-05
2024	5.70E-06

The difference between the oil price shock and the baseline scenarios have also been tested using the tests and statistics applied in the previous scenario forecasts. The results are presented in table 4.4.10 and figure 4.4.13 below.

Table 4.4. 10: Tests for the difference between the baseline and the oil price shock scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	OIL_PRICE_SHOCK
BASELINE	1.000000	

OIL_PRICE_SHOCK	0.769344	1.000000
t-statistic	3.406253	-----
Probability	0.0093	-----

b) Absolute prediction error

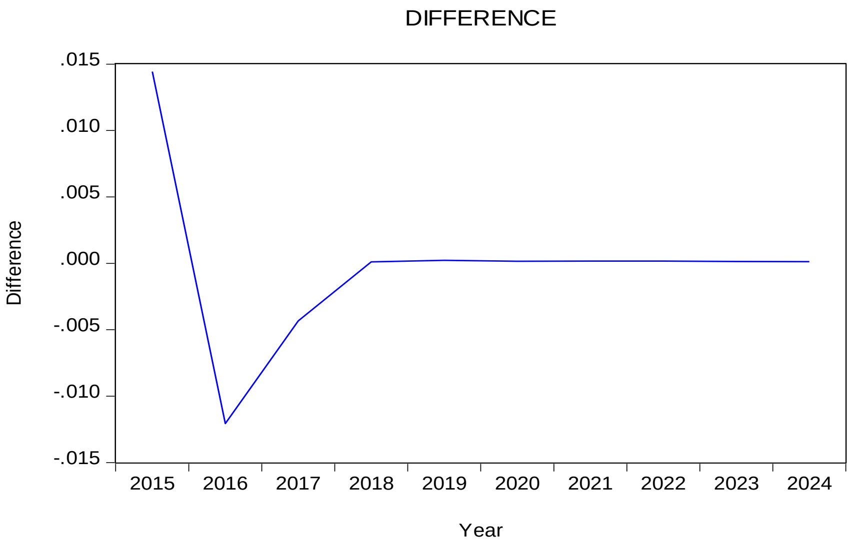
Year	APE
2015	39.69917
2016	66.16720
2017	36.67320
2018	1.104172
2019	2.94830
2020	2.20696
2021	2.80881
2022	3.13773
2023	3.20656
2024	3.22490

c) t-test results

Test of Hypothesis: Mean = 0.000000		
Sample Mean = -8.73e-05		
Sample Std. Dev. = 0.006438		
Method	Value	Probability
t-statistic	-0.042884	0.9667

MAPE=16.117

Figure 4.4. 13: Difference between baseline and higher oil price scenarios



The covariance analysis (depicted in table 4.4.10a) shows that the correlation coefficient between the two series is 76.9% which is significant at the 5% level (t-statistic=3.4). The calculated MAPE for the two series (see table 4.4.10) is 16.117% which implies the average difference between the two series for each year is around 16%. Note that this MAPE is higher than the MAPE in the higher oil price scenario. Also, as shown in table 4.4.10c, the t-test is not significant, indicating that the difference between the two series average values is insignificantly different from zero. This suggests that, on average, the different forecasting assumptions do not produce different forecasts. However, the APEs shown in table 4.4.10b reveal that the absolute prediction errors are high for three years (2015, 2016, and 2017) whilst the other years have smaller APEs. It therefore, implies that although the two series are not significantly different on average, there are large differences between them from 2015 to 2017.

Asymmetric Impact

Many previous studies in the literature have investigated the possibility of an asymmetric effect of oil price shocks on the macro economy, in which positive and negative shocks have a different size of response (e.g. see Hooker 1997, 2002, Hamilton 2003, 2011, and Rahman and Serletis 2011) To explore this asymmetry, we introduce two exogenous variables in the VAR by making ancillary series denoted as $DLCOPP$ and $DLCOPN$. The ancillary series are defined as;

$DLCOPP = DLCOP$ for $DLCOP > 0$, otherwise $DLCOPP = 0$

$DLCOPN = DLCOP$ for $DLCOP < 0$, otherwise $DLCOPN = 0$

Consequently, DLCOPP represents positive oil price changes whilst DLCOPN represent negative changes

The VAR is re-estimated with both DLCOPP and DLCOPN as exogenous variables replacing the DLCOP variable included in the previous VAR analysis that imposed a symmetric response to positive and negative shocks. The results of the new model are presented in table 4.4.11. As it can be seen, DLCOPN has the expected negative sign in the DLRNOGDP equation, whilst the coefficient of DLCOPP does not have the expected sign. The negative coefficient of DLCOPN is consistent with popular findings in the literature, that negative shocks to oil prices boosts economic growth for oil importing countries. Note however, that the coefficient of both DLCOPN and DLCOPP are highly insignificant which, even given the non-normality of residuals, indicates insignificance, although the t-stat and R^2 are improved relative to the model in table 4.4.6. This outcome also supports the works of Hooker (1997, 2002), Hamilton (2003, 2011), and Rahman and Serletis (2011). In their papers to investigate the asymmetric effects of oil price shocks for oil importing countries, these studies established that negative shocks improve economic growth, but such shocks do not significantly affect economic growth compared to positive shocks.

Table 4.4. 11: Estimated Results of the Asymmetric Five-Variable VAR

	DLRNOGDP	DLCPI	DLEXR	DLIR
DLRNOGDP(-1)	0.145281	-0.379633	-0.477422	0.325439
	(0.22468)	(0.29435)	(0.64033)	(0.39819)
	[0.64662]	[-1.28972]	[-0.74559]	[0.81729]
DLCPI(-1)	-0.148252	0.384491	0.153750	0.201182
	(0.18126)	(0.23747)	(0.51660)	(0.32125)
	[-0.81789]	[1.61909]	[0.29762]	[0.62625]
DLEXR(-1)	0.041462	-0.018024	0.272292	0.125968
	(0.06169)	(0.08082)	(0.17582)	(0.10933)
	[0.67210]	[-0.22301]	[1.54871]	[1.15215]
DLIR(-1)	-0.071608	-0.178872	-1.017804	-0.343868
	(0.10198)	(0.13360)	(0.29063)	(0.18073)
	[-0.70221]	[-1.33887]	[-3.50205]	[-1.90266]
C	0.058831	0.196786	0.199683	-0.033499
	(0.05838)	(0.07648)	(0.16638)	(0.10347)
	[1.00771]	[2.57288]	[1.20013]	[-0.32377]
DLCOPP	0.015453	-0.059245	-0.285552	-0.199498
	(0.08755)	(0.11470)	(0.24951)	(0.15516)
	[0.17651]	[-0.51654]	[-1.14445]	[-1.28577]
DLCOPN	-0.097945	0.036905	-0.320075	0.124773
	(0.16054)	(0.21033)	(0.45755)	(0.28453)
	[-0.61008]	[0.17546]	[-0.69954]	[0.43852]
R-squared	0.153344	0.306599	0.295992	0.172189
Adj. R-squared	0.008203	0.187730	0.175305	0.030278
Sum sq. resids	0.575993	0.988632	4.678527	1.809194
S.E. equation	0.128285	0.168067	0.365612	0.227357
F-statistic	1.056520	2.579303	2.452560	1.213363

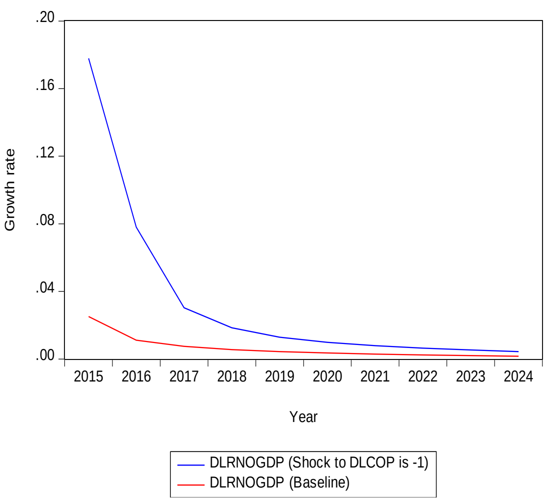
Standard errors in ( ) & t-statistics in [ ]

We explore the implications of the estimated asymmetric VAR for the dynamic responses by employing a scenario-based forecasting exercise similar to that used in the previous analysis. Since the coefficient of DLCOPP does not have the expected sign, we shall focus mainly on the scenario forecast for negative oil price shocks. The process is repeated using the VAR with DLCOPN as the exogenous variable. To test for the response to a negative shock, we introduce an oil price blip for the first year (2015) of our forecast period (which ranges from 2015 to 2024) and assign a value of -1 to it. The negative blip to oil price growth (i.e. a 100% reduction to oil price) causes a permanently lower oil price level relative to the baseline scenario. The result of this exercise produced graphs for the comparative forecasts (with the baseline scenario) and the net effect of a negative shock to the oil price growth rate. These graphs are shown in figures 4.4.14a and 4.4.14b below.

Figure 4.4. 14: Impact to a negative shock to oil price growth rate

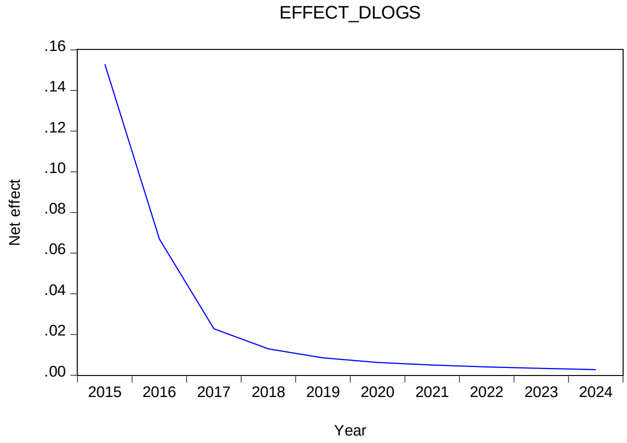
Comparative forecast of a negative oil price shock on growth rate

(a)



Net effect of a negative oil price shock on growth

(b)



From figures 4.4.14a and 4.4.14b, the graphs for the comparative forecasts and the net effect both predict that the non-oil GDP growth rate will become higher than the baseline following a temporary negative shock to the oil price. However, this surplus growth will slowly evaporate, being almost equal to zero by 2024. Again, this is not surprising from economics perspective, given that the effects of such shocks diminish over time. However, it contrasts with the previous analysis in the sense that the shock does not evaporate after one period and the magnitude of the effect is much larger – the effect is to increase growth by about 15% in the first year, and this is a very substantial effect.

We can also determine the multiplier effects by examining the graphs in figure 4.4.9 (comparative forecast of a negative oil price on growth rate). The gap between negative oil price shock and baseline is the multiplier effect. The effects are negative and they decline as time passes. This is shown in table 4.4.12. As it can be seen, the multiplier effect in 2015 was -0.099791. This declined to almost zero by 2024. The multiplier effects are negative because they are the ratios of positive response to negative shocks.

Table 4.4. 12: Multiplier effects of negative oil price shocks

Year	Multiplier Effect
2015	-0.099791
2016	-0.023439
2017	-0.005401
2018	-0.005462
2019	-0.002476
2020	-0.000991
2021	-0.000517
2022	-0.000252
2023	-0.000116
2024	-5.55E-05

We have also performed a correlation coefficient test, t-test, and MAPE under this scenario to determine whether the negative oil price shock and the baseline scenarios are not significantly different. The results of these tests are reported in table 4.4.13 and figure 4.4.15.

Table 4.4. 13: Tests for the difference between the baseline and the negative oil price shock scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	NEGATIVE_OIL_PRICE_SHOCK
BASELINE	1.000000	

NEGATIVE_OIL_PRICE_SHOCK	0.984088	1.000000
t-statistic	15.66518	-----
Probability	0.0000	-----

b) Absolute percentage error

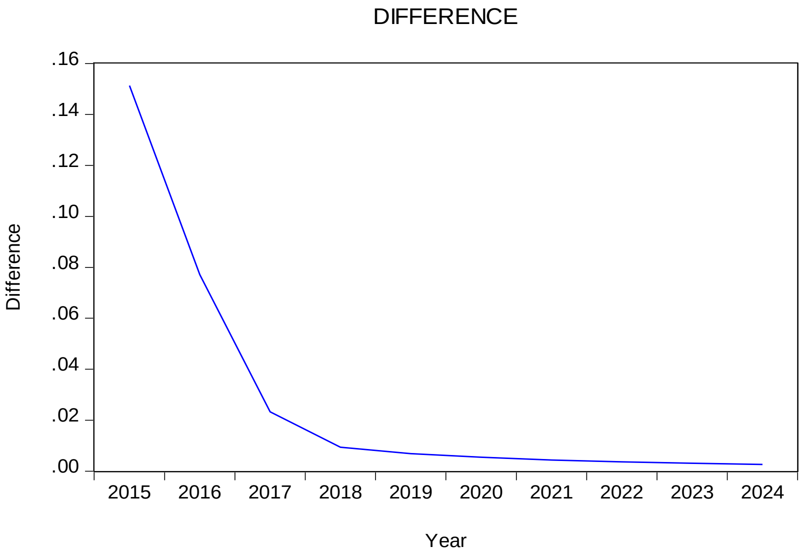
Year	APE
2015	497.68102
2016	733.16060
2017	409.85976
2018	202.83621
2019	179.72002
2020	171.63438
2021	163.29808
2022	160.11184
2023	159.50686
2024	159.33877

MAPE=283.714

c) t-test results

Test of Hypothesis: Mean = 0.000000		
Sample Mean = -0.028712		
Sample Std. Dev. = 0.048711		
Method	Value	Probability
t-statistic	-1.863922	0.0952

Figure 4.4. 15: Difference between baseline and higher oil price scenarios



From table 4.4.13a, the correlation between the two scenarios is positively high at 98.4% which is significant at the 5% level (t-statistic=15.665). This suggests that the two series are very similar. The MAPE calculated for the two series is 283.714 (see table 4.4.13), which implies the average difference between the two series for each year is around 283.7% which is substantially higher than the MAPE for the higher oil price and the oil price shock scenarios. The t-test for the average difference between the two series is -1.8634 which is almost significant at the 5% level (and is insignificant at the 10% level). This suggests that the average difference between the series is on the borderline of being significantly different from zero. Moreover, there are substantially large differences in 2015, 2016, and 2017 as indicated by the APE in table 4.4.13b and figure 4.4.15. Note that the APEs are generally high for all the years. In general, the statistics suggests that the two series are almost significantly different on average and look very different for some years. Unlike in the previous scenarios, the different forecasting assumptions here produce different forecasts.

In the VAR models that have been used to estimate the graphs of the forecast scenarios, we have ordered the variables based on equation (5.8). To check the robustness of the graphs and determine whether the ordering of the variables in the VAR affects the graphs, we have performed several replications of the VAR models using different ordering of the variables in the models. After performing this exercise, it appeared that the ordering of the variables in the VAR does not affect the graphs of the forecast scenarios. We only report the results of two more orderings for each oil price shock in the appendix to save space. The replicated graphs for the impact of higher oil prices from 2005 to 2010 are reported in **appendices B13a and B13b**, whilst **appendices B14a and B14b** show the replicated graphs for the impact of oil price shock between 2015 and 2024. The graphs for the impact of negative shocks are reported in **appendices B15a and B15b**

Structural Break in 2011

Ghana officially became an oil producing country in 2011, and up until then, the country had been an established oil importer. Thus, it is possible that the effect of oil price shocks on the Ghanaian economy will be different before and after 2011. To explore such a possibility, we estimate a VAR with a structural break in 2011 in which the effect of the oil shocks depends on:

- Whether the effect is positive or negative
- Whether or not it is before 2011

This gives four exogenous variables: DLCOPP, DLCOPN, DLCOPP11, and DLCOPN11 in the VAR. The variables are defined as follows;

DLCOPP denotes a rise in oil prices prior to 2011, DLCOPP11 denotes an oil price rise after 2011; DLCOPN and LCOPN11 denote the oil price drops before and after 2011, respectively. The results of this model are presented in table 4.4.14.

Table 4.4. 14: Estimated Five-Variable VAR with Structural Break in 2011

	DLRNOGDP	DLCPI	DLEXR	DLIR
DLRNOGDP(-1)	0.200259	-0.420869	-0.308917	0.403671
	(0.21923)	(0.28216)	(0.60771)	(0.38316)
	[0.91346]	[-1.49158]	[-0.50833]	[1.05353]
DLCPI(-1)	-0.091042	0.320806	0.493448	0.265174
	(0.17416)	(0.22415)	(0.48277)	(0.30438)
	[-0.52275]	[1.43119]	[1.02212]	[0.87118]
DLEXR(-1)	0.001358	0.005651	0.036304	0.030239
	(0.01420)	(0.01828)	(0.03937)	(0.02482)
	[0.09563]	[0.30918]	[0.92225]	[1.21836]
DLIR(-1)	-0.053548	-0.195438	-1.084739	-0.311465
	(0.10569)	(0.13603)	(0.29298)	(0.18472)
	[-0.50665]	[-1.43672]	[-3.70249]	[-1.68615]
C	0.049050	0.217552	0.153575	-0.024068
	(0.06274)	(0.08075)	(0.17390)	(0.10965)
	[0.78185]	[2.69430]	[0.88310]	[-0.21951]
DLCOPN	-0.110366	0.059694	-0.488949	0.129677
	(0.16655)	(0.21436)	(0.46167)	(0.29108)
	[-0.66266]	[0.27848]	[-1.05908]	[0.44550]
DLCOPN11	0.003041	0.479589	-2.412783	0.059627
	(1.32248)	(1.70211)	(3.66592)	(2.31135)
	[0.00230]	[0.28176]	[-0.65817]	[0.02580]
DLCOPP	0.014534	-0.055740	-0.276406	-0.184174
	(0.09187)	(0.11825)	(0.25467)	(0.16057)
	[0.15820]	[-0.47138]	[-1.08533]	[-1.14699]
DLCOPP11	0.098428	-0.458490	-0.997939	-0.471651
	(0.41375)	(0.53252)	(1.14691)	(0.72312)
	[0.23789]	[-0.86099]	[-0.87012]	[-0.65224]
R-squared	0.144181	0.323540	0.348719	0.186245
Adj. R-squared	-0.063290	0.159549	0.190833	-0.011029
Sum sq. resids	0.582227	0.964477	4.473850	1.778475
S.E. equation	0.132828	0.170958	0.368200	0.232149
F-statistic	0.694944	1.972920	2.208673	0.944091

Standard errors in ( ) & t-statistics in [ ]

From the DLRNOGDP equation in table 4.4.14, DLCOPN11 has a very small t-statistic, suggesting that oil price drops have the same effect before and after 2011. Perhaps, this result reflects the fact that Ghana's oil production is still at an infant stage, with the current production standing at just over one hundred thousand barrels per day. Thus, the economy's overall response to price drops after 2011 would not be significantly different from its response to such shocks prior to 2011.

DLCOPP also has a very small t-statistic, suggesting that price rises had no effect prior to 2011. Finally, the coefficient for DLCOPP11, whilst not significantly different from zero, is positive, and – giving some support to the suggestion that oil price rises improve GDP once oil is part of domestic production.

The results presented above are the findings of the five-variable VAR. In the next set of models, we shall examine the crude oil price effect in a bivariate VAR where the crude oil price and non-oil GDP are the only variables following Hamilton (2003) and Oladosu (2009). A model of this kind will help to determine whether the exclusion of the other macroeconomic variables in the model affects the oil price and non-oil GDP relationship. As in the five-variable VAR, the crude oil price is included in the two-variable model as an exogenous variable.

Going back to equation (5.7), ΔY_t is a vector of endogenous variables in first differences, here simply non-oil GDP whilst ΔX_t is a vector of the international price of oil. In this model, the optimal lag length chosen by the Schwarz criterion and the Hannan-Quinn criterion is 2, and using 2 lags produces no serial correlation, but the residuals are not normally distributed (**see appendices B17, B18 and B19**). The explanations given in footnote 6 for the normality test also apply to this model. The results of this model are presented in table 4.4.15. Because there are only two variables in this model, treating any variable as exogenous transforms the model from a VAR into a single equation model with two variables. Hence, we will simply describe the two-variable models as two-variable equation models.

Table 4.4. 15: Estimated results for the basic two-variable equation model

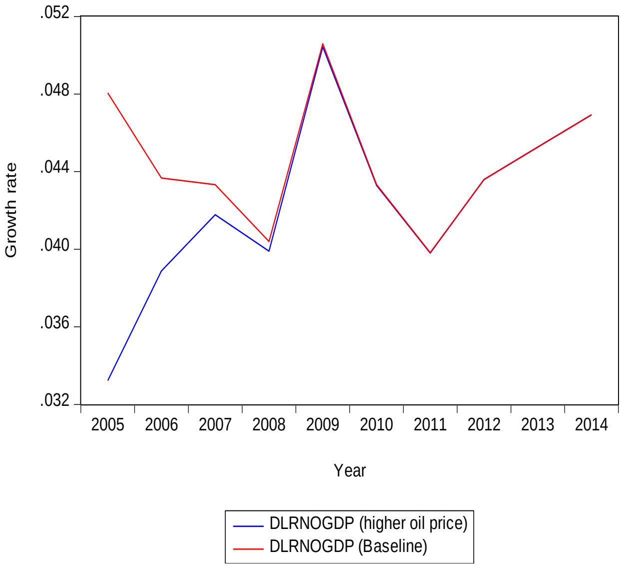
	DLRNOGDP
DLRNOGDP(-1)	0.252031
	(0.16060)
	[1.56931]
DLRNOGDP(-2)	0.223101
	(0.16098)
	[1.38591]
C	0.024020
	(0.02161)
	[1.11154]
DLCOP	-0.011880
	(0.06246)
	[-0.19020]
R-squared	0.149034
Adj. R-squared	0.080037
Sum sq. resids	0.578798
S.E. equation	0.125073
F-statistic	2.160001

Standard errors in ( ) & t-statistics in [ ]

From table 4.4.15, the coefficient of DLCOP in the DLRNOGDP equation is negative and statistically insignificant. This result is consistent with our findings in the basic five-variable VAR model (see table 4.4.6). This suggests that the crude oil price effect on the non-oil GDP growth rate in Ghana does not depend on the inclusion of other macroeconomic variables in the model. Using the forecast scenarios, we can also forecast the effects of crude oil price shocks on the non-oil GDP growth using the two-variable equation model. Following the forecasting procedures explained earlier, the impact of higher oil prices between 2005 and 2014, and the effect of oil price shocks from 2015 to 2024 are estimated in figures 4.4.16 and 4.4.17 as follows:

Figure 4.4. 16: Impact of higher oil price on non-oil GDP growth rate, 2005 to 2014

(a)
Comparative forecast of oil price shock on growth rate



(b)
Net Effect of oil price shock on growth rate

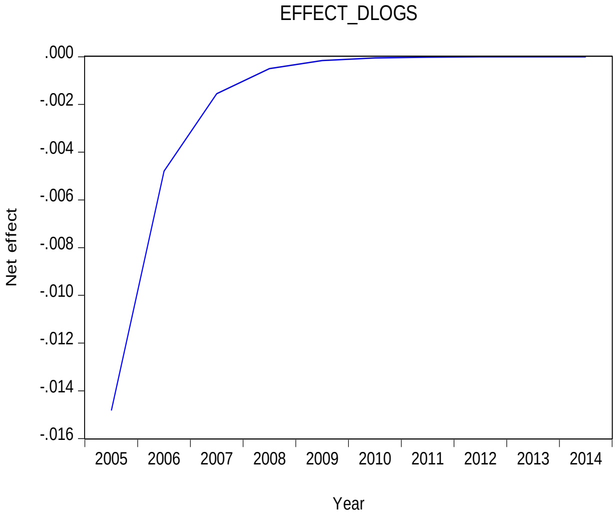
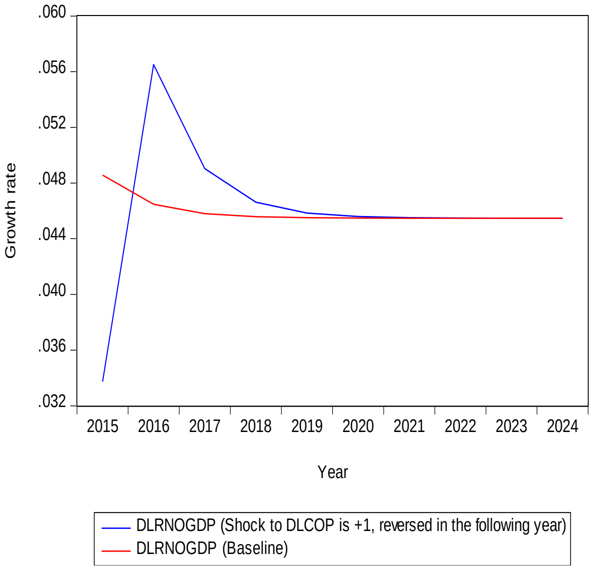
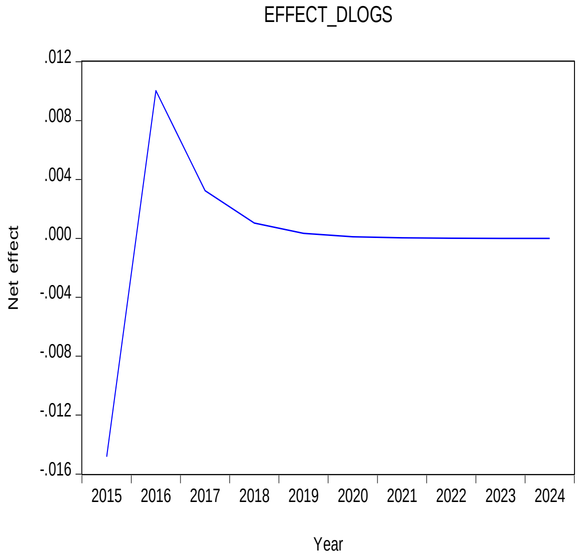


Figure 4.4. 17: Impact of oil price shock on non-oil GDP growth rate, 2015 to 2024

(a) Comparative forecast of oil price shock on growth rate



(b) Net Effect of oil price shock on growth rate



If we compare these graphs to the graphs in the five-variable model, the oil price effect is qualitatively similar for both models. From figure 4.4.16 and figure 4.4.17, both the comparative forecast and net effects of oil price shocks show that oil price shocks initially reduce output. However, this effect is very temporary which will diminish immediately and become almost zero after one and a half to two years. This result is similar to what was found under the five-variable VAR (although the impact of higher oil price has become zero more quickly in the five-variable VAR than in the bivariate equation model).

The baseline and the higher oil price scenarios have also been tested to determine whether the two series are significantly different using the statistics that were applied previously. The results for the tests are reported in table 4.4.16 and figure 4.4.18.

Table 4.4. 16: Tests for the difference between the baseline and the higher oil price scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	HIGHER_OIL_PRICE
BASELINE	1.000000	

HIGHER_OIL_PRICE	0.374659	1.000000
t-statistic	1.142945	-----
Probability	0.2861	-----

b) Absolute prediction error

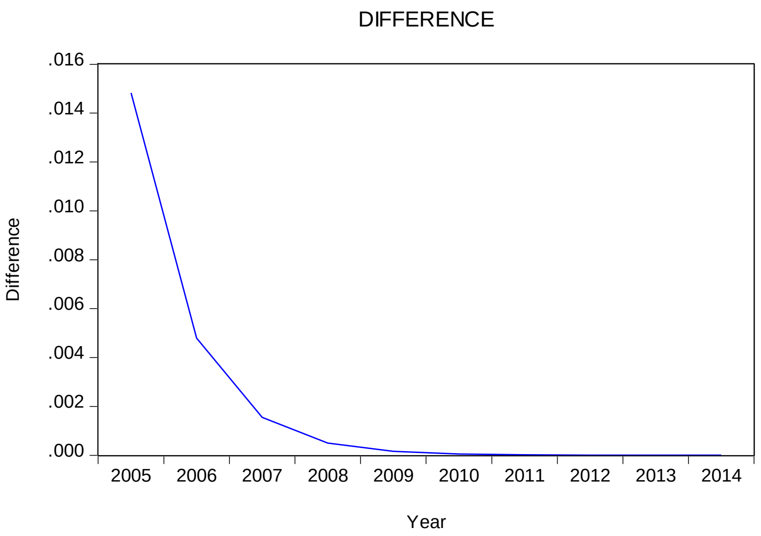
Year	APE
2005	30.85607
2006	10.97432
2007	3.57521
2008	1.23907
2009	0.31982
2010	0.12066
2011	0.04243
2012	0.01261
2013	0.00375
2014	0.00127

c) t-test results

Test of Hypothesis: Mean = 0.000000		
Sample Mean = 0.002191		
Sample Std. Dev. = 0.004685		
Method	Value	Probability
t-statistic	1.478906	0.1733

MAPE=47.145

Figure 4.4. 18: Difference between baseline and higher oil price scenarios



Similar to the statistical analysis in the five-variable model for the higher oil price scenario, the statistics reported in table 4.4.16 show that the baseline and the higher oil price scenarios are insignificantly different on average. The two series have a correlation of 37% which is low. However, this correlation is not significant at the 5% level (t-statistic=1.143). The calculated MAPE for the two series is 47.145 (see table 4.4.16). This implies the average difference between them is 47%. However, the t-test result is not significant at the 5% (t-statistic=1.479). In general, these tests suggest that the differences of the two series are not significantly different on average. However, in 2005, there does appear to be a large difference between the series (see table 4.4.16b and figure 4.4.18). This implies the different forecasting assumptions do not produce different forecasts.

We have also tested the difference between the baseline scenario and the oil price shock scenario which we forecasted from 2015 to 2024. The results of the tests are reported in table 4.4.17 and figure 4.4.19.

Table 4.4. 17: Tests for the difference between the baseline and the oil price shock scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	OIL_PRICE_SHOCK
BASELINE	1.000000	

OIL_PRICE_SHOCK	-0.539518	1.000000
	-1.812393	-----
	0.1075	-----

b) Absolute percentage error

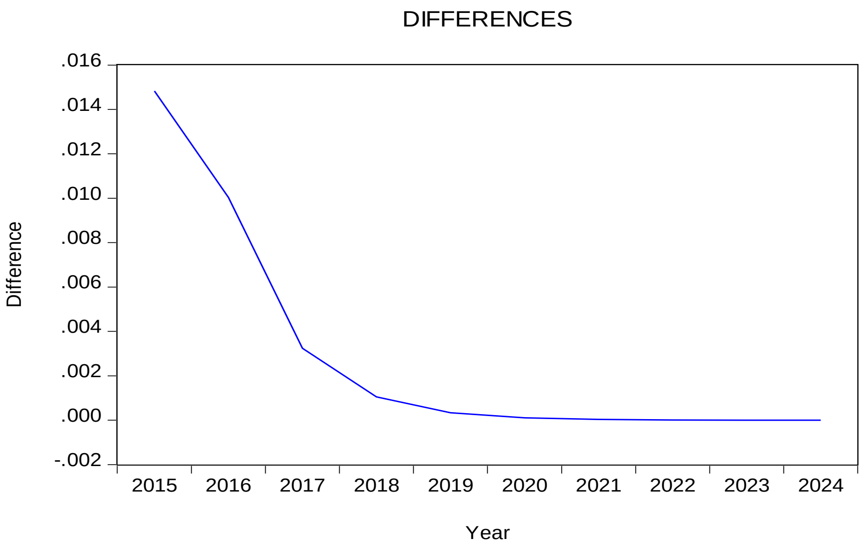
Year	APE
2015	30.53014
2016	21.59341
2017	7.08229
2018	2.29998
2019	0.74470
2020	0.24073
2021	0.07784
2022	0.02528
2023	0.00813
2024	0.00043

c) t-test results

Test of Hypothesis: Mean = 0.000000	
Sample Mean = 0.002965	
Sample Std. Dev. = 0.005211	
Method Value	Probability
t-statistic 1.799551	0.1055

MAPE=6.26

Figure 4.4. 19: Difference between baseline and oil price shock scenarios



From table 4.4.17, the two series have a negatively average correlation of -53.95% which is not significant at the 5% level, although it is almost significant (t-statistic=-1.812). This suggests that the two series are not significantly highly correlated. The series also have an MAPE of 6.26 (see table 4.4.17) suggesting that the average difference between the series is about 6%. The t-test statistic of 1.799 is also insignificant at the 1%, 5%, and 10% levels suggesting that the average difference is not significantly different from zero. In general, the tests indicate that the two series are not significantly different from zero. This implies the different forecasting assumptions do not produce different forecasts. Note however, that the APE and the difference graph indicate large differences in 2015 and 2016 (APE is 30.53% and 21.59% respectively).

We can also estimate an asymmetric model for the bivariate equation model to determine the effects of positive and negative shocks. Using the DLCOPP to denote positive shocks and DLCOPN to denote negative shocks, the results of the asymmetric VAR is reported in table 4.4.18 below.

Table 4.4. 18: Estimated results of the asymmetric two-variable equation Model

	DLRNOGDP
DLRNOGDP(-1)	0.237096
	(0.16290)
	[1.45545]
DLRNOGDP(-2)	0.225881
	(0.16204)
	[1.39395]
C	0.011257
	(0.02788)
	[0.40380]
DLCOPP	0.030696
	(0.08566)
	[0.35836]
DLCOPN	-0.113160
	(0.15202)
	[-0.74436]
R-squared	0.161504
Adj. R-squared	0.068337
Sum sq. resids	0.570317
S.E. equation	0.125866
F-statistic	1.733499

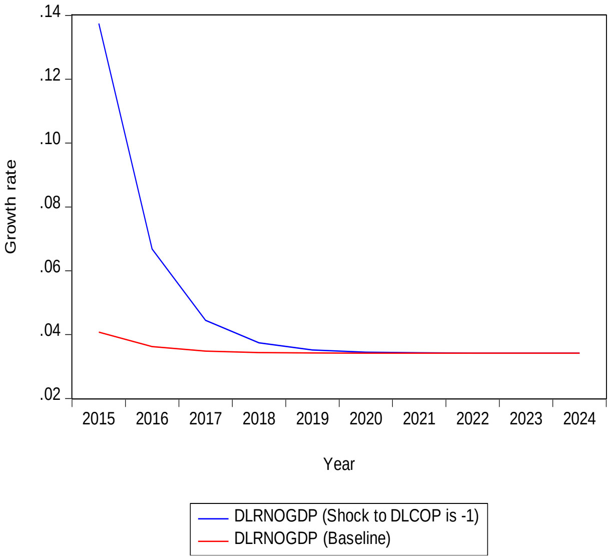
Standard errors in ( ) & t-statistics in [ ]

From the results in table 4.4.18, the coefficients of both DLCOPP and DLCPN are statistically insignificant suggesting that both the positive and negative shocks have little impact on the non-oil GDP growth rate. The negative shock however, has the appropriate negative sign whilst the positive shock does not have the expected sign. These coefficient results are similar to the findings obtained in the five-variable VAR model. However, the coefficient of DLCOPN appears to be higher in the two-variable model than in the five-variable model.

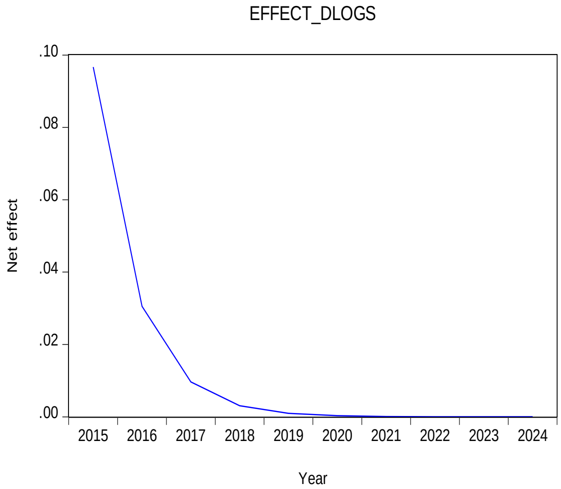
Using this result, we can also estimate forecast scenarios for oil price shocks to predict the effects of such shocks on economic growth. Again, our focus here is on the negative oil price shock since the coefficient of DLCOPN has the expected sign. The graphs in figure 4.4.20 illustrate the estimated results of a negative oil price shock. Consistent with the findings in the five-variable model, the graphs for both the comparative forecast and the net effect show that the initial effect of negative oil price shocks is to increase output, but this extra growth disappears as time passes. Note however, that the extra growth evaporates more quickly in this model than in the five-variable model.

Figure 4.4. 20: Impact of negative shock to oil price growth rate

(a)
Comparative forecast of a negative oil price shock on growth rate



(b)
Net effect of a negative oil price shock on growth



The baseline and the negative oil price shock scenarios have also been tested to determine whether the two scenarios are significantly different. The results of the tests are reported in table 4.4.19 and figure 4.4.21 below.

Table 4.4. 19: Tests for the difference between the baseline and the negative oil price shock scenarios

a) Covariance analysis

Correlation		
t-Statistic		
Probability	BASELINE	NEGATIVE_OIL_PRICE_SHOCK
BASELINE	1.000000	

NEGATIVE_OIL_PRICE_SHOCK	1.000000	1.000000
	209732.6	-----
	0.0000	-----

b) Absolute prediction error

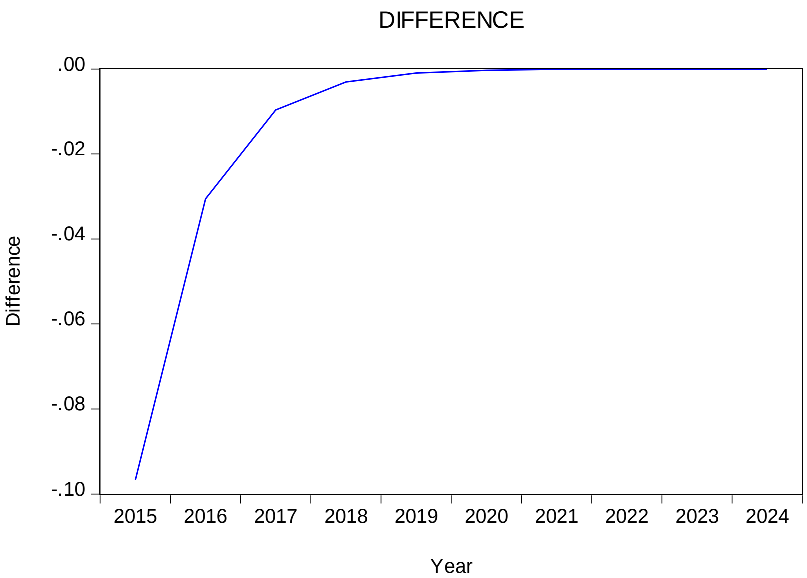
Year	APE
2015	237.15120
2016	84.21428
2017	27.68515
2018	8.85849
2019	2.80923
2020	0.88861
2021	0.28082
2022	0.08864
2023	0.02779
2024	0.00877

c) t-test results

Sample Mean = -0.014132		
Sample Std. Dev. = 0.030526		
Method	Value	Probability
t-statistic	-1.463924	0.1772

MAPE=36.201

Figure 4.4. 21: Difference between baseline and oil price shock scenarios



The covariance analysis in table 4.4.19 reveals that the two series have a very high correlation of 100% which is statistically significant at the 5% level. The MAPE also suggests that the average difference between the series is about 36% (see table 4.4.19). However, the t-test statistic is insignificant, indicating that the average difference between the two series is not significantly different from zero. Yet, the absolute percentage error (APE) series shows a large difference in 2015, 2016, and 2017. This is suggestive that there is significant difference between the series in these years, although the two series are not significantly different on average.

Finally, it is also important to estimate a two-variable model with structural break in 2011 as we did for the five-variable VAR. The exogenous variables to be included will be the same as those used in the five-variable model. These variables include; DLCOPN, DLCOPN11, DLCOPP, and DLCOPP11 where the variables are defined as the same as in the previous model. The results of this model are presented in table 4.4.20 below:

Table 4.4. 20: Results of the two-variable equation model with Structural Break in 2011

	DLRNOGDP
DLRNOGDP(-1)	0.229509
	(0.16882)
	[1.35949]
DLRNOGDP(-2)	0.232134
	(0.16709)
	[1.38925]
C	0.010476
	(0.02906)
	[0.36051]
DLCOPN	-0.117078
	(0.15611)
	[-0.74999]
DLCOPN11	0.108425
	(1.26402)
	[0.08578]
DLCOPP	0.026009
	(0.08885)
	[0.29272]
DLCOPP11	0.198303
	(0.39603)
	[0.50072]
R-squared	0.167877
Adj. R-squared	0.021032
Sum sq. resids	0.565982
S.E. equation	0.129021
F-statistic	1.143226

Standard errors in ( ) & t-statistics in [ ]

The results reported in the table above suggest that all the exogenous variables have little effect on non-oil GDP growth rate as their t-ratios are all statistically insignificant. These results are also consistent with our findings in the five-variable model, and the interpretations of the results will be the same as before. For example, the positive coefficient for DLCOPP11 could be a support to the suggestion that oil price rises improves non-oil GDP once oil becomes part of domestic production (if not significantly).

In the discussions so far, we have examined the macroeconomic impact of oil price shocks in Ghana within two frameworks; firstly, we analysed the oil price effect using a five-variable VAR where other macroeconomic variables are included in the model. Secondly, we modelled the oil price effect using a bivariate analysis where the non-oil GDP and oil price are the only variables in the model. Our analysis shows that the oil price effect on the non-oil GDP growth rate is not significant in both models. The results highlight the fact that the dynamic interactions of other macroeconomic variables have no influence on the oil price and macro economy relationship.

We have also repeated the five-variable VAR model and the two-variable single equation model with GDP as a measure of economic growth rather than the non-oil GDP. The aim of estimating these models is to determine whether the use of the different GDP variables will yield different results. The results (reported in **appendices B20 and B21**) are qualitatively similar to the results in table 4.4.6 and 4.4.15. This indicates that the crude oil price effect is insignificant on both GDP and non-oil GDP.

It is also important to note that the results of all the models we discussed are estimates of short run oil price effects. It is also imperative to examine the long run impact of oil price shocks on the GDP growth rate. One method of estimating the long run relationship is to use the Johansen's cointegration approach. However, because the oil price is treated as an exogenous variable in the VAR models, the Johansen approach will not be appropriate because this approach treats all variables as endogenous. As an alternative, we can employ the Engle and Granger cointegration analysis and the ARDL.

Long Run Relationship

The Engle and Granger (1987) test for cointegration can be explained if we consider a set of variables X and Y. The procedure is described as follows:

(i): Estimate the long run equilibrium equation:

$$Y_t = \delta_0 + \delta_1 X_t + u_t \quad (4.4.12)$$

The OLS residuals of equation (4.4.12) are a measure of disequilibrium. The residuals can be expressed as:

$$\hat{u}_t = Y_t - \hat{\delta}_0 - \hat{\delta}_1 X_t \quad (4.4.13)$$

(ii): A test for cointegration is a test of whether $\hat{u}_t$ is stationary, and this is determined by ADF tests on the residuals using the Mackinnon (2010) critical values. Note that the only important question here is the stationarity or otherwise of the residuals, hence, traditional diagnostic tests from (4.4.12) are unimportant.

Thus, the hypotheses are:

H_0: The residuals are $I(1)$: there is no cointegration

H_1: The residuals are $I(0)$: there is cointegration

Using the Engle and Granger's approach, we can test for cointegration in both the five-variable system and the two-variable system. As a first step, the equations for the two systems can be estimated as follows:

$$LRNOGDP = \underset{[40.06]}{\underset{(0.53)}{21.59}} + \underset{[2.44]}{\underset{(0.14)}{0.34}}LCOP - \underset{[-2.71]}{\underset{(0.13)}{0.36}}LCPI - \underset{[-5.00]}{\underset{(0.14)}{0.70}}LIR + \underset{[4.74]}{\underset{(0.10)}{0.48}}LEXR \qquad (4.4.14)$$

$$LRGDP = \underset{[53.01]}{\underset{(0.32)}{17.16}} + \underset{[5.01]}{\underset{(0.09)}{0.49}}LCOP \qquad (4.4.15)$$

The OLS residuals of the two models are tested for stationarity using the ADF test, and the results are presented in table 4.4.21. Note that the reported critical values are inappropriate since they do not allow for the estimated coefficients. As a result, we used the critical values provided by MacKinnon (2010). Also, the tests are conducted without intercept or trend because the residuals must have a zero mean.

Table 4.4. 21: ADF unit root test of the residuals for the five-variable and the two-variable models

a) Five-variable model		b) Two-variable model	
Data in levels		Data in levels	
t-statistic	Lag	t-statistic	t-statistic
-2.57	0	-1.13	-1.13
Critical Values			
Five-variable model		Two-variable model	
1%	-2.62	-2.62	
5%	-1.95	-1.95	
10%	-1.61	-1.61	

Note: * indicate significance at 10% level
** indicate significance at 5% level
*** indicate significance at 1% level

The asymptotic 5% critical value from MacKinnon (2010) is -4.72 when five series are being tested for cointegration and -3.34 when two series are being tested. As the t-statistic (-2.57) reported in table 4.4.21a is less than -4.72, and the t-statistic (-1.13) reported in table 4.4.21b is also less than -3.34, the the null hypothesis of a unit root cannot be rejected for both models. This implies the OLS residuals of the two models are non-stationary in their levels. Since the residuals are non-stationary, we can conclude that there is no cointegrating relationship between oil prices and the non-oil GDP growth rate both in the five-variable model and the two-variable model. This also means that estimating the error correction model (ECM) is not required.

The Engle-Granger test can also be performed in eviews using the pre-programed feature dedicated for conducting the Engle and Granger test. Using this method, equilibrium equations are estimated such that each series is a dependent variable in each equation. Hence, the total number of equilibrium equations to be estimated depends on the number of variables in the model, and the existence of cointegration can depend on which variable is the dependent variable based on theory or the sample size. For our five-variable model, the following equilibrium equations have been estimated:

$$LRNOGDP = \beta_{11}C + \beta_{21}LCOP + \beta_{31}LCPI + \beta_{41}LIR + \beta_{51}LEXR \qquad (4.4.16)$$

$$LCOP = \beta_{12}C + \beta_{22}LRNOGDP + \beta_{32}LCPI + \beta_{42}LIR + \beta_{52}LEXR \qquad (4.4.17)$$

$$LCPI = \beta_{13}C + \beta_{23}LCPO + \beta_{33}LRNOGDP + \beta_{43}LIR + \beta_{53}LEXR \qquad (4.4.18)$$

$$LIR = \beta_{14}C + \beta_{24}LCPI + \beta_{34}LCOP + \beta_{44}LRNOGDP + \beta_{54}LEXR \qquad (4.4.19)$$

$$LEXR = \beta_{15}C + \beta_{25}LIR + \beta_{35}LCPI + \beta_{45}LCOP + \beta_{55}LRNOGDP \qquad (4.4.20)$$

For the two-variable model, the equilibrium equations can be expressed as:

$$LRNOGDP = \beta_{11}C + \beta_{21}LCOP \qquad (4.4.21)$$

$$LCOP = \beta_{12}C + \beta_{22}LRNOGDP \qquad (4.4.22)$$

The output results of the two models are presented in tables 4.4.22 and 4.4.23

Table 4.4. 22: Engle and Granger cointegration test output results with five variables

Null hypothesis: Series are not cointegrated				
Automatic lags specification based on Schwarz criterion (maxlag=9)				
Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
LRNOGDP	-2.570111	0.7975	-12.76347	0.7484
LCOP	-6.543451	0.0008	-80.25023	0.0000
LCPI	-6.281836	0.0015	-81.55334	0.0000
LIR	-3.149414	0.5402	-16.74616	0.5120
LEXR	-5.570741	0.0086	-64.13952	0.0000
*MacKinnon (1996) p-values.				

Table 4.4. 23: Engle and Granger cointegration test output results with two variables

Null hypothesis: Series are not cointegrated				
Automatic lags specification based on Schwarz criterion (maxlag=9)				
Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
LRNOGDP	-1.133885	0.8750	-2.657773	0.8973
LCOP	-3.387821	0.0611	-9.153625	0.3747

From table 4.4.22, the equation with LRNOGDP as the dependent variable has a tau statistic of $\tau = -2.570$, and the probability value is 0.7975 which is greater than 5% (0.05). Similarly, in the equation where LIR is the dependent variable, the tau statistic ($\tau = -3.149$) has a probability value of 0.5402 which is greater than 5%. These results suggest that the model do not exhibit cointegration when LRNOGDP and LIR are the dependent variables. Hence, there is no cointegration in the LRNOGDP model. However, for the equilibrium equations where LCOP, LCPI, and LEXR are dependent variables, the null hypothesis of no cointegration is rejected since the probability values associated with the tau-statistics are less than 5%. This implies the variables are cointegrated when LCOP, LCPI, and LEXR are dependent variables. However, based on our prior theoretical belief that LRNOGDP is the dependent variable, we can assume that the variables are not cointegrated. In the two-variable case (see table 4.4.23), it also appears that LRNOGDP and LCOP are not cointegrated in both equilibrium equations. The null hypothesis is not rejected in both the LRNOGDP and the LCOP equations as the probability values of the tau-statistics are greater than 5% in both equations. This implies the two variables are not cointegrated regardless of which of the variables is a dependent variable. In general, this result seems to be consistent with the results of the Engle and Granger two-step method.

The problem with the Engle and Granger method is that the test has low power, and as a result, it fails to reject the null hypothesis as often as it should. As a result, the ARDL bounds test approach to cointegration proposed by Pesaran et al (2001) has become a popular alternative. Hence, we shall also apply the ARDL approach to our data to determine whether the results will be different from the results obtained from the Engel and Granger method. The ARDL bounds test offers some advantages over the Engle-Granger method such as its flexibility that it can be applied when variables are integrated of different orders (in particular, it is appropriate when there is uncertainty over whether the series are I(0) or I(1)). The ARDL framework pertaining to the five variables in our study can be expressed as follows:

$$\Delta LRNOGDP_t = a_0 + \sum_{j=0}^{n} \alpha_j \, \Delta LRNOGDP_{t-j} + \sum_{j=0}^{n} \mu_j \, \Delta LCOP_{t-j} + \sum_{j=0}^{n} \lambda_j \, \Delta LCPI_{t-j} + \sum_{j=0}^{n} \Theta_j \, \Delta LIR_{t-j} + \sum_{j=0}^{n} \Psi_j \, \Delta LEXR_{t-j} + \delta_1 RNOGDP_{t-1} + \delta_2 COP_{t-1} + \delta_3 CPI_{t-1} + \delta_4 IR_{t-1} + \delta_5 EXR_{t-1} + \varepsilon_t \qquad (4.4.21)$$

where Δ is the first difference operator and ε_t is the white noise error term. The other variables are as defined earlier. The terms with the summation signs represent the error correction dynamics, whilst the second part (terms with δs) correspond to the long run relationship. The null hypothesis of no cointegration is $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$. The test is performed by means of F-statistic using upper and lower bands. The decision rule is that if the calculated F-statistic lies below the lower level of the band, the null hypothesis cannot be rejected indicating that there is no cointegration. If the F-statistic lies above the upper level of the band, the null hypothesis is rejected indicating the existence of cointegration. However, if the F-statistic falls within the band, the result is inconclusive. To select the optimal model, we used the AIC criterion by selecting a maximum of 4 lags. The selected model using this criterion is ARDL (1, 1, 1, 0, 0). To ensure that this model is adequate, diagnostic tests have been conducted for the model and the results are reported in **appendices B24 and B25**. The tests indicate that the model is free from autocorrelation and heteroscedasticity effects. The results of the bounds test and the long run relations between the variables and non-oil GDP are reported in tables 4.4.24 and 4.4.25.

Table 4.4. 24: results of ARDL bound test

F-Bounds Test		Null Hypothesis: No cointegration relationship		
Test Statistic	Value	Signif.	Lower bound	Upper bound
F-statistic	10.47642	10%	2.2	3.09
		5%	2.56	3.49
		1%	3.29	4.37

Table 4.4. 25: ARDL model (1, 1, 1, 0, 0) long run results

Dependent variable: LRNOGDP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCOP	0.389636	0.302569	1.287756	0.2063
LCPI	-0.379042	0.290691	-1.303932	0.2008
LIR	-0.833126	0.302863	-2.750835	0.0093
LEXR	0.547579	0.228502	2.396385	0.0220

According to the results in table 4.4.24, there is sufficient evidence to reject the null hypothesis of no cointegration at any level of significance since the value of the F-statistic lies above the upper bound at all levels of significance. This indicates the existence of a long run relationship between the variables. The long run results in table 4.4.25 suggest that LIR and LEXR both have a significant effect on LRNOGDP in the long run because of their significant t-statistics. The effect of LIR is negative whilst the effect of LEXR is positive in the long run. These signs are consistent with economic theory – higher interest rates increases the cost of borrowing which reduces investment and retards output growth, whilst a rise in exchange rate (i.e. domestic currency depreciation) may stimulate economic growth by increasing the prices of foreign goods relative to home goods. However, the t-statistics of LCPI and LCOP are statistically insignificant suggesting that these variables have no long run effect on LRNOGDP. Hence, although the ARDL bounds test reveals that there is cointegration among the variables, the long run analysis indicates that crude oil prices have no long run effect on the non-oil GDP growth. This result is consistent with the Engle and Granger test results to the extent that the Engle and Granger test did not find a cointegration relationship between LCOP and LRNOGDP.

The Engle and Granger and the ARDL models have also been estimated with GDP and the other variables. The Engle and Granger results are reported **appendix B22** and **B23** whilst the ARDL results are reported in appendices **B26 and B27**. The results in the appendices are consistent with the results reported here. The results indicate that the cointegration relation between oil prices and GDP, and oil prices and non-oil GDP are qualitatively the same. In both sets of models, the long run effect of crude oil prices on economic growth rate is insignificant.

The analyses throughout this section have reviewed the oil price effect on growth rate where the crude oil price is treated as an exogenous variable. In all the various models, we discovered that crude oil price movements have no significant impact on the real GDP/non-oil GDP growth rate in Ghana. Whilst the approach we adopted in the investigations is not very common in the literature, it is also prudent to examine the oil price effect using the common approach in the literature by way of treating the crude oil price as endogenous. This will enable us to evaluate the robustness of our results as well as compare our results to previous studies. These models will be referred to as the endogenous crude oil price models. The next section discusses these models.

4.4.4.2: Endogenous Crude Oil Price Models

VAR/VECM Analysis

In standard reduced form VARs, all variables are treated as endogenous. Hence, these models are suitable for studies where there are no exogenous variables. In the literature, several papers have used these models to examine the oil price effect on economic activities for both developed and developing countries (e.g. see Hooker 1997, Hamilton 2003, Rafiq et al 2009, and Chang and Wong 2003). As a result, we have decided to use the standard reduced form VAR model as expressed in equations 4.3.8 and 4.3.9 under section 4.3.3 to investigate the oil priced-macro economy relationship in our endogenous crude oil price models.

In the unit root testing, all our variables were assumed to be I(1). Hence, before proceeding with the analysis, it is important to perform a cointegration test to determine whether long relationships exist between the variables. Because we are using the standard VAR, the most suitable method of testing for the existence of cointegration is the Johansen's approach (see Johansen 1995). This approach has also been used by Chang and Wong (2003), Adam and Tweneboah (2009), Jumah and Pastuszyn (2007), and Qianqian (2011) to test for cointegration between oil prices and economic activities. Following the approach in the exogenous crude oil price models where we estimated five-variable and two-variable models, we shall also estimate these two separate models for the endogenous crude oil price models. Thus, starting with the Johansen cointegration test, the results of the estimated long run equilibrium relationships for the five-variable model and the two- variable model are reported in tables 4.4.26 and 4.4.27 below.

Table 4.4. 26: Johansen's Cointegration Results for the Five-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.628155	112.6210	88.80380	0.0004
At most 1 *	0.512641	71.07135	63.87610	0.0110
At most 2	0.430162	40.88366	42.91525	0.0787
At most 3	0.238768	17.26275	25.87211	0.3956
At most 4	0.129076	5.804432	12.51798	0.4855
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.628155	41.54966	38.33101	0.0206
At most 1	0.512641	30.18769	32.11832	0.0844
At most 2	0.430162	23.62090	25.82321	0.0951
At most 3	0.238768	11.45832	19.38704	0.4671
At most 4	0.129076	5.804432	12.51798	0.4855

Note: CE(s) denotes the null hypothesis that there is no cointegration, r represents the number of cointegrating relationships, and * denotes rejection of the null hypothesis at the 5% significance level

Table 4.4. 27: Johansen's Cointegration Results for the Two-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.295987	16.03215	15.49471	0.0415
At most 1	0.030291	1.291887	3.841466	0.2557
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen	0.05 Critical Value	Prob.**
None *	0.295987	14.74026	14.26460	0.0420
At most 1	0.030291	1.291887	3.841466	0.2557

Note: CE(s) denotes the null hypothesis that there is no cointegration, r represents the number of cointegrating relationships, and * denotes rejection of the null hypothesis at the 5% significance level

From the cointegration tests, the trace test indicates two cointegrating equations whilst the maximum eigenvalue test indicates one cointegrating equation for the five-variable model. For the two-variable model, both the trace test and the maximum eigenvalue test indicate one cointegrating equation. This result suggests that there is a long run relationship between the variables in the models. As a result, we can proceed to estimate a VECM. As noted by Hanck (2006), the Johansen procedure tends to over-reject the null of “less cointegration” in favour of the alternative of “more cointegration” for tests for more than 1 cointegrating equation and this can be affected by the small sample size. Hence, the cointegration tests that produce more than 1 cointegrating equation may be due to this reason. As a result, we will impose a theoretical prior belief of 1 cointerating equation on all our models. We believe this is reasonable given that this is generally supported by the Johansen test results

In estimating the models, we used the various information criteria to obtain the optimum lags for each model. For the five-variable model, 1 lag was chosen by the final prediction error, the Schwarz criterion, and the Hannan-Quinn criterion, whilst in the two-variable model, 1 lag was chosen by all the criteria (except the likelihood ratio criterion which selected lag 3). The lag selection results for the two models are reported in **appendices C1 and C5**. Both models have passed the autocorrelation and heteroscedasticity tests using lag 1, but neither passed the normality test in the joint tests although the individual components seem to suggest that the residuals of both models are normally distributed. The explanations given in footnote 6 for the normality test also apply to these models. The diagnostic tests for the five-variable model are presented in **appendices C2, C3, and C4** whilst the diagnostic tests for the two-variable model are presented in **appendices C6, C7, and C8**. The results of the estimated VECM for both models are reported in tables 4.4.28 and 4.4.29 respectively. We also estimated the cointegrating coefficients normalised on non-oil GDP. The results of these estimates are presented in tables 4.4.30 and 4.4.31.

Table 4.4. 28: Estimated VECM results for the Five-Variable Model

	D(LRNOGDP)	D(LCOP)	D(LCPI)	D(LIR)	D(LEXR)
ECT	0.020818	0.139098	-0.022479	-0.053404	0.109832
	(0.01973)	(0.04639)	(0.02602)	(0.03475)	(0.05285)
	[1.05514]	[2.99856]	[-0.86396]	[-1.53679]	[2.07812]
D(LRNOGDP(-1))	0.108963	0.148593	-0.357439	0.373140	-0.700332
	(0.22174)	(0.52133)	(0.29240)	(0.39054)	(0.59397)
	[0.49139]	[0.28502]	[-1.22242]	[0.95545]	[-1.17907]
D(LCOP(-1))	0.025673	0.353994	-0.055378	-0.043528	-0.065535
	(0.08242)	(0.19378)	(0.10869)	(0.14516)	(0.22078)
	[0.31148]	[1.82677]	[-0.50952]	[-0.29985]	[-0.29683]
D(LCPI(-1))	-0.247387	-0.218723	0.474696	0.417129	-0.304640
	(0.18801)	(0.44204)	(0.24793)	(0.33114)	(0.50363)
	[-1.31579]	[-0.49481]	[1.91467]	[1.25969]	[-0.60489]
D(LIR(-1))	0.034716	0.403651	-0.281958	-0.578923	-0.454096
	(0.13569)	(0.31902)	(0.17893)	(0.23898)	(0.36347)
	[0.25585]	[1.26528]	[-1.57580]	[-2.42244]	[-1.24933]
D(LEXR(-1))	0.060347	0.041868	-0.037070	0.090461	0.348519
	(0.06314)	(0.14845)	(0.08326)	(0.11121)	(0.16914)
	[0.95572]	[0.28203]	[-0.44521]	[0.81344]	[2.06057]
C	0.086859	0.090357	0.171674	-0.115187	0.285882
	(0.05187)	(0.12196)	(0.06840)	(0.09136)	(0.13895)
	[1.67448]	[0.74090]	[2.50979]	[-1.26082]	[2.05747]
R-squared	0.175542	0.239006	0.315942	0.203921	0.394407
Adj. R-squared	0.034206	0.108549	0.198675	0.067451	0.290591
Sum sq. resids	0.560892	3.100369	0.975310	1.739842	4.024508
S.E. equation	0.126592	0.297627	0.166931	0.222957	0.339096
F-statistic	1.242019	1.832076	2.694207	1.494251	3.799093

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 29: Estimated VECM Results for the Two-Variable Model

	D(LRNOGDP)	D(LCOP)
ECT	-0.021079	0.189518
	(0.02227)	(0.04948)
	[-0.94646]	[3.83038]
D(LRNOGDP(-1))	0.319533	0.156279
	(0.15147)	(0.33649)
	[2.10961]	[0.46444]
D(LCOP(-1))	-0.026411	0.002374
	(0.06216)	(0.13810)
	[-0.42486]	[0.01719]
C	0.032027	0.080711
	(0.02111)	(0.04690)
	[1.51705]	[1.72092]
R-squared	0.128072	0.281414
Adj. R-squared	0.059236	0.224683
Sum sq. resids	0.593186	2.927594
S.E. equation	0.124941	0.277564
F-statistic	1.860532	4.960534

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 30: Estimated Cointegrating Coefficients Normalised on non-oil GDP – Cointegrating Equation1 (Five-variable model)

	LRNOGDP	LCOP	LCPI	LIR	LEXR
Coefficients	1.000000	5.082974	-5.022253	2.817468	3.919344
Standard errors		(0.65960)	(0.66050)	(0.57420)	(0.50684)
t-statistics		[7.60616]	[-7.60371]	[4.90676]	[7.73291]

Table 4.4. 31: Estimated Cointegrating Coefficients Normalised on non-oil GDP (Two-variable model)

Variable	LRNOGDP	LCOP
Coefficient	1.000000	1.355513
Standard errors		(0.27843)
t-statistics		[4.86836]

From the results in tables 4.4.30 and 4.4.31, the coefficient of crude oil prices is positive and statistically significant in both long run models. Note that the signs of the coefficients have been reversed by multiplying the coefficients by -1. The result implies an increase in oil prices will cause output to increase. However, this result is not consistent with theoretical expectations. Also, the coefficient of the error correction term (ECT) in the LRNOGDP equation (reported in tables 4.4.28 and 4.4.29) is positive and statistically significant in the five-variable specification, and insignificant in the two-variable specification. This implies that LRNOGDP is not being forced to its long run value (the cointegrating equation is therefore, more appropriately normalised on one of the other variables in the model). For a variable to be cointegrated, the ECT must be negative and statistically significant for the variable to be forced towards its long run value. All of these contradict the expectation that crude oil prices have a negative long run effect on output. In the ARDL model (see table 4.4.25), LCOP did not have a significant long run effect on LRNOGDP, whilst the Engle and Granger test also revealed that LCOP and LRNOGDP have no cointegration relationship. Therefore, the general indication could be that crude oil prices have no long run effect on non-oil GDP.

The t-ratios of the other variables in table 4.4.30 are statistically significant, and LCPI has a negative sign whilst LIR and LEXR have positive signs. The negative sign of LCPI is consistent with theoretical expectations since economic theory suggests that a rise in the general price level is inflationary, which has a potential negative effect on output growth (see section 4.2). However, the positive signs of LIR and LEXR are rather surprising since interest rates and exchange rates are expected to have a negative impact on economic growth.

The short run dynamic relations between the variables are also reported in the second part of the results in tables 4.4.28 and 4.4.29. The results show that oil price shocks have no significant impact on the output growth rate in the short term since the coefficient of DLCOP in the DLRNOGDP equation is statistically insignificant in both the five-variable and two-variable models. We have also repeated the models in tables 4.4.28 and 4.4.29 by replacing non-oil GDP with GDP, and the results are reported in **appendices C9 and C10**. As can be seen, the results using GDP are qualitatively the same as the results with non-oil GDP.

These results contradict with the findings of Adam and Tweneboah (2009). Adam and Tweneboah (2009) used the VECM model and the set of variables we used in the five-variable model to examine the macroeconomic effects of oil price movements in Ghana. Contrary to the results we reported here, their study found significant effects of oil price shocks on output growth rate both in the short run and the long run. Although we also found a significant long run oil price effects, the coefficients have unexpected positive signs whilst the error correction term in our models are not significant. These results are not consistent with Adam and Tweneboah's results. Our results also differ from the findings of Jumah and Pastuszyn (2007) who found significant correlations between oil prices and economic growth in Ghana. It is important to note that the data we used in our paper are different from the data used by the two previous papers. For example, Adam and Tweneboah (2009) used a frequency conversion method to convert the GDP data of Ghana from annual to quarterly. Whilst the use of quarterly data is preferable to annual data, the data generated by this interpolation method may not be reliable. Also, our sample period covered a more recent period than the study period of the previous studies. Perhaps, these explain the differences in results between our paper and the previous papers.

4.4.4.3: Domestic Oil Price Models

The aim of this section is to examine the relationship between domestic oil prices and the non-oil GDP growth rate in Ghana. In doing so, this paper uses the prices of diesel, petrol, and kerosene in Ghana as proxies of domestic oil prices. We shall also include the other macroeconomic variables that were included in the previous sections (i.e. CPI inflation, interest rates, and exchange rates) and estimate two-variable models and five-variable models for each domestic oil price as we did for the international crude oil price models. Unlike the crude oil price data, the domestic oil price data are shorter, running from 1982 to 2015 making a total of 33 observations (hence, our results are indicative and explanatory in nature and represent what can be done given current data constraints). Also, because of the government's petroleum tax policies, as well as the subsidies it provided on petroleum products, domestic policies and domestic macroeconomic conditions are likely to influence domestic oil prices. As a result, it will not be necessary to treat domestic oil prices as exogenous. Hence, the domestic oil prices are only treated as endogenous variables in these models.

To examine the domestic oil price and the non-oil GDP relationship, we will employ the standard reduced form VAR (or the VECM if necessary) in the form of equations 4.4.16 and 4.4.17. Since the domestic oil prices were all assumed to be I(1) we will first perform a cointegration test using the Johansen approach to determine whether a long run relationship exist between each domestic oil price and the macroeconomic variables. The Johansen cointegration results in the five-variable models for the domestic oil price series show that there is a cointegration relationship between the variables in all the domestic oil price models. These results are reported in tables 4.4.32 to 4.4.34. In the diesel price model, the trace test indicates one cointegrating equation whilst the max-eigenvalue test indicates no cointgrating equation. For the petrol price model, the trace test indicates two cointegrating equations whilst the max-eigrnvalue test indicates one cointegrating equation, whereas in the kerosene price model, the trace test indicates three cointegrating equations whilst the max-eigenvalue test indicates two cointegrating equations. For the two-variable models (reported in tables 4.4.35 to 4.4.37), both the trace test and max-eigenvalue test indicate one cointegrating equation in all the domestic oil price models.

Table 4.4. 32: Johansen's Cointegration Results for Diesel Price Effects in the Five-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.608045	92.03476	88.80380	0.0286
At most 1	0.470702	62.06326	63.87610	0.0704
At most 2	0.441942	41.70475	42.91525	0.0658
At most 3	0.372878	23.03940	25.87211	0.1082
At most 4	0.223818	8.107771	12.51798	0.2430
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.608045	29.97150	38.33101	0.3284
At most 1	0.470702	20.35851	32.11832	0.6236
At most 2	0.441942	18.66535	25.82321	0.3283
At most 3	0.372878	14.93163	19.38704	0.1973
At most 4	0.223818	8.107771	12.51798	0.2430

* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.4. 33: Johansen's Cointegration Results for Petrol Price Effects in the Five-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.747191	108.6171	88.80380	0.0009
At most 1 *	0.546478	65.98832	63.87610	0.0329
At most 2	0.458134	41.47623	42.91525	0.0692
At most 3	0.401638	22.48141	25.87211	0.1248
At most 4	0.190750	6.561069	12.51798	0.3925
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.747191	42.62880	38.33101	0.0151
At most 1	0.546478	24.51209	32.11832	0.3157
At most 2	0.458134	18.99483	25.82321	0.3057
At most 3	0.401638	15.92034	19.38704	0.1487
At most 4	0.190750	6.561069	12.51798	0.3925

* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.4. 34: Johansen's Cointegration Results for Kerosene Price Effects in the Five-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.826005	121.0153	76.97277	0.0000
At most 1 *	0.608252	66.80477	54.07904	0.0025
At most 2 *	0.454866	37.75353	35.19275	0.0259
At most 3	0.300937	18.94511	20.26184	0.0751
At most 4	0.223624	7.846669	9.164546	0.0884
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.826005	54.21052	34.80587	0.0001
At most 1 *	0.608252	29.05123	28.58808	0.0436
At most 2	0.454866	18.80842	22.29962	0.1433
At most 3	0.300937	11.09844	15.89210	0.2446
At most 4	0.223624	7.846669	9.164546	0.0884

* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.4. 35: Johansen's Cointegration Results for Diesel Prices for the Two-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s0	Eigenvalue	Trace Statistic	0.05 Critical Value	Prpb.**
None *	0.462266	25.28896	20.26184	0.0093
At most 1	0.156241	5.436419	9.164546	0.2389
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.462266	19.85254	15.89210	0.0113
At most 1	0.156241	5.436419	9.164546	0.2389

Note: CE(s) denotes the null hypothesis that there is no cointegration, r represents the number of cointegrating relationships, and * denotes rejection of the null hypothesis at the 5% significance level

Table 4.4. 36: Johansen's Cointegration Results for Kerosene Prices for the Two-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.407745	21.23669	20.26184	0.0366
At most 1	0.130492	4.474503	9.164546	0.3460
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.407745	16.76219	15.89210	0.0365
At most 1	0.130492	4.474503	9.164546	0.3460

Note: CE(s) denotes the null hypothesis that there is no cointegration, r represents the number of cointegrating relationships, and * denotes rejection of the null hypothesis at the 5% significance level

Table 4.4. 37: Johansen's Cointegration Results for Petrol Prices for the Two-Variable Model

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.440465	23.55468	20.26184	0.0170
At most 1	0.143957	4.973920	9.164546	0.2863
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.440465	18.58076	15.89210	0.0185
At most 1	0.143957	4.973920	9.164546	0.2863

Note: CE(s) denotes the null hypothesis that there is no cointegration, r represents the number of cointegrating relationships, and * denotes rejection of the null hypothesis at the 5% significance level

The cointegration results reported in the tables above indicate that a long run relationship exist between the non-oil GDP and the domestic oil prices. Hence, we shall proceed to estimate VECM models for all the domestic oil price effects. As noted earlier, all the models will be estimated with 1 cointegrating equation although the cointegration test for some models indicate more than 1 cointegrating equations. If this turns out to be inappropriate, it will likely be reflected in the single cointegrating equations, yielding unexpected results. As a first step, it is necessary to determine the optimal lag lengths for all the models. For the five-variable models, the final prediction error, the Schwarz criterion, and the Hannan-Quinn criterion selected lag 1 for all the three domestic oil price models (**see appendices D1, D2, and D3**). Using lag 1, all the three models are free from serial correlation and heteroscedasticity. However, the models have failed the tests of normality since the test statistics of the joint tests are very high. This suggests that the residuals of the models are not normally distributed (although the individual components of the Jarque-Bera statistic indicate that the residuals could be normally distributed). The explanations given in footnote 6 for the normality test also apply to these models. These diagnostic tests are presented in **appendices D4 to D12**. We shall first analyse the VECM results of the five-variable models which are presented in tables 4.4.38 to 4.4.40

Table 4.4. 38: Estimated VECM Results for Diesel Prices for the Five-Variable Model

Error Correction:	D(LRNOGDP)	D(LDIESEL)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.051881	-0.027161	0.064724	0.065489	0.046267
	(0.01860)	(0.03989)	(0.01200)	(0.03723)	(0.03587)
	[-2.78871]	[-0.68098]	[5.39458]	[1.75904]	[1.28969]
D(LRNOGDP(-1))	-0.161523	-0.073463	0.179474	0.534388	0.010603
	(0.20111)	(0.43115)	(0.12970)	(0.40245)	(0.38780)
	[-0.80317]	[-0.17039]	[1.38381]	[1.32784]	[0.02734]
D(LDIESEL(-1))	0.099055	-0.129626	-0.156995	-0.073439	-0.057221
	(0.08630)	(0.18503)	(0.05566)	(0.17271)	(0.16642)
	[1.14774]	[-0.70058]	[-2.82069]	[-0.42522]	[-0.34383]
D(LCPI(-1))	-0.245981	0.131640	0.287643	-0.494332	-0.484849
	(0.22343)	(0.47901)	(0.14409)	(0.44712)	(0.43085)
	[-1.10093]	[0.27481]	[1.99623]	[-1.10558]	[-1.12534]
D(LIR(-1))	0.046915	0.086002	-0.021187	-0.109275	-0.058734
	(0.09738)	(0.20878)	(0.06280)	(0.19488)	(0.18779)
	[0.48175]	[0.41192]	[-0.33735]	[-0.56072]	[-0.31277]
D(LEXR(-1))	-0.038953	0.305269	0.106848	0.358546	0.335197
	(0.06719)	(0.14406)	(0.04333)	(0.13447)	(0.12957)
	[-0.57971]	[2.11905]	[2.46564]	[2.66639]	[2.58693]
C	0.128989	0.202274	0.135331	-0.002682	0.246761
	(0.04457)	(0.09555)	(0.02874)	(0.08919)	(0.08594)
	[2.89431]	[2.11703]	[4.70857]	[-0.03007]	[2.87138]
R-squared	0.306140	0.409651	0.696843	0.293703	0.245500
Adj. R-squared	0.139613	0.267967	0.624086	0.124192	0.064420
Sum sq. resids	0.210959	0.969641	0.087740	0.844828	0.784437
S.E. equation	0.091861	0.196941	0.059242	0.183829	0.177137
F-statistic	1.838385	2.891305	9.577597	1.732644	1.355756

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 39: Estimated VECM Results for Petrol Price Effects in the Five-Variable Model

	D(LRNOGDP)	D(LPETROL)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.078133	-0.080412	0.086861	0.093037	0.058931
	(0.02533)	(0.06444)	(0.01949)	(0.05217)	(0.05064)
	[-3.08409]	[-1.24778]	[4.45563]	[1.78332]	[1.16377]
D(LRNOGDP(-1))	-0.140482	-0.270410	0.097646	0.518182	-0.019643
	(0.18778)	(0.47767)	(0.14450)	(0.38670)	(0.37534)
	[-0.74811]	[-0.56610]	[0.67576]	[1.34001]	[-0.05233]
D(LPETROL(-1))	0.119921	0.049720	-0.063049	-0.064809	-0.013958
	(0.07951)	(0.20225)	(0.06118)	(0.16373)	(0.15892)
	[1.50827]	[0.24583]	[-1.03051]	[-0.39582]	[-0.08783]
D(LCPI(-1))	-0.214116	0.039026	0.180273	-0.518775	-0.518898
	(0.20293)	(0.51621)	(0.15616)	(0.41790)	(0.40562)
	[-1.05510]	[0.07560]	[1.15443]	[-1.24138]	[-1.27926]
D(LIR(-1))	0.081190	0.240514	-0.042510	-0.138290	-0.067601
	(0.09709)	(0.24698)	(0.07471)	(0.19994)	(0.19407)
	[0.83621]	[0.97383]	[-0.56898]	[-0.69165]	[-0.34834]
D(LEXR(-1))	-0.072770	0.011466	0.121290	0.383226	0.340456
	(0.06862)	(0.17454)	(0.05280)	(0.14130)	(0.13715)
	[-1.06054]	[0.06569]	[2.29715]	[2.71213]	[2.48238]
C	0.124619	0.255036	0.131766	-0.006137	0.241769
	(0.04457)	(0.11338)	(0.03430)	(0.09178)	(0.08909)
	[2.79599]	[2.24947]	[3.84190]	[-0.06687]	[2.71383]
R-squared	0.344823	0.143072	0.592459	0.293777	0.234540
Adj. R-squared	0.187581	-0.062590	0.494650	0.124283	0.050829
Sum sq. resids	0.199198	1.288927	0.117951	0.844740	0.795832
S.E. equation	0.089263	0.227062	0.068688	0.183819	0.178419
F-statistic	2.192940	0.695665	6.057264	1.733260	1.276681

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 40: Estimated VAR Results for Kerosene Price Effects in the Five-Variable Model

	D(LRNOGDP)	D(LKEROSENE)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.090968	0.001460	0.108575	0.090578	0.045948
	(0.03098)	(0.09517)	(0.02106)	(0.06317)	(0.06085)
	[-2.93647]	[0.01534]	[5.15667]	[1.43386]	[0.75510]
D(LRNOGDP(-1))	-0.132314	-0.025931	0.127593	0.508334	-0.051975
	(0.19389)	(0.59568)	(0.13178)	(0.39537)	(0.38084)
	[-0.68242]	[-0.04353]	[0.96823]	[1.28571]	[-0.13647]
D(LKEROSENE(-1))	0.037650	-0.139553	-0.096510	-0.048648	0.042650
	(0.06710)	(0.20614)	(0.04560)	(0.13683)	(0.13180)
	[0.56110]	[-0.67697]	[-2.11622]	[-0.35555]	[0.32360]
D(LCPI(-1))	-0.194836	-0.097522	0.221485	-0.501302	-0.538188
	(0.20989)	(0.64485)	(0.14266)	(0.42801)	(0.41228)
	[-0.92826]	[-0.15123]	[1.55256]	[-1.17125]	[-1.30540]
D(LIR(-1))	0.046362	0.086957	-0.021388	-0.089361	-0.022024
	(0.09713)	(0.29841)	(0.06602)	(0.19807)	(0.19079)
	[0.47732]	[0.29140]	[-0.32398]	[-0.45117]	[-0.11544]
D(LEXR(-1))	-0.034298	0.325665	0.112964	0.346305	0.293601
	(0.06981)	(0.21446)	(0.04745)	(0.14235)	(0.13712)
	[-0.49133]	[1.51851]	[2.38094]	[2.43282]	[2.14126]
C	0.132424	0.251646	0.135043	-0.002630	0.243558
	(0.04497)	(0.13816)	(0.03057)	(0.09170)	(0.08833)
	[2.94467]	[1.82139]	[4.41822]	[-0.02868]	[2.75728]
R-squared	0.304755	0.173091	0.662618	0.265172	0.215581
Adj. R-squared	0.137897	-0.025367	0.581646	0.088813	0.027320
Sum sq. resids	0.211380	1.995155	0.097646	0.878955	0.815543
S.E. equation	0.091952	0.282500	0.062497	0.187505	0.180615
F-statistic	1.826428	0.872182	8.183312	1.503594	1.145120

Standard errors in ( ) & t-statistics in [ ]

The short run dynamics from the tables above show that there is no significant relationship between any of the domestic oil prices and output growth rate in the short run as the t-ratios of the domestic oil prices in all the three models are statistically insignificant in the DLRNOGDP equation. However, the long run analysis suggests that diesel, petrol and kerosene prices have a long run effect on the non-oil GDP growth rate both in terms of the speed of adjustment and cointegrating coefficients. The t-ratios of the ECTs in the DLRNOGDP equations in tables 4.4.38

to 4.4.40 are all negative and significant (hence, LRNOGDP is being forced towards its long run value). The cointegrating coefficient for petrol price effects (reported in tables 4.4.42) is also significant at the 5% level, whilst the cointegrating coefficient for diesel price effect of 1.79285 (see table 4.4.41) is very close to 2 and almost significant at the 5% level (it is probably significant at the 10% level). However, the cointegrating coefficient for kerosene price (see table 4.4.43) is not significant. The signs of the t-ratios of diesel, petrol, and kerosene price effects are negative indicating that these variables have a negative long run relationship with the non-oil GDP growth rate. Note that the signs of the coefficients in the cointegrating equations have been reversed by multiplying the coefficients by -1. In general, the cointegration analyses suggest that diesel and petrol prices have a significantly negative effect on the non-oil GDP growth rate in the long run.

Table 4.4. 41: Estimated Cointegrating Coefficients for Diesel Price Effects Normalised on non-oil GDP

	LRNOGDP	LDIESEL	LCPI	LIR	LEXR
Coefficients	1.000000	-1.253653	4.217917	-1.154786	-2.039852
Standard errors		(0.69925)	(1.06300)	(0.69808)	(0.77278)
t-statistic		[-1.79285]	[3.96796]	[-1.65424]	[-2.63962]

Table 4.4. 42: Estimated Cointegrating Coefficients for Petrol Price Effects Normalised on non-oil GDP

	LRNOGDP	LPETROL	LCPI	LIR	LEXR
Coefficients	1.000000	-1.151195	2.719292	-1.376910	-0.885109
Standard errors		(0.48228)	(0.74126)	(0.52184)	(0.59625)
t-statistics		[-2.38696]	[3.66849]	[-2.63857]	[-1.48445]

Table 4.4. 43: Estimated Cointegrating Coefficients for Kerosene Price Effects Normalised on non-oil GDP

	LRNOGDP	LKEROSENE	LCPI	LIR	LEXR
Coefficients	1.000000	-0.217950	2.395327	-0.711353	-1.638263
Standard errors		(0.38679)	(0.54442)	(0.43864)	(0.54304)
t-statistics		[-0.56348]	[4.39977]	[-1.62173]	[-3.01683]

The coefficients of LCPI are positive with significant t-ratios in tables 4.4.41, 4.4.42, and 4.4.43. On the other hand, the coefficients of LIR and LEXR are negative in all the three tables. The t-ratio of LIR is significant in table 4.4.42 whilst the t-ratios of LEXR are significant in tables 4.4.41 and 4.4.43. The positive sign of LCPI is not expected as it suggests that the price level has a positive effect on output growth. However, LIR and LCPI are appropriately signed since interest rates and exchange rates are expected to have a negative effect on output. These results are opposite of the results obtained in the world crude oil price model (see table 4.4.30). Hence, the long run effects of the CPI, interest rates, and exchange rates on output growth are not robust across the world oil price and the domestic oil price models.

In the next models, we shall analyse the domestic oil price effects in the two-variable case for each of the domestic oil prices. From the lag selection criteria, lag 1 was chosen by all the various criteria (except the likelihood ratio) for all the models (**see appendices D13, D14, and D15**). As in the previous models, all the models have passed the autocorrelation and heteroscedasticity tests using lag 1, but the normality tests based on the joint test statistics indicate that the residuals of the models are not normally distributed[7]. Meanwhile, the Jarque-Bera statistic for the individual components of the normality test suggests that the residuals could be normally distributed since the Jarque-Bera statistics for some of the individual components are less than six. The explanations given in footnote 6 for the normality test also

[7] For all the models in this chapter that failed the normality test, we re-estimated the models with dummy variables to determine whether the inclusion of the dummies will overcome the non-normality issue. However, the inclusion of the dummies did not solve the non-normality problem neither has that improved the coefficient estimates. Because of the large number of models we estimated, it is not convenient to report results with the dummy variables because some of the results became very large as a result of the inclusion of the dummies.

apply to these models. These diagnostic tests are reported in **appendices D16 to D24**. The results of these models are presented in tables 4.4.44 to 4.4.46.

Table 4.4. 44: Estimated VECM Results for Diesel Prices for the Two-Variable Model

Error Correction:	D(LRNOGDP)	D(LDIESEL)
ECT	-0.025586	0.132232
	(0.02340)	(0.04675)
	[-1.09336]	[2.82853]
D(LRNOGDP(-1))	0.063862	-0.325413
	(0.18358)	(0.36674)
	[0.34787]	[-0.88731]
D(LDIESEL(-1))	0.050234	-0.058413
	(0.08729)	(0.17438)
	[0.57546]	[-0.33496]
C	0.062611	0.319712
	(0.03429)	(0.06850)
	[1.82606]	[4.66757]
R-squared	0.052369	0.299960
Adj. R-squared	-0.049163	0.224955
Sum sq. resids	0.288114	1.149807
S.E. equation	0.101439	0.202644
F-statistic	0.515790	3.999233

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 45: Estimated VECM Results for Kerosene Prices for the Two-Variable Model

Error Correction:	D(LRNOGDP)	D(LKEROSENE)
ECT	-0.022169	0.141883
	(0.02420)	(0.06330)
	[-0.91590]	[2.24147]
D(LRNOGDP(-1))	0.076946	-0.192184
	(0.18363)	(0.48021)
	[0.41903]	[-0.40021]
D(LKEROSENE(-1))	8.29E-05	-0.035053
	(0.06278)	(0.16418)
	[0.00132]	[-0.21350]
C	0.076847	0.307218
	(0.03175)	(0.08304)
	[2.42023]	[3.69983]
R-squared	0.044628	0.176688
Adj. R-squared	-0.057734	0.088476
Sum sq. resids	0.290468	1.986477
S.E. equation	0.101852	0.266356
F-statistic	0.435981	2.002993

Standard errors in ( ) & t-statistics in [ ]

Table 4.4. 46: Estimated VECM Results for Petrol Prices for the Two-Variable Model

Error Correction:	D(LRNOGDP)	D(LPETROL)
ECT	-0.016694	0.070282
	(0.01347)	(0.02726)
	[-1.23931]	[2.57784]
D(LRNOGDP(-1))	0.070273	-0.172024
	(0.18248)	(0.36933)
	[0.38510]	[-0.46577]
D(LPETROL(-1))	0.073805	-0.083961
	(0.08484)	(0.17172)
	[0.86989]	[-0.48895]
C	0.055667	0.302598
	(0.03412)	(0.06906)
	[1.63140]	[4.38164]
R-squared	0.067572	0.227959
Adj. R-squared	-0.032331	0.145241
Sum sq. resids	0.283492	1.161246
S.E. equation	0.100622	0.203649
F-statistic	0.676373	2.755840

Standard errors in ( ) & t-statistics in [ ]

From the results in the tables above, the ECT in the DLRNOGDP equation is negative but statistically insignificant in all the models, suggesting that the speed of adjustments of the non-oil GDP growth rate to its long run equilibrium is very slow. In other words, LRNOGDP is not convincingly forced to its long run value. The short run dynamics shown in the second part of the results also reveal that all the domestic oil prices have no significant impact on the output growth in the short run. On the other hand, the cointegrating coefficients normalised on non-oil GDP suggest that the non-oil GDP is affected by the domestic oil prices in the long run. These results are reported in tables 4.4.47 to 4.4.49. However, the coefficients of the domestic oil prices are all positive with significant t-ratios. The results show that increases in diesel, kerosene, and petrol prices will improve output growth in the long run. Note that the signs of the cointegrating coefficients have been reversed by multiplying the coefficients by -1.

Table 4.4. 47: Estimated Cointegrating Coefficients Normalised on non-oil GDP for Diesel Price Effects

	LRNOGDP	LDIESEL
Coefficients	1.000000	0.638109
Standard errors		(0.11211)
t-statistics		[5.69190]

Table 4.4. 48: Estimated Cointegrating Coefficients Normalised on non-oil GDP for Kerosene Price Effects

	LRNOGDP	LKEROSENE
Coefficients	1.000000	0.577971
Standard errors		(0.13573)
t-statistics		[4.25810]

Table 4.4. 49: Estimated Cointegrating Coefficients Normalised on non-oil GDP for Petrol Price Effects

	LRNOGDP	LPETROL
Coefficients	1.000000	0.898714
Standard errors		(0.20943)
t-statistics		[4.29127]

From these analyses, it can be observed that the short run effects of the domestic oil price shocks on output growth is qualitatively the same in both the two-variable specifications and the five-variable specifications. However, in terms of the long run effects, the two sets of models produced different results. In the five-variable specifications, the error correction terms of LRNOGDP were negative and significant, and the cointegrating coefficients also suggest that the domestic oil prices have a negatively significant effect on output. On the contrary, the error correction terms in the two-variable specifications were insignificant, and the domestic oil prices have an unexpected positive effect on output in the long run. Hence, the five-variable specifications produce more plausible results than the two-variable specifications. It also implies that the exclusion of the other macro variables in the model has an effect on the long run relationship between domestic oil prices and non-oil GDP.

As in the previous models, we have also repeated the domestic oil price models by replacing the non-oil GDP with GDP. The results (reported in **appendices D25 to D30)** show that the domestic oil price effects on GDP are not statistically different from the results we reported above. In general, the results highlight the fact that oil price movements have qualitatively the same effect on non-oil GDP and total GDP in Ghana. This is due to the fact that the Ghana oil industry is still at an infant stage because the oil production only started in 2011. Hence, the differences between total GDP and non-oil GDP may not be significant enough to cause the oil price effects on the two variables to be significantly different. Nevertheless, the use of non-oil GDP in this study is important because it will lay the foundation for future research about the oil price and non-oil GDP growth in Ghana as the oil industry expands and more data becomes available.

Most previous papers have studied the macroeconomic effects of international crude oil price shocks for both developed and developing countries and, whilst some studies found a significantly negative effect of oil price movements on output growth, others found that oil prices are neither necessary nor sufficient in determining economic activities. In this paper, we have re-examined the crude oil price effect using several models to determine whether the treatment of the crude oil price, or the interaction of other macroeconomic variables have any influence on the crude oil price-GDP growth relationship. We also examined the domestic oil price effect on the non-oil GDP growth rate in Ghana. As we have discovered from the forgoing analysis, world crude oil prices do not appear to have any significant impact on the non-oil GDP or total GDP both in the short run and in the long run. This result is robust in both the exogenous crude oil price models and the endogenous crude oil price models. For the domestic oil price models, there is some evidence that the oil price effects are significant in the long run, but they are insignificant in the short run.

4.5: Discussion of Results

The results from the crude oil price models generally suggest that international crude oil price movements have an insignificant effect on economic growth in Ghana whilst domestic oil prices appear to have only a long run effect. This result may be explained if one considers the nature of the Ghanaian economy. Like most countries in the West African sub region, primary production dominates economic activities in Ghana. The agricultural sector has been the largest sector in Ghana from the 1960s through to the mid-2000s. The sector's average contribution to GDP was over 50% - in some years, its contribution to GDP reached 60%. Yet, agriculture in Ghana is not mechanized. Mechanized farming in Ghana is still at an infant stage, with many farmers still using subsistence farming tools such as hoes and cutlasses to cultivate the land. The use of more labour and less machines means the farming system in Ghana does not depend much on fuel from oil. Also, the services sector, which surpassed agriculture to become the largest sector in Ghana since 2006, is dominated by communication, finance (banking and insurance), and general administration services. Similar to the case of agriculture, the production of these services generally does not entail the use of oil, making the industry less sensitive to oil price shocks.

The industrial sector is the smallest sector in Ghana, and output from this sector mainly comes from mining and hydroelectricity from the Akosombo dam. The manufacturing subsector in Ghana has been very weak, contributing relatively less to total industrial output. Some of these industries include Aluminium smelting by the Volta Aluminium company (VALCO), textiles, food processing, craft, weaving, and some glass making. These industries also rely mostly on electricity for energy rather than oil. Thus, a possible cause of the insignificant short run effect of domestic oil price shocks on output growth could be due to the relatively weak manufacturing sector and the overall structure of the Ghanaian economy.

On the other hand, the transport sector is the largest consumer of oil in Ghana, and it plays a key role in linking together various trade and business activities. Therefore, whilst the domestic oil price pass-through effect is not immediate, the domestic oil price shocks will eventually feed through to the GDP growth rate over time through transportation or transport related activities. Increases in the domestic oil prices can possibly increase the cost of doing business by increasing the cost of the transport of goods and services. Although this may not affect production in the short term, it can affect production in the long term. Perhaps, this helps to explain the short run and long run impact of the domestic oil price shocks on output growth rate in Ghana.

This result may also imply that domestic oil prices are most significant determinants of GDP growth rate in Ghana than crude oil prices. To this extent, this finding is consistent with the results of Cunado and de Gracia (2005). In a study to examine the relationship between oil prices, economic activity, and inflation in some Asian countries, Cunado and de Gracia (2005) concluded that the oil price effects on economic activity are more significant when oil price shocks are defined in local currencies than when they are defined in US dollars (world oil prices). However, contrary to our results, the findings of Cunado and de Gracia (2005) suggest that the impact of oil prices on economic activity is significant only in the short run for both proxies of oil prices (i.e. world oil prices measured in US dollars and oil prices measured in local currency). The difference though between our study and Cunado and de Gracia (2005) is that whilst we used actual domestic oil prices such as petrol, diesel, and kerosene as domestic oil price proxies, Cunado and de Gracia (2005) obtained domestic oil price proxies by converting world oil prices in US dollars into local currency using the bilateral exchange rates.

If we consider the exogenous crude oil price models, the crude oil prices have no impact on output growth rate both in the short run and in the long run. This paper believes that this result could also be due to the reasons given above, as well as subsidies the government provided on petroleum products for several years (although this has not been empirically tested). In Ghana, petroleum products are imported by the Bulk Distribution Companies (BDCs), and these companies are regulated by the National Petroleum Authority (NPA); an institution mandated to set petroleum product prices in Ghana (Acheampong and Ackah (2015). The total cost incurred by the BDCs to land refined oil at the ports of Ghana and distribute to the pumps – the “pre-pump price”, forms about 65 per cent of the pump price, with the remaining 35 per cent coming from fuel taxes and margins.

The government, through the NPA, has the exclusive rights to intervene in the price build up. This implies the full cost of petroleum products is not always passed on to consumers through the final pump price. The government does not import crude oil or refined petroleum products, but it pays the BDCs the full cost of the pre-pump component, regardless of the pump price. Effectively, in order to stabilise the pump price, the government is subsidising the BDCs by accepting reduced tax revenue. This also means putting a cap on the ex-pump price at a certain amount, thereby, reducing the prices paid by consumers below a benchmark price. This type of subsidy arises when the prices consumers pay is below the international price adjusted for transportation and distribution costs. It is referred to as a pre-tax subsidy.

However, the NPA's decision in 2015 to pursue a full deregulation has significantly changed the petroleum product pricing system in Ghana. The deregulation policy has all but removed petroleum product subsidies and allowed petroleum product prices to be determined by market forces. Since the data we used in this paper ended in 2014, the effect of the withdrawal of the petroleum subsidies is not captured in our results. Hence, the failure of the international crude oil prices to significantly affect the GDP growth rate could also be due to the petroleum subsidies. It should be noted however, that this has not been formally tested. This result could also be explained by the low level of industrialization and mechanized farming, as well as the overall structure of the Ghanaian economy as we noted above.

4.6. Conclusion

This paper investigates the macro economic impact of domestic and international oil price shocks in Ghana. In doing so, we used several models to analyse the oil price effects, and these include exogenous and endogenous oil price models, and two-variable and five-variable models. In the exogenous oil price models, we employed the structural VAR and some scenario-based forecasting from a reduced form VAR in which the oil price is included as an exogenous variable. We also employed the Engle and Granger and the ARDL models to test for the existence of cointegration and long run relationship among the variables. For the endogenous oil price models, we used the standard reduced form VAR where all the series are treated as endogenous variables.

Overall, the results suggest that both domestic and crude oil price shocks have little effect on the GDP growth rate in the short run. In the long run, the results from the domestic oil price models suggest that the domestic oil prices have a strong relationship with the output growth rate. However, we did not find any evidence of a long run relationship between crude oil prices and the GDP growth rate in any of the exogenous crude oil price models which we believe to be most appropriate in modelling the crude oil price and macro economy relationship for a small country such as Ghana. Opinions in the literature are divided about the crude oil price-macro economy relationship – whilst papers such as Hamilton (1996, 2003), Fofana et al (2009), Rafiq et al (2009), Park et al (2011), and many others found sufficiently large negative impact of crude oil price shocks on economic growth, other papers such as Bernanke Gertler and Watson (1997), Hooker (1996), Basky and Kilian (2004), and

Leduc and Sill (2004) argued that crude oil prices by themselves are not relevant in explaining macroeconomic performance.

As we did not find any short run or long run relationship between crude oil prices and GDP growth relationship in the exogenous crude oil price models, we argued that this insignificant crude oil price effect could be caused by the low level of industrialization and mechanized farming in Ghana, the overall structure of the Ghanaian economy, and the subsidization of petroleum products which has been in place for several years (although the effects of subsidies have not been formally tested). Jumah and Pastuszyn (2007) and Tweneboah and Adam (2008) also examined the crude oil price and macro economy relationship in Ghana using the standard VECM where the crude oil price is endogenous. These papers found significant short run and long run effects of crude oil price shocks on output growth in Ghana. Our endogenous crude oil price model with five variables is based on the approach of these papers. Yet, we did not find any significant relationship between crude oil prices and GDP growth. The differences between our results and the results of the previous papers could be due to the fact that the previous papers e.g. Tweneboah and Adam (2008) used a frequency conversion method to convert the GDP data from annual to quarterly which can affect the reliability of the data. Also, our data sample covers more recent period than the data samples used by the other papers. Papers such as Fofana et al (2009), Rafiq et al (2009), Park et al (2011) also examined the crude oil price-macro economy relationship for developing countries, but the results we reported are not consistent with the findings of these papers.

Based on our results, this paper suggests that the domestic oil prices are most important to the Ghanaian economy than the crude oil prices. The results from the domestic oil price models suggest that all the domestic oil prices (i.e. diesel, kerosene, and petrol) have a long run effect on the non-oil GDP growth rate although the short run effects are insignificant. Here, we noted that the insignificant short run effects of domestic oil prices on output growth rate could be due to the heavy dependence of the Ghanaian economy on primary production activities. However, the effects of the domestic oil price shocks will eventually feed through to the economy in the long run.

This paper also discovered from the exogenous crude oil price models that although the GDP growth rate and crude oil prices have no significant correlation between them, the scenario-based forecasting produced some interesting results which are worth mentioning here. The graphs from this exercise predict that the effect of a onetime crude oil price shock on GDP growth is negative and very temporary. Two forecast periods have been examined; the first period covered 2005 to 2014 whilst the second period covered 2015 to 2024. For both forecast periods, the effect of the shock is transitory. In the first period, the effect almost becomes zero after about one and a half years, whereas in the second period, the effect almost becomes zero after about two years. The graphs for asymmetric shocks also predict that GDP growth will become higher following negative crude oil price shocks, but this surplus growth slowly evaporates as time passes. Thus, although the coefficients explaining the effects of the crude oil price shocks on the GDP growth rate are not statistically significant in the VAR models, the simulation graphs from the VARs suggest that the crude oil price shocks have some notable effects which have economic significance to the Ghanaian economy. The results from the forecast scenarios are consistent with both economic theory and some empirical works. Hence, whilst the results are not standard in terms of statistical significance, we do not discount the fact that the results could be useful in understanding how crude oil price shocks affect the Ghanaian economy.

This paper has made the following contributions to the literature. Firstly, this paper used two approaches to examine the macroeconomic effects of world crude oil price shocks in Ghana by treating crude oil prices as both exogenous and endogenous. In doing so, we discovered that the world crude oil price effect is not significant regardless of whether the crude oil price is treated as exogenous or endogenous. Such analyses have not yet been made by any previous paper. Also, there has not been any research that used oil price as an exogenous variable in a VAR, or a scenario-based dynamic forecasting exercise to predict the response of the economy to oil price shocks. To the best of our knowledge, this paper is the first to adopt this approach in examining the relationship between crude oil price movements and economic activities.

Besides, our paper examined the domestic oil price effects on output growth rate, and the results have been compared to the results of the world crude oil price effects. From these investigations, we discovered that the domestic oil prices have greater effects on the Ghanaian economy than the world crude oil prices. Although there has been a large body of literature examining the macroeconomic effects of international crude oil price shocks, very little attention has been given to the domestic oil price effects. Papers such as Cunado and de Gracia (2005) used world oil prices converted into local currency as a proxy for domestic oil prices. However, this form of measuring domestic oil prices may not reflect the actual prices of domestic oil because of price-controls and varying taxes on petroleum products. Furthermore, this paper has included more recent data, which implies our results are likely to capture recent events that happened in the world oil market than most of the previous studies.

The results reported here also have some implications for policy and decision makers. Firstly, our findings can help the government identify effective monetary policies to cope with crises in the world oil market. The fundamental point here is that because the crude oil price has not been a significant economic variable, policy makers have a wide discretion in deciding the path of output under most circumstances. An oil price spike for example, does not put a binding constraint on the monetary authorities to loosen monetary policy to offset its effect on output. If inflation is a priority, policy makers could focus on inflation stabilization by tightening monetary policy during oil price rises.

Also, as our findings suggest that the domestic oil price shocks could have some long run effects on output growth, there is the need for the government to initiate policies and programs aimed at lessening the impact of such shocks. One way forward is to promote the use of renewable and bio-fuels. With the abundant sunshine in Ghana, solar energy can provide a valuable source of alternative to oil. There are also good prospects for bio-fuels in Ghana because the country is very rich in biomass (feedstock). Hence, policies aimed at insuring the viability of bio-fuel without compromising food security should be encouraged. This will help lessen the dependence of the economy on oil. Energy efficiency policies designed to promote oil saving should also be encouraged. Furthermore, the government should formulate transport-related policies such as promoting mass transportation or encouraging the use of electrically powered vehicles. After all, oil plays a crucial role in the transport sector and it is reasonable to conjecture that one of the main channels by which oil price shocks could feed into the economy is through transport.

Also, the government’s tax policies on petroleum products should be focused on achieving a balance between generating revenue and keeping domestic oil prices lower, since higher taxes on petroleum products will increase domestic oil prices which can be detrimental to the economy in the long run. The government can also offset the impact of higher prices of imported refined petroleum products by reducing taxes on petroleum products to reduce the prices consumers pay for petroleum products.

This paper has identified some avenues for future research. Firstly, due to data unavailability, the domestic oil price data used in this paper have covered a relatively short sample period. Hence, the macroeconomic effects of the domestic oil price shocks can be re-examined in the future as longer data samples become available. Secondly, because the government removed all subsidies on petroleum products in 2015, the results may be different if the oil price effect were to be examined after the subsidies were withdrawn. Hence, as more data becomes available, future research could also examine the oil price macro economy relationship during the post-subsidy era. Finally, because agriculture historically accounted for a large percentage of Ghana’s GDP, future research can look at the sectoral effects of oil price shocks focusing on how oil prices affect the agricultural, services, and industrial sectors.

Chapter 5: A multivariate approach to modelling the dynamic interactions among oil prices, exchange rates, and stock markets: Evidence from Ghana

5.1. Introduction

The aim of this chapter is to investigate the shock and volatility spill over effects of crude oil prices and domestic oil prices on the Ghanaian currency exchange rate and the stock market. This topic is important because of the financialization of the oil market in recent years (Antonakakis et al 2017). According to some researchers, the financialization of the oil market is as a result of the increased hedging and speculative activities by investors (Hamilton and Wu 2014, Alquist and Kilian 2010, and Buyukashin et al 2010).

The traditional view argues that oil prices affect exchange rates through the terms of trade effect (Chen and Chen 2007). A rise in oil prices reduces the demand for the domestic currency of an oil importing country, hence driving down the value of the currency. Traditional finance theory also posits that oil prices can affect stock prices directly by impacting on future cash flows or indirectly through an impact on the discount rate used to discount the future cash flows (e.g. see Basher and Sadorsky, 2006 and Muhtaseb and Al-Assaf, 2017). This is based on the assumption that increases in oil prices will increase the cost of production and the cost of doing business, and hence, reduces profits. Consequently, as profits decline, the share prices of the companies are expected to fall.

The relationship between oil prices and exchange rates, and oil prices and stock markets has been examined by previous research (e.g. Gosh 2011, Lizardo and

Mollick 2011, Amano and Norden 2008, Masih et al 2011, Basher and Sadorsky 2006, Chen 2010, and Filis 2010). However, studies that investigated the exogenous crude oil price effects on the exchange rates and the stock market for any small country are still lacking. This has opened the door for a new line of research in this topic. Besides, despite the large body of literature investigating the relation between crude oil prices and financial assets, there is still a shortage of literature that examined the link between domestic oil prices and financial variables. Hence, this chapter seeks to explore two new lines of research.

Firstly, this paper will examine the effects of exogenous crude oil price shocks and volatilities on the Ghana currency exchange rates and the Ghana stock market by treating the crude oil price as exogenous. The result will then be compared to the oil price effects in the commonly known approach where crude oil prices and other variables in the model are all specified as endogenous. Treating crude oil prices as exogenous is interesting in the case of Ghana given that Ghana is an example of a small country where economic activities are not likely to have any significant impact on world crude oil prices. To the best of our knowledge, no paper has used this approach in the existing literature to examine the link between crude oil prices and financial markets for any small country. Hence, the treatment of crude oil prices (as exogenous) to study a small country like Ghana will represent a contribution of this paper.

Secondly, the paper will examine the shock and volatility spillover effects between domestic oil prices, the Ghana currency exchange rates, and the Ghana stock market. Again, the domestic oil price effects have not been extensively examined in the literature unlike the international crude oil price effects. Therefore, this study will be contributing to the literature in two ways; 1) it will examine and compare the oil price effect when the crude oil price is exogenous, and when it is endogenous for a small country. 2) It will be among the first to examine the dynamic interactions between domestic oil prices, exchange rates, and stock markets. In order to conduct this investigation, we shall use monthly data from January 1991 to December 2015 to model the variables using a multivariate GARCH-BEKK model. The rest of the chapter is organised as follows;

Section 5.2 describes the data to be used as well as some preliminary analysis of the data. This includes some descriptive statistics of the data and unit root testing. Section 5.3 discusses the research methodology whilst section 5.4 presents the results. Section 5.5 concludes the chapter.

5.2. Data and Preliminary Analysis

This study uses data on stock market indices of Ghana and the US, Ghanaian currency exchange rate, domestic oil prices, and world crude oil prices. The stock market indices are the Ghana stock exchange composite index (GSECI) of Ghana, and the S&P 500 of the US. For the Ghana currency exchange rate, we used the Ghana cedi exchange rate vis-à-vis the US dollar, whilst the Brent crude oil price is used to represent the international price of crude petroleum oil. We also used the prices of diesel, petrol, and kerosene to denote the domestic oil prices. All the data are obtained from different sources. The Ghana stock market data are not available within the public domain, and so the data was obtained directly from the Ghana stock exchange upon a special request. The S&P 500 data was obtained from yahoo finance whilst the Ghana cedi exchange rate data was obtained from www.oanda.com. Domestic oil prices were obtained from the Bank of Ghana website, and the Brent crude oil price data was obtained from the Energy Information Administration website at www.eia.com

The full sample period under study runs from January 1991 to December 2015. This period was chosen for a number of reasons. Firstly, data was available for all the series during this period. Secondly, this period witnessed sharp movements in the price of oil caused by both supply-led and demand-led factors such as conflicts in the Middle East, the actions of OPEC, and increases in global demand propelled by China's economic growth. However, some structural changes to the Ghana stock market and the Ghanaian currency happened during the sample period. Prior to 2011, the main index of the Ghana stock exchange was the GSE All-Share index. In January 2011, a new index was introduced to replace the GSE All-Share index. This is known as the Ghana stock exchange composite index (GSECI). The measurement of the data set for the Ghana stock exchange index therefore, is not the same over the whole period (i.e. 1991 to 2015). The two indices need to be linked together before the data can be used to represent a single variable for the sample period. We explain how this problem is addressed below. Also, after a sustained period of depreciation of the Ghana currency, the monetary authorities in Ghana became worried about the credibility of the local currency among Ghanaian citizens and the possibility of a loss of confidence in the cedi in the mid-2000s. As a result, in 2007, the government redenominated the local currency in an attempt to reassert the monetary control of the country. Finally, this period captures the global financial crises of 2008 which led to the crash of stock markets.

The data are monthly, and so we have 12 trading months per year, yielding a total of 300 observations. By using monthly data we can overcome some of the problems associated with the use of very high frequency data such as daily data. For example, we can avoid the interferences associated with the use of synchronized data, as a public holiday in one country may coincide with a trading day in another country. Also, daily data have the problem with time zones because one country may be located in a different time zone, leading to different opening and closing times from another country. In this study, the US, located in North America, is on a different time zone from Ghana which is located in West Africa. We bear in mind however, that daily data do have some advantages compared to monthly or weekly data. In particular, the use of daily data can capture more information than weekly and monthly data. For instance, daily data can capture some interactions that may only last a few days.

In this study, we used the widely accepted benchmark indices for Ghana and the US. Each index represents the equity market of that country, and they describe the overall performance of large capitalization firms in those countries. These are the Ghana stock exchange composite index (GSECI) for Ghana, and the S&P 500 of the US. We also include an international benchmark price of crude petroleum oil, and the Ghanaian cedi exchange rate. The GSECI is a capitalization-weighted index that tracks the performance of all companies traded on the Ghana stock exchange. It is the only stock exchange in Ghana and the criteria for listings on the exchange include profitability, capital adequacy, years of existence, spread of shares, and management efficiency. There are 37 listings and 2 corporate bonds on the GSE as of 2015. The closing prices of listed equities are calculated using the volume weighted average price of each equity for every given trading day. As noted earlier, the Ghana stock exchange introduced the GSECI in 2011 to replace the previous GSE All-Share index. This means two indices existed for the Ghana stock exchange at different times within our sample period; the GSE All-Share index covering the period from January 1991 to December 2010, and the GSECI covering the period from January 2011 to December 2015. It is important to note that the method of calculating the closing prices of shares since the GSECI was introduced is different from the method that was used during the regime of the GSE All-Share index. As a result, the series of the two indices are not on the same scale. Hence, using them together to represent a single period poses practical problems unless the two indices are linked together. To link the two indices, we used a three-period moving average extrapolating method to forecast the GSE All-Share index one date ahead into January 2011. We then used this forecast value and the actual value of the GSECI for January 2011 to form a ratio, and used this ratio to rescale the GSECI series so that both indices are on the same scale. The two series are spliced together to form a single broadly consistent series (see Appendix E1). The graphs show that the change in measurement of the series does not substantially change the general trend and variation of the data (once spliced). Hence, this makes the spliced series (from the joining of the two series) a valid approximation of Ghana's stock price movements over the whole sample period.

The S&P 500 index tracks 500 leading companies in different industries in the US. It is a capitalization-weighted index and all the data are closing prices adjusted for dividends and splits. This index is considered the most accurate reflection of the US stock market. The S&P 500 index is included in this study to capture the role of a global financial centre such as the US in transmitting macroeconomic news. In addition to the Ghana stock market index, we also included the Ghana cedi exchange rate as a domestic financial market variable. The official exchange rate is the Bank of Ghana rate, and this rate is the benchmark at which forex bureaus buy and sell currencies. Since the mid-1980s, the Bank of Ghana maintained a managed floating exchange rate system. This allows the Bank of Ghana to intervene in the foreign exchange market only to smooth fluctuations in the market. For the exchange rate, we used the Ghanaian currency exchange rate relative to the US dollar. Thus, the exchange rate is defined in terms of the Ghana cedi over the US dollar (GHS/USD). Because the US dollar serves as the world's reserve currency, and the fact that most international transactions are denominated in US dollars, it is reasonable to use a domestic currency exchange rate in relation to the US dollar in a study of this nature. The domestic currency exchange rates vis-à-vis the US dollar have also been used by Uddin et al (2013), Ghosh (2011), Chaudhuri and Daniel (1998), and Ding and Vo (2012) to examine the oil price-exchange rates relationship.

For the world price of oil, we used the Brent crude oil price following Ghosh (2011) and Chen and Chen (2007). The Brent crude oil price is a major benchmark price for oil purchases worldwide. About two thirds of the world's traded crude oil supplies are priced using the Brent. The Brent oil contracts are quoted in US dollars, and one contract equals 1000 barrels. We included the Brent oil price in this study to examine how international fluctuations in the price of oil affect movements in the Ghana stock market and the Ghana cedi exchange rates.

In a separate investigation, we examined the interactions between domestic oil prices, the Ghanaian currency, and the Ghana stock market. Because of the subsidies in Ghana, there could be sufficiently large differences between domestic and world oil prices that may cause significant differences in inference from using the different measures of oil price. Perhaps, investigating such differences will help answer this question, and that will also represent a novel contribution of our work. For the domestic oil price variables, we used the prices of diesel, petrol, and kerosene as proxies for domestic oil prices. These prices were not reported in full as some values were missing for certain dates. To obtain the missing values we used the cubic spline interpolation method. According to McKinley and Levine (no date), a cubic spline interpolation is a type of interpolation where a series of unique cubic polynomials are fitted between each data points, with the condition that the curve obtained be continuous and appear smoother. In this form of interpolation, the interpolant is a special type of a piecewise polynomial called a spline. This type of interpolation is often preferred over other methods of interpolation because it is often used to avoid the problem of Runge’s phenomenon and also has smaller error than other interpolation methods. The graphs in **appendix E** show the original series and the interpolated series for each of the domestic oil price variables. The graphs show that the interpolation have smoothed the series suggesting that the values generated from the interpolation are consistent with the actual values reported.

All the variables are defined in table 5.2.1 below. We used GSECI and S&P 500 to denote the Ghana stock exchange index and the US stock exchange index respectively, whilst EXR represents the Ghana cedi exchange rate. International crude oil price is denoted by COP. We also use DIESEL, PETROL, and KEROSENE to denote the domestic prices of diesel, petrol, and kerosene respectively. The variables are used in their logarithmic forms and this transformation is indicated with an “L” prefix in the variable names.

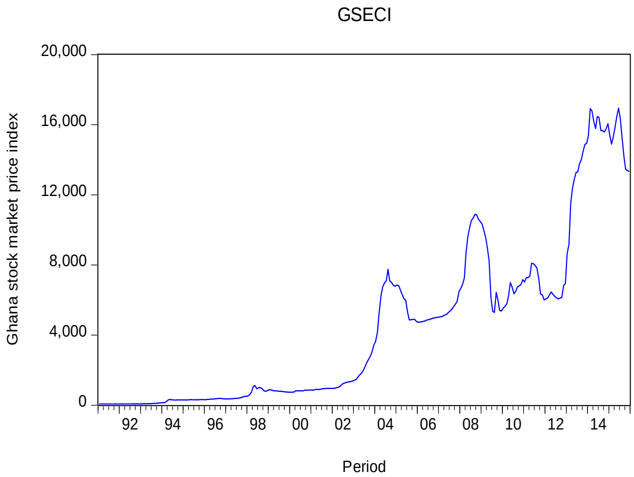
Table 5.2. 1: Variable definitions and sources

Variable	Description	Source
Data obtained from sources		
GSECI	Ghana stock exchange index	Ghana Stock Exchange head office, Accra
EXR	Ghana cedi exchange rate against the US dollar	Oanda website
S&P 500	US stock market index	Yahoo Finance
COP	International Crude Oil Price (UK Brent)	Energy Information Administration website
DIESEL	The domestic price of diesel	Bank of Ghana website
PETROL	Domestic price of petrol	Bank of Ghana website
KEROSENE	Domestic price of kerosene	Bank of Ghana website
Computed Variables		
LGSECI	Log of Ghana stock exchange index	LN(GSECI)
LEXR	Log of Ghana cedi exchange rate	LN(EXR)
LS&P 500	Log of the S&P 500	LN(S&P 500)
LCOP	Log of international crude oil prices (UK Brent)	LN(COP)
LDIESEL	Log of diesel price	LN(DIESEL)
LPETROL	Log of petrol price	LN(PETROL)
LKEROSENE	Log of kerosene price	LN(KEROSENE)

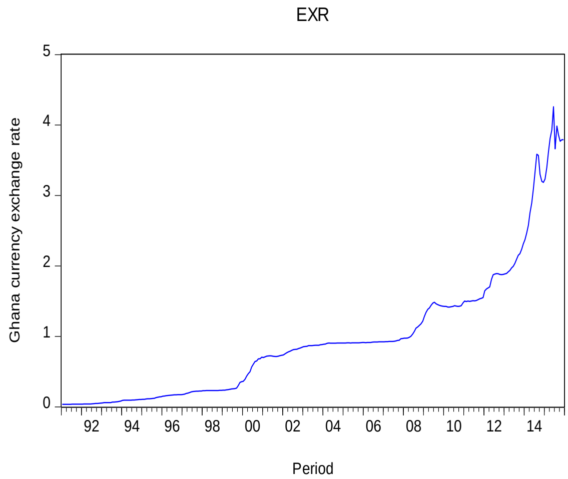
Figure 5.2.1 shows the time plot of the average monthly prices of the seven variables. The Ghana stock exchange composite index, the S&P 500, and crude oil prices declined sharply in late 2008. This is a reflection of the global financial crisis in 2008 which affected oil prices and stock markets across the world. The S&P 500 also experienced structural shocks around 1997 and 1998. These shocks represent

the 1997 Asian financial crisis and the dot com bubble that occurred between the middle and later part of the 1990s. As we can see, the S&P 500 declined from 1998 through to 2001 and this was the period when the dot com bubble collapsed.

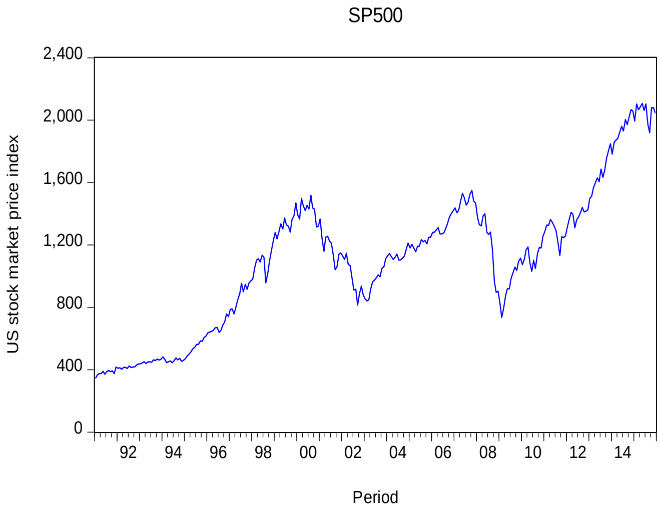
Figure 5.2. 1: Market price for the variables



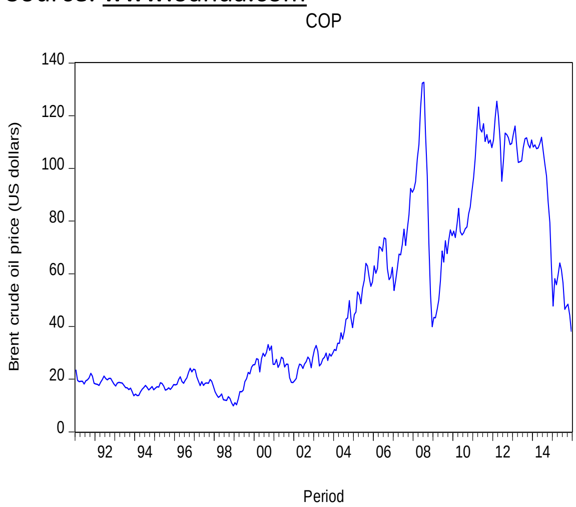
Source: Ghana Stock Exchange archives, Accra



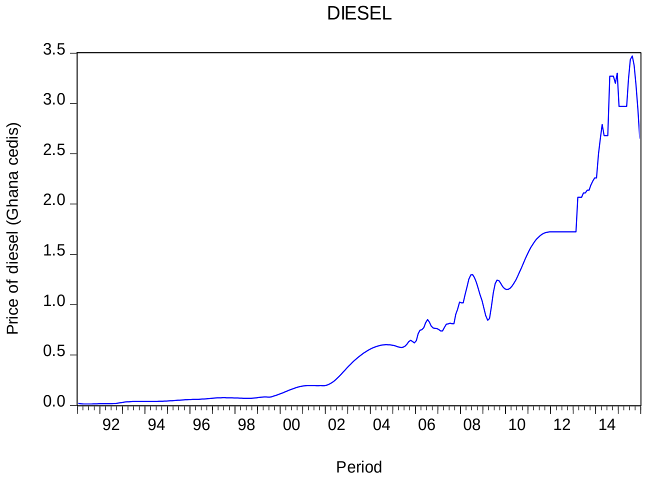
Source: www.oanda.com



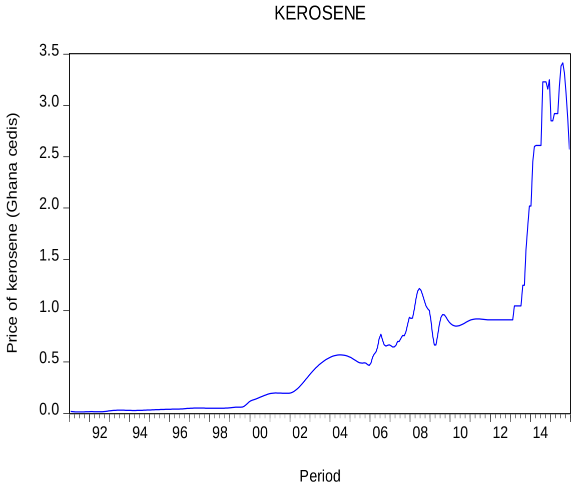
Source: Yahoo finance



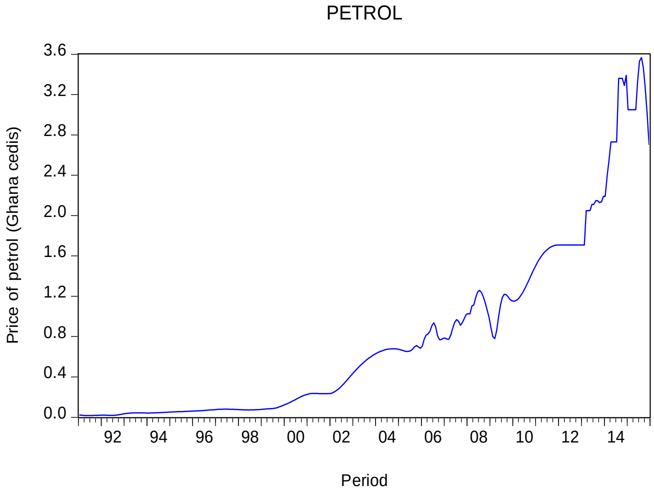
Source: Energy Information Administration



Source: Bank of Ghana statistical bulletin available at www.bog.gov.gh



Source: Bank of Ghana statistical bulletin available at www.bog.gov.gh



Source: Bank of Ghana statistical bulletin available at www.bog.gov.gh

The Ghana stock exchange index experienced a sudden and dramatic rise in 2012. This shock was due to positive sentiments about the economy following an impressive economic performance in the previous year – Ghana achieved an unprecedented 14% growth rate in GDP in 2011. This boosted investor confidence in 2012 and resulted in astronomically higher gains for the stock market. A similar factor accounted for the stock market shock in 2002. In the previous year, a new government was elected amid rising inflation, persistent currency depreciation, and stagnant economic growth. The new government, through pragmatic macroeconomic policies, was able to stabilize the cedi exchange rate, reduce inflation to a single digit, and achieve an increase in economic growth rate by 1% by the end of 2001. This created a healthy economic environment and a renewed confidence for investors going into 2002. The stock market rallied sharply as a result, but only to crash again in 2004.

All the variables have also trended upward on a longer-term basis. The structural shocks to the exchange rate mostly occurred in 2000, 2008, and 2012. These were election years, and one possible cause of these shocks is the fact that recent elections in Ghana have been keenly contested and often created uncertainty. As a result, the cedi often experience depreciation when elections approach as traders sell their cedis and buy more foreign currency because of the uncertainty. It can also be noticed that towards the end of the sample period, i.e. late 2014, there was a considerable drop in the price of oil, reflecting the collapse in oil prices towards the end of 2014, whilst the S&P 500 and the Ghana cedi exchange rate are trending upwards. From 2014, the Ghana stock exchange index also trended downwards, but this trend is less obvious compared to the oil price decline.

The domestic oil prices rose sharply from 2001. In 2001, the government of Ghana was required to increase tariffs on energy products and public utilities as part of the HIPC program Ghana joined in that year. This resulted in a shock to fuel prices, and coupled with the surges in world oil prices from 2003, the domestic oil prices have been increasing since that first shock. There was another shock around August 2008 when the fuel prices took a dip. This was a consequence of political pressure on the government to reduce fuel prices as the 2008 election was approaching. The rising fuel prices since 2001 led to a public discontent, and towards the 2008 election, the government opted to reduce the price of fuel which many viewed as a political expediency. However, the prices rose again after the elections although kerosene prices remained stable until around June 2013 when they rose sharply. Such interventions (subsidies) represent a reason why the domestic and world oil price movements may diverge sufficiently to warrant a consideration of using both domestic and world oil prices to ascertain if the results are different or similar. The other structural shocks to domestic fuel prices occurred around September 2014 and August 2015. The 2014 shock could be attributed to the decline in world oil prices whilst the 2015 shock could be a consequence of the withdrawal of state-controlled policies in the domestic oil market. In general, the graphs reveal that all the domestic fuel prices trended upwards since 2001. One implication of this analysis is that all the series are likely to be non-stationary and will need to be transformed to become stationary.

Before proceeding with further analysis of the data, it is important to conduct a covariance analysis to determine the degree of dependence or association between the domestic oil prices and the world oil prices. Correlation tests involving the prices of diesel, petrol, kerosene, crude oil are shown in the tables 5.2.2 and 5.2.3 below. We conduct the tests for the variables in logs of levels and differences. The tests in levels are shown in table 5.2.2 whilst the tests in differences are shown in table 5.2.3

Table 5.2. 2: Covariance Analysis in levels

Correlation t-Statistic Probability	LDIESEL	LKEROSENE	LPETROL	LCOP
LDIESEL	1.000000 ----- -----			
LKEROSENE	0.958913 {58.34821} (0.0000)	1.000000 ----- -----		
LPETROL	0.999001 {385.8445} (0.0000)	0.963313 {61.96231} (0.0000)	1.000000 ----- -----	
LCOP	0.763460 {20.40605} (0.0000)	0.613140 {13.39846} (0.0000)	0.751866 {19.68591} (0.0000)	1.000000 ----- -----

Note: t-statistics are in curly brackets and probability values are in parenthesis. Correlation coefficient between 0-0.19 implies very weak correlation, 0.20-0.39 implies weak correlation, 0.40-0.59 implies moderate correlation, 0.60-0.79 implies strong correlation, and 0.80-1.00 implies very strong correlation.

Table 5.2. 3: Covariance Analysis in differences

Correlation t-Statistic Probability	DLDIESEL	DLKEROSENE	DLPETROL	DLCOP
DLDIESEL	1.000000 ----- -----			
DLKEROSENE	0.847270 {27.53606} (0.0000)	1.000000 ----- -----		
DLPETROL	0.949669 {52.33403} (0.0000)	0.808932 {23.75285} (0.0000)	1.000000 ----- -----	
DLCOP	0.216171 {3.822056} (0.0002)	0.169840 {2.975122} (0.0032)	0.240930 {4.285327} (0.0000)	1.000000 ----- -----

Note: t-statistics are in curly brackets and probability values are in parenthesis. Correlation coefficient between 0-0.19 implies very weak correlation, 0.20-0.39 implies weak correlation, 0.40-0.59 implies moderate correlation, 0.60-0.79 implies strong correlation, and 0.80-1.00 implies very strong correlation

The covariance analysis show that the correlation coefficients between all the series are significant for both the levels and differenced data as indicated by the significant t-statistics and probability values. The correlations between the domestic oil prices (kerosene, diesel, and petrol) are very strong in both the levels and differenced series. Meanwhile, correlations between crude oil prices and the domestic oil prices appear to be higher for the series in levels as the correlations range between 60% and 76%. However, because all series are trended, this could reflect exaggerated correlation due to spurious correlation. The correlation between the crude oil prices and the domestic oil prices is very low for the series in the differenced series, which is the form that the series are used in our modelling. Because correlations between the crude oil prices and the domestic oil prices are not high in the differenced series, we can conclude that the correlation between the world oil prices and the domestic oil prices is not sufficiently strong to automatically assume that domestic oil prices are well approximated by world oil prices (although the correlations for the series in levels are non-trivial). In other words, the dependence of the domestic oil prices on the world oil prices is not extremely strong. Therefore, this justifies our decision to conduct additional investigations that examine the link between domestic oil prices, the Ghana currency exchange rates, and the Ghana stock market. Such investigations will enable us to compare the response of the two financial variables in Ghana to the domestic oil price movements as opposed to their response to the world oil price movements. This will facilitate a consideration of the similarity and/or differences of results arising from the use of world oil prices compared with domestic oil prices in our models.

Figure 5.2.2 shows the growth rates of the prices (the return series) for each variable. The returns are given by the first differences of the natural logarithms of the series. The graphs in figure 5.2.2 indicate that all the series appear to exhibit the typical feature of volatility clustering associated with financial data, i.e. small (larger) volatility followed by small (large) volatility. This observation supports the consideration of the use of a GARCH specification because GARCH models intend to more accurately describe this phenomenon. Hence, the likely presence of volatility clustering in all the variables in this study justifies our consideration of a GARCH specification. Note also that taking the differences of the logs of each series removes the trend leaving data that broadly have constant means and are therefore, likely to be stationary. The differencing has also removed the structural breaks (transforming them into pulse outliers). This implies that there appears to be no need to model structural breaks using the differenced data. Hence we will not consider modelling structural breaks in our analysis.

Figure 5.2. 2: Price returns for the variables

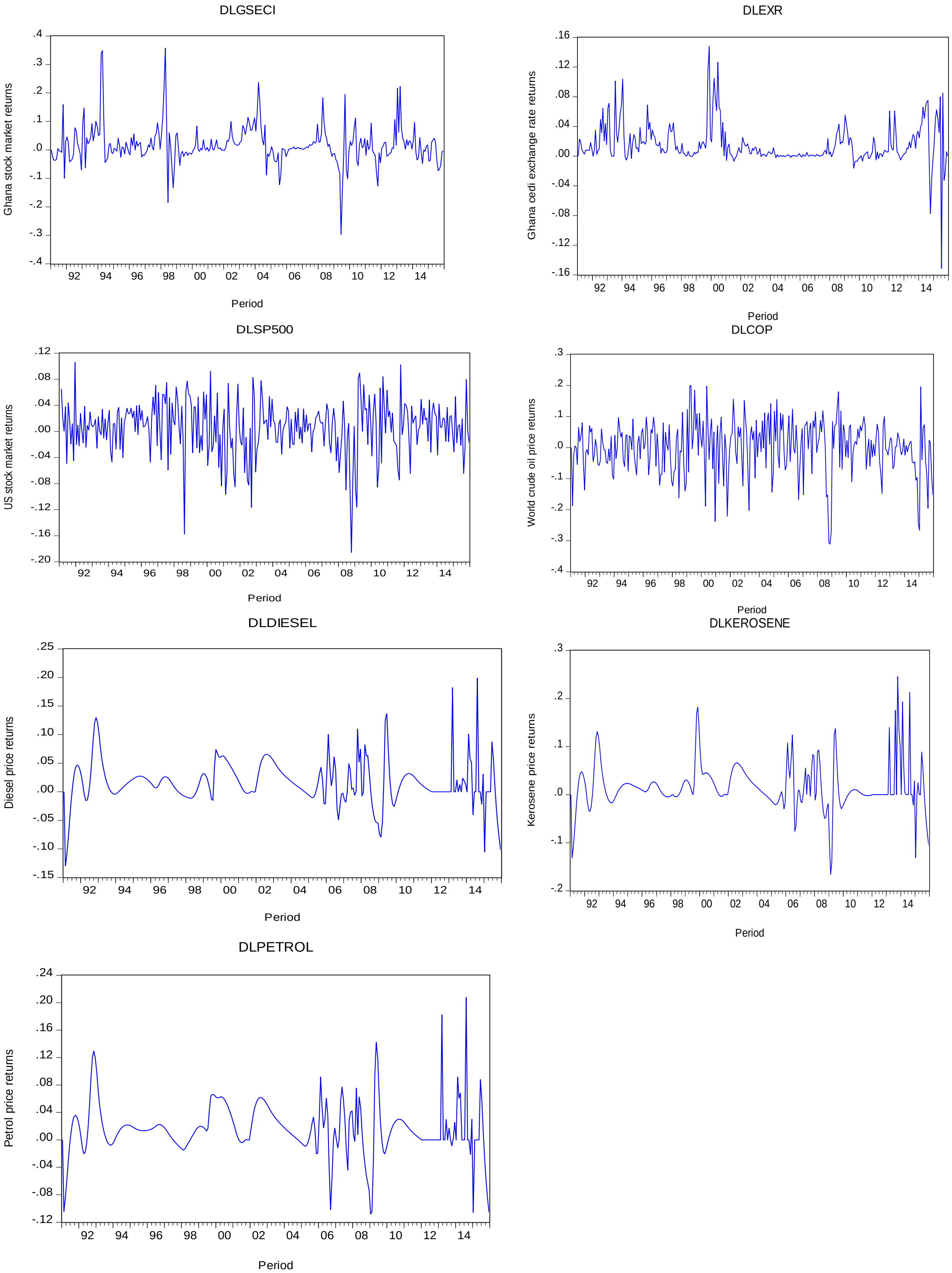


Table 5.2.4 reports the descriptive statistics of the price returns of the seven variables. The monthly mean returns of all the variables are slightly positive. If the average returns are used to measure performance, the Ghana stock exchange index has the highest mean returns (0.0176), followed by the domestic oil prices which have mean returns of 0.0166. Meanwhile, the crude oil price has the worst performance since the mean return is (0.0016). The Ghana stock market also performs better than the S&P 500 since it grew on average, by 1.76% per month over the period whilst the S&P 500 only grew by 0.56% per month over the same period. In general, the mean returns of the domestic variables are higher than the mean returns of the global oil price and the S&P 500. In terms of volatility, the coefficient of variation (denoted as CV in table 5.2.4) suggests that the Ghana cedi exchange rate is the least volatile since it has the smallest CV (1.7134), and the domestic oil prices (diesel, kerosene, and petrol) have the second smallest CVs. On the other hand, the crude oil price is most volatile since it has the highest CV of 53.6875 whilst the US stock market has the second highest volatility with a CV of 7.1186. This suggests that the world oil price and the developed stock market are more volatile than the domestic variables which include the Ghana currency exchange rate, the domestic oil prices, and the Ghana stock market during our sample period.

Table 5.2. 4: Summary statistics for the return series

	Ghana Stock Exchange	Ghana Cedi Exchange rate	S&P 500	Crude Oil Price	Diesel	Keros ene	Petrol
Mean	0.0176	0.0157	0.0059	0.0016	0.0165	0.0166	0.0160
Median	0.0079	0.0077	0.0106	0.0074	0.0118	0.0072	0.0136
Maximum	0.3575	0.1479	0.1058	0.2007	0.1989	0.2453	0.2076
Minimum	-0.2972	-0.1513	-0.1856	-0.3109	-0.1298	- 0.1658	-0.1081
Std. Dev	0.0669	0.0269	0.0420	0.0859	0.0388	0.0490	0.0389
CV	3.8011	1.7134	7.1186	53.6875	2.3515	2.9518	2.4313
Skewness	1.1992	0.7040	-0.8033	-0.7082	0.4720	0.8185	0.4296
Kurtosis	10.485	11.493	4.8187	4.1993	7.0723	7.5823	7.4128
Jarque-Bera	772.1457	926.4731	73.36426	43.05854	218.4444	295.96 55	252.636 4
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LB-Q(12)	115.23 (0.00)	156.40 (0.00)	11.07 (0.52)	30.77 (0.00)	179.61 (0.00)	168.69 (0.00)	190.12 (0.00)
LB-Q(24)	153.69 (0.00)	164.98 (0.00)	17.70 (0.82)	44.92 (0.01)	233.68 (0.00)	198.08 (0.00)	252.46 (0.00)
LB-Qs(12)	54.52 (0.00)	148.83 (0.00)	55.01 (0.00)	84.47 (0.00)	45.39 (0.00)	89.84 (0.00)	50.35 (0.00)
LB-Qs(24)	63.06 (0.00)	154.08 (0.00)	72.97 (0.00)	89.77 (0.00)	66.53 (0.00)	96.72 (0.00)	66.73 (0.00)
ARCH LM(1)	38.46 (0.000)	31.05 (0.000)	17.93 (0.000)	59.30 (0.000)	29.09 (0.00)	33.25 (0.00)	29.46 (0.00)
ARCH LM(12)	38.20 (0.00)	49.29 (0.00)	35.32 (0.00)	80.53 (0.00)	39.65 (0.00)	55.14 (0.00)	41.93 (0.00)
ARCH LM(24)	38.72 (0.03)	50.19 (0.00)	46.72 (0.00)	89.44 (0.00)	91.89 (0.00)	71.72 (0.00)	94.89 (0.00)

Note: LB-Q(12) and (24) denote the Ljung-Box Q-statistics for return series up to 12 and 24 lags whilst LB-Qs(12) and (24) represent the Ljung-Box Q-statistics for the squared return series. ARCH LM is the Lagrange multiplier test of autoregressive conditional heteroscedasticity for ARCH orders 1, 12, and 24.

According to the estimated skewness, the Ghana stock exchange index, the Ghana cedi exchange rate and the domestic oil prices are positively skewed, indicating that large positive returns are more common than large negative returns. In particular, the Ghana stock exchange index is highly positively skewed (1.1992). In contrast, the S&P 500 and crude oil prices have negative skewness. It should be noted here that the world oil price has negative skewness whilst the domestic oil prices have positive skewness. This is another difference in the different oil price series that motivates the consideration of both domestic and world oil prices in the modelling. Furthermore, all the return series are leptokurtic, since the kurtosis of their distributions are all greater than 3. Leptokurtic distributions have significantly fatter tails and higher peaks, and because the tails asymptotically approach zero more gradually, the distributions tend to produce more outliers than the normal distribution. This characteristic is expected as it is common with many financial return series. Finally, the Jarque-Bera statistics (proposed by Jarque and Bera 1987) which is given as:

$$Jarque - Bera = \frac{N}{6}\left(s^2 + \frac{(K-3)^2}{4}\right),$$

where S is skewness and K is kurtosis also indicate that we should reject the null hypotheses that the return series are normally distributed for all the series.

Besides these basic statistics, we also test the series for serial correlation to determine whether the return series are autocorrelated using the Ljung-Box (1979) test. Table 5.2.4 presents the Q-statistics and the p-values for this test. The Ljung-Box test is computed as:

$$Q_{LB} = N(N+2)\sum_{k=1}^{m}\frac{r_k^2}{N-k},$$

where r_k is the k-th order autocorrelation coefficient, N is the number of observations, and m is the number of lags included in the joint test. The Q-statistic at lag m is a test for the null hypothesis that there is no serial correlation up to lag m. We report the statistics for lag orders 12 and 24 for both the return series and the squared return series following the work of Li and Giles (2015). Based on the Q-statistics reported in table 5.2.4, we can strongly reject the null hypothesis of no autocorrelation for all the return series and their squared terms since their test statistics are statistically significant at any level of significance (except for the returns of the S&P 500). The Q-statistic for the returns of the S&P 500 is statistically insignificant meaning that their returns are serially uncorrelated although the squared S&P 500 returns are significantly correlated). Therefore, we can conclude that all the series have serial correlation in both their returns series and their squared return series, whilst the US stock market only has autocorrelation in the squared return series. These results suggest the need to model the autocorrelation in the mean and variance of all variables, with the possible exception of the US stock market's mean.

To test for the presence of ARCH effects, we used the ARCH LM test proposed by Engle (1982). This test is a Lagrange multiplier test that assesses the significance of ARCH effects. We reported the ARCH LM test results for ARCH (1), ARCH (12), and ARCH(24) for all the return series, and these results are also reported in table 5.2.4. As we can see, the reported ARCH statistics for all the return series are significant at all levels of significance. These results indicate strong presence of an ARCH structure in all the return series. An important implication of Engle's ARCH test is that conditional heteroscedasticity in the variance process is equivalent to autocorrelation in the squared residuals. Thus, a time series exhibiting autocorrelation in the squared series is said to have an autoregressive conditional heteroscedasticity

(ARCH) effect. To verify the results of the Engle's ARCH test, we also checked for serial dependence (ARCH effects) in the residual series by conducting a Ljung-Box test of the squared residual series. The results (reported in table 5.2.4 above) confirm the ARCH LM test results for all the series. That is, all the series are serially correlated in their squared terms, suggesting the presence of ARCH effects. The possible presence of ARCH (or the more general GARCH) effects in all the return series further justifies the suitability of the application of ARCH/GARCH models to examine the volatility dynamics of these variables.

Another characteristic that is worth checking is whether the series are stationary. The stationarity or otherwise of a series is important because the use of non-stationary data can lead to spurious regression (see section 4 of the previous chapter). In this study, we employed two commonly used procedures to test our series for non-stationarity. These are; the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) tests. The null hypothesis in both tests is that the series contain a unit root (see section 4.3.2 of chapter 4 for a detailed discussion of ADF and PP tests). The results of these tests are presented in table 5.2.5.

Table 5.2. 5: ADF and PP unit root test results

Panel (a): ADF test								
	Intercept only				**Intercept and trend**			
	Data in levels		Data in first differences		Data in levels		Data in first differences	
	t-statistic	Lag	t-statistic	Lag	t-statistic	Lag	t-statistic	Lag
LGSECI	-1.55	1	-10.05***	0	-1.90	1	-10.11***	0
LEXR	-1.83	2	-7.38***	1	-1.77	2	-7.52***	1
LS&P 500	-1.69	0	-16.53***	0	-1.85	0	-16.53***	0
LCOP	-1.41	1	-14.11***	0	-1.77	1	-14.01***	0
LDIESEL	-1.72	1	-8.39***	0	-2.01	1	-8.48***	0
LKEROSENE	-1.20	0	-8.69***	0	-2.08	1	-8.69***	0
LPETROL	-1.60	1	-8.15***	0	-1.96	1	-8.22***	0

Panel (b): PP test				
	Intercept only		**Intercept and trend**	
	Data in levels	Data in first differences	Data in levels	Data in first differences
	t-statistic	t-statistic	t-statistic	t-statistic
LGSECI	-1.45	-10.21***	-1.87	-10.24***
LEXR	-1.87	-12.43**	-1.73	-12.55***
LS&P 500	-1.69	-16.61***	-2.00	-16.61**
LCOP	-1.27	-14.11***	-2.00	-14.10***
LDIESEL	-1.05	-8.25***	-1.69	-8.22***
LKEROSENE	-0.63	-8.67***	-1.96	-8.64***
LPETROL	-1.03	-7.76***	-1.61	-7.68***

Note: * indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

The ADF test results are shown in panel (a) while the PP test results are reported in panel (b). In the ADF test, the test statistics for all the series in their levels are less than the critical values at any conventional level of significance (for both the model with intercept only and the model with intercept and trend). This evidence suggests that the null hypothesis of a unit root cannot be rejected for all the series in their levels. In first differences however, all the series become stationary at all conventional significant levels. This result is confirmed in the PP test in panel (b) of table 5.2.5. The PP test reveals that all the series are non-stationary in levels, but stationary in first differences. Based on the ADF and PP tests, we can conclude that all the series contain a unit root, and therefore, are $I(1)$. These results are consistent with our visual inspection of the graphs of all the series in both levels and first log differences (as discussed above). Hence, to avoid spurious regression, we model the stationary difference of the logs of the series (the returns). These results are consistent with studies such as Li and Giles (2015), Amano and Norden (1998), Huang and Guo (2007), Chen and Chen (2007), Kutty (2010), Cakan and Ejara (2013), Boako et al (2015), and Adjasi et al (2011). These studies found that the international price of oil, exchange rates, and stock markets across different countries follow I(1) process, and this feature is common among many financial time series.

Based on all the features observed in this section about our data, GARCH models will be appropriate. Since the aim of this paper is to examine the dynamic interactions across the variables, we will use a multivariate GARCH BEKK model proposed by Engle and Kroner (1995). Given the autocorrelation in the return series, we will employ a vector autoregression to model the mean equations in the system in addition to the GARCH BEKK specification for the variance equation. The latter is suggested by the evident autocorrelation we find in the squared return series. The next section will discuss the model.

5.3. Methodology

As the aim of this study is to examine the interdependence or spill over effects across different variables, and given the observed features of the series in the previous section, a multivariate GARCH model will be appropriate. This requires a specification of both the mean and the variance-covariance equations for the model to be used.

The mean equation can be estimated by a standard vector autoregressive (VAR) model. In VAR modelling, the covariance matrix of the disturbance vector is time invariant. However, because the returns of financial assets vary over time, (Fama, 1965 and Mandelbrot, 1963), it is crucial to model time-varying second-order moments. Autoregressive Conditional Heteroscedasticity (ARCH) models and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models proposed by Engle (1982) and Bollerslev (1986) respectively are designed to deal with issues of this nature. Indeed, as Bollerslev et al (1988) used a multivariate GARCH in mean (GARCH(1,1)-M) to implement a CAPM model for a market portfolio, multivariate GARCH models and their extensions are widely used by researchers in finance to analyse financial time series data.

Bollerslev et al (1988) first proposed a general vectorised (VEC) GARCH model which suggests that H_t is a linear function of the lagged squared errors and cross-products of errors and lagged values of each element of H_t. The model is as follows:

$$vech(H_t) = vech(C) + \sum_{i=1}^{q} A_i vech(\varepsilon_{t-1}\acute{\varepsilon}_{t-i}) + \sum_{i=1}^{p} G_i vech(H_{t-i}) \quad (5.3.6)$$

where vech$(.)$ is the operator that stacks the lower triangular portion of a symmetric matrix into a vector. However, there are some limitations with this formulation. Firstly, the model requires a large number of parameters to be estimated. The number of parameters is N(N+1)(N(N+1)+1)/2. Therefore, even in a simple scenario where N=2 (i.e. p=1, q=1), the number of parameters that still need to be estimated is 21, if N=3, the number of parameters will be 78, and so on (Li and Giles 2015). Also, without imposing strong restrictions on the parameters, it is difficult to guarantee positive definiteness of H_t (Gourieroux, 1997). To overcome this limitation, Bollerslev et al (1998) proposed the diagonal VEC (DVEC) model in which the $\boldsymbol{A}$ and $\boldsymbol{G}$ matrices are assumed to be diagonal. This restriction reduces the number of parameters to N(N+5)/2, suggesting that even if N=3, the number of parameters are only 12 (Bauwens et al., 2006). Even so, since the $\boldsymbol{A}$ and $\boldsymbol{G}$ matrices are diagonal, it is assumed that each element of H_t depends only on its own lag and the previous value of the shocks. Consequently, the DVEC model does not capture cross-market volatility or volatility spillover effects between different markets. Furthermore, the model still does not guarantee positive definiteness of H_t. To overcome the above two limitations, Engle and Kroner (1995) propose a new parameterization for H_t, which is the BEKK model. The BEKK(1,1) model is expressed as follows:

$$H_t = \acute{C}C + \acute{A}\varepsilon_{t-1}\acute{\varepsilon}_{t-1}A + \acute{G}H_{t-1}G, \tag{5.3.7}$$

where $\boldsymbol{C}$ is an $(n \times n)$ lower triangular matrix of constants, while $\boldsymbol{A}$ and $\boldsymbol{G}$ are $(n \times n)$ parameter matrices. By working with quadratic forms, the BEKK guarantees positive semi-definiteness. It also provides cross-market effects in the variance equation parsimoniously. Because stock price volatility tends to rise more in response to negative shocks (bad news) than positive shocks (good news), which is known as an asymmetric response, researchers are also interested in extending the multivariate

GARCH model to allow for asymmetric responses of volatility. To capture this asymmetric property, Kroner and Ng (1998) extend the BEKK model as follows:

$$H_t = \acute{C}C + \acute{A}\varepsilon_{t-1}\acute{\varepsilon}_{t-1}A + \acute{G}H_{t-1}G + \acute{D}\epsilon_{t-1}\acute{\epsilon}_{t-1}D, \tag{5.3.8}$$

where ϵ_t is defined as ε_t if ε_t is negative and zero otherwise. The last term on the right-hand side captures the asymmetric property of the time-varying variance-covariance. The BEKK model is an industrial standard model, and it is widely used in modelling volatility spillover in simultaneous equations. Given the variables we employ in this paper and our sample size, the GARCH-BEKK model is preferred.

In this study, we examine the volatility spillover effect from world and domestic oil prices to the Ghanaian currency exchange rate and the Ghana stock market, where in some models, crude oil prices are treated as endogenous whilst in other models, they are treated as exogenous. The exogeneity of the crude oil price is important in the context of Ghana because macroeconomic conditions in Ghana are not likely to have any influence on the prices of major world commodities such as crude oil due to the relatively small size of the country. However, crude oil prices are expected to have some influence on economic activities in Ghana. This approach will enable us to compare the oil price effects when they are specified as endogenous and when they are treated as exogenous. It will also allow a comparison of our results with previous papers that typically treat oil prices as endogenous.

We shall also examine the volatility spillovers between domestic oil prices (e.g. diesel, petrol, and kerosene) and the Ghanaian currency exchange rate as well as the Ghana stock market. As part of robustness checks, we shall also estimate both the crude oil price and the domestic oil price models without the stock markets to determine whether the inclusion of the stock markets have any impact on the oil price-exchange rate relationship. Hence, we shall first estimate a four-variable GARCH-BEKK model which will include the Ghana stock market, the Ghana currency exchange rate, the US stock market, and the world oil price/domestic oil prices. Secondly, a bivariate GARCH-BEKK will then be modelled to include the Ghana cedi exchange rate and the world oil price/domestic oil prices. Indeed, the bivariate analysis is in line with previous literature. For example, Ghosh (2011), Amano and Norden (1998), Chaudhuri and Daniel (1998), and Chen and Chen (2007) examined the oil price and exchange rate relationship using only the price of oil and the exchange rates of various countries in their models. In the four-variable case, the extended BEKK model becomes:

$$
\begin{aligned}
H_t &= \acute{C}C \\
&+ \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1.t-1}\varepsilon_{2,t-1} & \varepsilon_{1.t-1}\varepsilon_{3,t-1} & \varepsilon_{1.t-1}\varepsilon_{4,t-1} \\ \varepsilon_{2.t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 & \varepsilon_{2.t-1}\varepsilon_{3,t-1} & \varepsilon_{2.t-1,}\varepsilon_{4,t-1} \\ \varepsilon_{3.t-1}\varepsilon_{1,t-1} & \varepsilon_{3.t-1}\varepsilon_{2,t-1} & \varepsilon_{3,t-1}^2 & \varepsilon_{3.t-1}\varepsilon_{4,t-1} \\ \varepsilon_{4.t-1}\varepsilon_{1,t-1} & \varepsilon_{4.t-1}\varepsilon_{2,t-1} & \varepsilon_{4.t-1}\varepsilon_{3,t-1} & \varepsilon_{4,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \\
&+ \begin{bmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{bmatrix} \\
&+ \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ d_{21} & d_{22} & d_{23} & d_{24} \\ d_{31} & d_{32} & d_{33} & d_{34} \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix}' \begin{bmatrix} \in_{1,t-1}^2 & \in_{1.t-1}\in_{2,t-1} & \in_{1.t-1}\in_{3,t-1} & \in_{1.t-1}\in_{4,t-1} \\ \in_{2.t-1}\in_{1,t-1} & \in_{2,t-1}^2 & \in_{2.t-1}\in_{3,t-1} & \in_{2.t-1,}\in_{4,t-1} \\ \in_{3.t-1}\in_{1,t-1} & \in_{3.t-1}\in_{2,t-1} & \in_{3,t-1}^2 & \in_{3.t-1}\in_{4,t-1} \\ \in_{4.t-1}\in_{1,t-1} & \in_{4.t-1}\in_{2,t-1} & \in_{4.t-1}\in_{3,t-1} & \in_{4,t-1}^2 \end{bmatrix} \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} \\ d_{21} & d_{22} & d_{23} & d_{24} \\ d_{31} & d_{32} & d_{33} & d_{34} \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix}
\end{aligned}
$$

In the system above, we use the numbers 1, 2, 3, and 4 to denote the Ghana stock market, the Ghana currency exchange rate, the US stock market, and the world oil prices respectively for the crude oil price model. For the domestic oil price models, the Ghana stock market and the Ghana currency exchange rates are still denoted by 1 and 2, whilst the domestic oil prices are denoted by 3 and the US stock market is denoted by 4. These representations are based on the exogeneity of the variables to other variables. Hence, variables that are exogenous to all the other variables are assigned the highest value, in this case 4, whereas the variables that are endogenous to all the other variables are assigned the smallest value of 1. This explains why the US stock market takes a value of 3 in the crude oil price model whilst in the domestic oil price models, it takes a value of 4. Although all the variables are endogenous in some models, the purpose of numbering the variables based on exogeneity is for consistency with the models where some variables (such as crude oil prices) are considered as exogenous. In the model that treats crude oil prices as exogenous, the US stock market is only affected by the world oil price. In the domestic oil price models that treat the US stock market as exogenous however, none of the variables affect the US stock market whilst the US stock market affects all the variables.

In the two-variable case, the model is expressed as;

$$H_t = \acute{C}C + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$$

$$+ \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}' \begin{bmatrix} \in_{1,t-1}^2 & \in_{1,t-1}\in_{2,t-1} \\ \in_{2,t-1}\in_{1,t-1} & \in_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}$$

Here, 1 denotes the Ghana currency exchange rate whilst 2 represents either the world oil price (in the crude oil price models) or the domestic oil prices (in the domestic oil price models). Note that the two systems above i.e. the four-variable GARCH and two-variable GARCH are the full BEKK models and all variables including crude oil prices are treated as endogenous in both models.

To treat crude oil prices as exogenous, we employ the triangular BEKK (TBEKK) model which was used by Beirne et al (2010) to examine volatility spillovers from mature stock markets to regional and local emerging stock markets. The TBEKK model uses the same formula as the full BEKK model, but the As, Gs, and Ds are constrained to be lower triangular. Hence, some restrictions are required in order to estimate this model. Based on our assumption that macroeconomic conditions in Ghana are not likely to influence crude oil prices, the crude oil prices are allowed to affect the domestic variables (i.e. the Ghana currency exchange rate and the Ghana stock market) as well as the US stock market. However, the domestic variables are not allowed to affect the crude oil price. These restrictions make crude oil prices exogenous. Also, the US stock market affects the Ghana cedi exchange rates and the Ghana stock market, but both variables do not affect the US stock market due to the fact that the Ghana cedi exchange rate and the Ghana stock market may both have little influence on the world stage.

For the models with domestic oil prices, all the variables in the models including domestic oil prices can potentially be treated as endogenous because they are all determined by domestic economic conditions and government policies. For example, besides being influenced by fuel taxes, the domestic oil prices were not allowed to automatically adjust to changes to world oil prices because of the petroleum product subsidies and government regulations that existed until their withdrawal in 2015. Hence, restricted models will not be required for the domestic oil price models. However, the US stock market can be treated as exogenous in these models because the US stock market is an important global market which can affect macroeconomic conditions in Ghana (including the domestic oil prices, the exchange rate, and the stock market). On the other hand, due to the relatively small size of the

Ghanaian economy, these domestic variables are not so important to the US stock market. Therefore, for the models with domestic oil prices, we shall apply the same restrictions as before except that the US stock market is exogenous to all the other variables (i.e. the Ghana stock market, the Ghana currency exchange rate, and the domestic prices)[8]. This implies the US stock market affects all of these variables, but none of the variables affect the US stock market. In cases where the US stock market is not included however, (e.g. the bivariate BEKK models with only domestic oil prices and the Ghana currency exchange rates) these restrictions will not be required.

Based on the restrictions stated above, we shall estimate four-variable triangular BEKK models where the crude oil prices and the US stock market are treated as exogenous. As we did for the full BEKK model, we shall also apply specifications that omit the Ghana stock market and the US stock market from the triangular BEKK models and re-estimate the models with only two variables (i.e. the world crude oil price and the Ghana currency exchange rate; or the domestic oil prices and the Ghana currency exchange rates). This is part of our robustness checks to determine whether the inclusion of the stock market has any influence on the volatility spillover between oil prices and the Ghana currency exchange rates. The four-variable triangular BEKK model can be expressed as follows;

[8] The US stock market is considered as endogenous in the model with world oil prices because world oil prices can determine the US stock market

$$
\begin{aligned}
H_t &= \acute{C}C \\
&+ \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & 0 & 0 & 0 \\ \varepsilon_{2.t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 & 0 & 0 \\ \varepsilon_{3.t-1}\varepsilon_{1,t-1} & \varepsilon_{3.t-1}\varepsilon_{2,t-1} & \varepsilon_{3,t-1}^2 & 0 \\ \varepsilon_{4.t-1}\varepsilon_{1,t-1} & \varepsilon_{4.t-1}\varepsilon_{2,t-1} & \varepsilon_{4.t-1}\varepsilon_{3,t-1} & \varepsilon_{4,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \\
&+ \begin{bmatrix} g_{11} & 0 & 0 & 0 \\ g_{21} & g_{22} & 0 & 0 \\ g_{31} & g_{32} & g_{33} & 0 \\ g_{41} & g_{42} & g_{43} & g_{44} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & 0 & 0 & 0 \\ g_{21} & g_{22} & 0 & 0 \\ g_{31} & g_{32} & g_{33} & 0 \\ g_{41} & g_{42} & g_{43} & g_{44} \end{bmatrix} \\
&+ \begin{bmatrix} d_{11} & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix}' \begin{bmatrix} \in_{1,t-1}^2 & 0 & 0 & 0 \\ \in_{2.t-1}\in_{1,t-1} & \in_{2,t-1}^2 & 0 & 0 \\ \in_{3.t-1}\in_{1,t-1} & \in_{3.t-1}\in_{2,t-1} & \in_{3,t-1}^2 & 0 \\ \in_{4.t-1}\in_{1,t-1} & \in_{4.t-1}\in_{2,t-1} & \in_{4.t-1}\in_{3,t-1} & \in_{4,t-1}^2 \end{bmatrix} \begin{bmatrix} d_{11} & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix}
\end{aligned}
$$

In the two-variable version with the restrictions stated above, the triangular BEKK model is expressed as;

$$
\begin{aligned}
H_t = \acute{C}C &+ \begin{bmatrix} a_{11} & 0 \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & 0 \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & 0 \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & 0 \\ g_{21} & g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & 0 \\ g_{21} & g_{22} \end{bmatrix} \\
&+ \begin{bmatrix} d_{11} & 0 \\ d_{21} & d_{22} \end{bmatrix}' \begin{bmatrix} \in_{1,t-1}^2 & 0 \\ \in_{2,t-1}\in_{1,t-1} & \in_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} d_{11} & 0 \\ d_{21} & d_{22} \end{bmatrix}
\end{aligned}
$$

The ordering and the numbering of the variables in the triangular BEKK models are the same as in the full BEKK models. These numberings/orderings are based on the relative degree of exogeneity of the variables.

From the systems above, we can analyse the variance or volatility across the varaibles. The matrix $\boldsymbol{A}$ measures past shock effects, and matrix $\boldsymbol{G}$ measures past volatility[9] effects. The asymmetric responses to negative and positive shocks, or 'bad

[9] Shocks are the errors (i.e. difference between actual and predicted values) and volatilities are the variances. All GARCH models predict the covariance matrix given past shocks. In the GARCH model, the coefficients on

news' and 'good news', are measured by matrix $\boldsymbol{D}$. The diagonal elements of matrix $\boldsymbol{A}(\boldsymbol{a_{ii}})$ measure the effects of market i's shocks on its own volatility, whilst the off-diagonal elements of $\boldsymbol{A}(\boldsymbol{a_{ij}})$ capture the effects of market i's shocks on market j's volatility[10]. Similarly, the diagonal elements of matrix $\boldsymbol{G}(\boldsymbol{g_{ii}})$ measure the effects of the own past volatility of market i on its conditional variance, whilst the off-diagonal elements of matrix $\boldsymbol{G}(\boldsymbol{g_{ij}})$ capture the effects of past volatility of market i on market j's conditional variance, also known as volatility spillover. Also, the diagonal elements of matrix $\boldsymbol{D}(\boldsymbol{d_{ii}})$ are the asymmetric response of market i to its own past shocks, and they measure the difference between positive shocks and negative shocks. On the other hand, the off-diagonal elements of matrix $\boldsymbol{D}(\boldsymbol{d_{ij}})$ are the asymmetric responses of market j to the past shocks of market i. They measure the difference between positive and negative shocks of market i on market j's volatility. To measure the volatility spill over effect of negative shocks, we take the sum of the coefficients of a_{ij} and d_{ij} (i.e. $a_{ij} + d_{ij}$). Similarly, for the effect of negative shocks of own volatility, we take the sum of a_{ii} and d_{ii} (i.e. $a_{ii} + d_{ii}$). Also, positive shocks are measured by a_{ii} and a_{ij}. Note that all the coefficients are squared in the BEKK specification. As a result, negative signs in the coefficients are not relevant because they become positive once squared.

It is also important to confirm the lag order for the BEKK models. In the literature, the GARCH (1,1) specification has been commonly used. Engle (1995, p.xii) noted that the GARCH (1,1) is a robust model, and in almost all cases, it does most of the work.

---

the lagged shocks are the ARCH coefficients, whilst the coefficients on the lagged variances/covariances are the GARCH coefficients. The ARCH and GARCH coefficients are used to describe shock spillover and volatility spillover respectively (e.g. see Li, 2007, Li and Giles, 2015, Musunuru, 2014, and Joshi, 2011).

[10] Because of the standard use of the transpose of A as the pre-multiplying matrix, the coefficients of the BEKK model have the opposite interpretation: A(i, j) is the effect of residual i on variable j, rather than j on i.

Bollerslev et al (1992) also mentioned that when modelling the variance dynamics over very long sample periods, the GARCH (1,1) model seems to be sufficient. In this study, we choose the BEKK (1,1) to model the variance-covariance equation for all our models because both the VAR models and the BEKK models include large numbers of parameters. As a result, increasing the lag order for the BEKK may pose practical issues. The models also pass the diagnostic tests of serial correlation and ARCH effects for our sample period (see the next section for details).

For the mean equations, we can estimate a vector autoregressive (VAR) model in first differences since all the series are I(1). Let $Y_t = (y_{1t}, y_{2t}, \dots, y_{nt})$ represent an (n*1) vector of monthly returns at time t. The basic VAR model of lag order k (VAR (k)) takes the form

$$\Delta Y_t = \delta + \sum_{i=1}^{k} \Gamma \Delta Y_{t-i} + v_t \tag{5.3.1}$$

where Γ is a matrix of short run parameters associated with the lagged returns, δ is a vector of constants whilst v_t is a vector of error terms. Note that since we are estimating four-variable and two-variable GARCH BEKK models, we will also have four-variable VAR and bivariate VAR models for the mean equations of the respective GARCH models. However, we also estimate trivariate models to ensure model adequacy (i.e. models free from autocorrelation and unmodeled ARCH effects). With the VAR model, we can analyse the return spillovers across the different markets. The diagonal elements in matrix Γ (R_{ii}) measure the effect of own past returns whilst the off-diagonal elements of matrix Γ (R_{ij}) capture the returns spillover across the varaibles. We use various information criteria to select the appropriate lag length for the VAR model as they are often used as a guide to select models. The criteria we examined are the Akaike Information Criterion (AIC), the Schwarz Information Criterion (SIC), the Hannan-Quinn Information Criterion (HIC), the sequential modified LR test statistic, and the Final Prediction Error (FPE). Selecting the optimal lag length from these criteria involves two stages. Firstly, choose the smallest lag length from among those suggested. Secondly, apply autocorrelation tests to the residuals, and increase the lag length incrementally until the null of no serial correlation is accepted. There are larger numbers of parameters to be estimated since the mean equations and the variance equations are estimated simultaneously. As a result, we only allowed a maximum lag of 4 for selection. **Appendix F** shows that the smallest lag selected by at least one of the information criteria is 1 for all the models and, using 1 lag order produces no autocorrelation in the mean equations of the BEKK models (see section 5.4).

Therefore, we shall estimate a four-variable VAR(1) and a bivariate VAR(1) in all the GARCH models to be estimated. The four-variable VAR(1) model can be expressed as;

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \\ y_{4t} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix} + \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \Gamma_{13} & \Gamma_{14} \\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} & \Gamma_{24} \\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} & \Gamma_{34} \\ \Gamma_{41} & \Gamma_{42} & \Gamma_{43} & \Gamma_{44} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{3,t-1} \\ y_{4,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix},$$

or equivalently, the model can be transformed into the following system of four equations

$$y_{1t} = \delta_1 + \Gamma_{11} y_{1,t-1} + \Gamma_{12} y_{2,t-1} + \Gamma_{13} y_{3,t-1} + \Gamma_{14} y_{4,t-1} + \varepsilon_1 \qquad (5.3.2)$$

$$y_{2t} = \delta_2 + \Gamma_{21} y_{1,t-1} + \Gamma_{22} y_{2,t-1} + \Gamma_{23} y_{3,t-1} + \Gamma_{24} y_{4,t-1} + \varepsilon_2 \qquad (5.3.3)$$

$$y_{3t} = \delta_3 + \Gamma_{31}y_{1,t-1} + \Gamma_{32}y_{2,t-1} + \Gamma_{33}y_{3,t-1} + \Gamma_{34}y_{4,t-1} + \varepsilon_3 \tag{5.3.4}$$

$$y_{4t} = \delta_4 + \Gamma_{41}y_{1,t-1} + \Gamma_{42}y_{2,t-1} + \Gamma_{43}y_{3,t-1} + \Gamma_{44}y_{4,t-1} + \varepsilon_4 \tag{5.3.5}$$

Similarly, the bivariate VAR models can be expressed as follows;

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} + \begin{bmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{21} & \Gamma_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$$

Or the model can be transformed into the following system of two equations

$$y_{1t} = \delta_1 + \Gamma_{11}y_{1,t-1} + \Gamma_{12}y_{2,t-1} \tag{5.3.6}$$

$$y_{2t} = \delta_2 + \Gamma_{21}y_{1,t-1} + \Gamma_{22}y_{2,t-1} \tag{5.3.7}$$

Note that a triangular model is required for both the variance equation and the mean equation in the TBEKK model because variables that are assumed to be exogenous must be treated as such in both equations. Thus, restrictions are imposed in the VAR model of the TBEKK specifications to formulate a mean equation that is identical in structure to the variance equation.

Engle and Kroner (1995) and Kroner and Ng (1998) state that the BEKK model can be estimated consistently and efficiently using the full information maximum-likelihood method. Let L_t be the log likelihood function of observation t and n be the number of variables. L is the joint log likelihood function assuming the errors are normally distributed, given by:

$$L = \sum_{t=1}^{T} L_t(\theta) \tag{5.3.9}$$

$$L_t(\theta) = \frac{n}{2}\ln(2\pi) - \frac{1}{2}ln|H_t| - \frac{1}{2}\varepsilon_t' H_t^{-1}\varepsilon_t \quad (5.3.10)$$

where T is the number of observations and θ denotes the parameter vector to be estimated.

Computation has been done in the RATS 8.2 software package. As recommended by Engle and Kroner (1995), we performed several iterations with the simplex algorithm. We then employed the BFGS (Broyden, Fletcher, Goldfarb, and Shanno) algorithm to obtain the final estimates of the variance-covariance matrices and the corresponding standard errors. The next section discusses the empirical results of the models.

5.4. Empirical Results

This section presents the estimated results from the sample period. As mentioned in section 5.3, this study uses monthly data on seven variables, namely; the international crude oil price, the Ghana cedi exchange rate against the US dollar, the Ghana Stock Exchange Composite index, the US stock market index (S&P500), and the domestic oil prices in Ghana which include kerosene, diesel, and petrol (although some interpolation was used to generate some missing values for these series). The data ranges from January 1991 to December 2015, making a total of 300 observations. In the GARCH models, the Ghana cedi exchange rate and the Ghana Stock Market index represent local market conditions whilst the Brent crude oil price is used as a measure of the effects of international crude oil prices. The S&P500 is used to capture the influence of a global stock market on the Ghanaian stock market and exchange rate. Also, kerosene, diesel, and petrol are used to determine the effects of domestic oil prices on the exchange rate and the stock market.

Before considering the estimated results, it is important to make sure that the models are properly specified. The most widely used diagnostic test is the Ljung-Box test, which is a test for serial correlation. In this study, we apply the test on multivariate residuals rather than the single return series. If the BEKK model is adequate, the mean model should be serially uncorrelated, meaning that all Q-statistics for the standardized residuals should not be significant; and the variance model should also have no ARCH effect. For the Q-test, selecting the appropriate lag order is an open question. As mentioned by Harvey (1981), if the chosen lag is too small, the test may not detect autocorrelation at higher order lags. On the other hand, if the chosen lag is too large, the test may have lower power. As a rule of thumb, an autocorrelation coefficient is considered significant if it is outside the $[\pm 1.96 * 1/(T)^{1/2}]$ band, where T is the number of observations (Brooks, 2002, p.264). In this study, we choose to report the statistics for lag orders12, 24 and 36 based on previous literature (e.g. see Li, 2007, Joshi, 2011, and Li and Giles, 2015). Harvey also suggested that the number of lags to be included in the test should be equal to the square root of the sample size. The total number of observations in this study is 300 and taking the square root of that yields 17. Thus, we also reported statistics for lag order 17. The test statistics and their p-values for both the mean model and the variance model are reported in the bottom section of the tables depicting the output results.

We shall start the analysis of the results with the models with world crude oil prices. These models will be referred to as the crude oil price models.

5.4.1: World Crude Oil Price Models

Endogenous Crude Oil Price Models

As noted earlier, we estimated a four-variable model and a two-variable model for the endogenous crude oil price models. In these models, world crude oil prices are treated as endogenous. Starting with the four-variable BEKK model, we use the numbers 1, 2, 3, and 4 to denote the Ghana stock market, the Ghanaian currency exchange rates, the US stock market, and crude oil prices respectively. The four-variable endogenous crude oil price model converges after 132 iterations and its results are presented in table 5.4.1. The diagnostic tests suggest that the model is adequately specified because the mean model is serially uncorrelated and the variance model has no significant unmodeled ARCH effects according the Q-statistics (see the lower section of panel B in table 5.4.1). The results can therefore, be used to analyse the transmissions between the global markets (i.e. oil prices and the US stock market) and the domestic markets (the Ghanaian currency exchange rate and the Ghana stock market).

Table 5.4. 1: Four-variable GARCH-BEKK Model for Endogenous Crude Oil Prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6827*** (0.0409)	0.9243*** (0.0808)	0.0367 (0.0954)	-0.0076 (0.2141)
(1,2)	-0.0194 (0.0641)	0.0016 (0.0130)	0.0085 (0.0141)	-0.0045 (0.0118)
(1,3)	0.1133* (0.0504)	0.0458 (0.0432)	-0,0316 (0.0465)	-0.2055*** (0.0501)
(1,4)	0.0301 (0.0230)	-0.0141 (0.1011)	0.0931 (0.1334)	0.2385 (0.1326)
(2,1)	0.0043 (0.0069)	0.1465 (0.1258)	0.1240 (0.1277)	-1.3953*** (0.3734)
(2,2)	0.6701*** (0.0418)	0.7799*** (0.0751)	0.7910*** (0.0361)	-0.0973 (0.1268)
(2,3)	-0.0387* (0.0151)	0.0494 (0.0933)	-0.0312 (0.0578)	0.0794 (0.1708)
(2,4)	0.0042 (0.0063)	0.4737* (0.2236)	-0.3764** (0.1570)	-1.5164*** (0.4130)
(3,1)	-0.0540* (0.0270)	-0.2128*** (0.0720)	0.0262 (0.0708)	-0.0562 (0.0961)
(3,2)	0.0899 (0.0594)	-0.0583*** (0.0160)	0.0033 (0.0116)	-0.0093 (0.0226)
(3,3)	-0.0726 (0.0556)	-0.2865*** (0.0769)	0.8406*** (0.0459)	0.4941*** (0.0977)
(3,4)	-0.0311 (0.0231)	0.5151*** (0.1483)	0.1243 (0.1518)	0.3315 (0.2232)
(4,1)	0.0275 (0.0699)	-0.0089 (0.0298)	-0.0385 (0.0599)	-0.0059 (0.0499)
(4,2)	0.1409 (0.1511)	0.0098** (0.0078)	-0.0250*** (0.0085)	0.0163** (0.0109)
(4,3)	0.1399 (0.1179)	-0.0804*** (0.0276)	0.0850** (0.0424)	-0.1324** (0.0531)
(4,4)	0.1858*** (0.0597)	-0.1570** (0.0801)	0.3894*** (0.1335)	0.4934*** (0.1239)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{13}^2 + d_{13}^2$	0.0443***	a_{13}^2	0.002	1. Ghana stock market
$a_{21}^2 + d_{21}^2$	3.3636***	a_{21}^2	0.0215	2. Exchange rates
$a_{24}^2 + d_{24}^2$	2.5239***	a_{24}^2	0.2243	3. US stock market
$a_{33}^2 + d_{33}^2$	0.3262***	a_{33}^2	0.0821	4. World oil prices
$a_{42}^2 + d_{42}^2$	0.0004**	a_{42}^2	0.0001	
$a_{43}^2 + d_{43}^2$	0.0240***	a_{43}^2	0.0065	
$a_{44}^2 + d_{44}^2$	0.0421***	a_{44}^2	0.0246	
Autocorrelation test in the mean equation				
MVLB-Q(12)	166.82 (0.905)			
MVLB-Q(17)	247.69 (0.852)			
MVLB-Q(24)	371.22 (0.671)			
MVLB-Q(36)	592.98 (0.3033)			
ARCH test in the variance equation				
MVARCH(6)	86.41 (0.832)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

The diagonal parameters in matrix A measure the effects of the own past shock on its conditional variance (ARCH effects). As indicated in table 5.4.1, the estimated diagonal parameters are all significant for matrix A: a_{11}, a_{22}, and a_{33} are significant at the 1% level of significance whilst a_{44} is significant at the 5% significance level. If we compare the magnitude of these four parameters, the Ghana stock market has the largest own shock effect with a coefficient of 0.9243, followed by the Ghana cedi exchange rate which has a coefficient of 0.7799. The US stock market and international price of oil have the smallest own shock effects as the magnitudes of their coefficients are 0.2865 and 0.1570 respectively, and these coefficients are also negative. Note that these negative coefficients are not an issue given that they will be squared in the BEKK specification. Consistent with the findings of Li (2007) and Li and Giles (2015), these results show that past shocks play a greater role in the volatility of emerging markets than they do in mature markets. As we have seen, past shocks of the Ghana stock market have a greater effect on its own volatility than do the US stock market's past shocks on its volatility. Li and Giles (2015) noted that this perhaps can be explained by the fact that the more mature a market is, the less affected it is by its own past shocks.

The diagonal parameters in matrix G measure the effects of the own past volatility of the markets on their conditional variance (GARCH effects). Except for g_{11} (which is insignificant at all conventional levels), all of the estimated parameters in the diagonal matrix G are significant at the 1% significance level. The magnitudes of g_{22} and g_{33} are large, indicating a high degree of volatility persistence of the Ghana cedi exchange rate (0.7910) and the US stock market (0.8406). The volatility persistence is lower for the Ghana stock market (where it is insignificant) and the international price of oil as we can see from the values of g_{11} (0.0367) and g_{44} (0.3894). This result is also consistent with the findings of Li (2007) and Li and Giles (2015). These papers both provided evidence that emerging stock markets derive relatively less of their volatility persistence from past volatility than developed or matured markets. Also, the significance of all the diagonal elements of matrices A and G (except g_{11})

indicates a strong GARCH (1,1) process driving the conditional variances of the four markets.

Besides the overall past shock effects, we also consider the asymmetric response of volatility, and this is captured by matrix D. The diagonal elements of matrix D measure the asymmetric response (which is the difference between the response to good news and bad news) of the markets to their own past shocks. As we can see from table 5.4.1, the estimated diagonal coefficients in matrix D are not significant for d_{11} and d_{22} suggesting that there are no significant asymmetric responses for the Ghana stock market and the exchange rate. Meanwhile, the coefficients for d_{33} and d_{44} are significant at the 1% level indicating the presence of significant asymmetric effects for the US stock market and world oil prices. Own past negative shocks, measured by the sum of the squared coefficient values of a_{ii} and d_{ii} are also reported in table 5.4.1. From the table, $(a_{33}^2 + d_{33}^2)$ is the own past negative effect of US stock market whilst $(a_{44}^2 + d_{44}^2)$ is the own past negative effect of world oil price. On the other hand, a_{33}^2 and a_{44}^2 represent own past positive effects of the US stock market and world oil price respectively. As we can see from table 5.4.1, the own past negative effect of the US stock market (0.3262) is larger in magnitude than its own past positive effect (0.0821). Similarly, the own past negative effect of oil price (0.0421) is larger in magnitude than its own past positive effect (0.0246). Thus, for both the US stock market and the world oil price, negative shocks have larger effects on their own conditional volatilities than positive effects.

Next, we focus on the off-diagonal parameters of matrices A, G and D which capture the transmissions across the markets. Indeed, an important aspect of this study is to analyse these transmissions. We start with matrix A which measures the overall shock spillovers among the variables. From table 5.4.1, the highly significant coefficients of a_{31} and a_{32} indicate that there are shock spillovers from the US stock market to the Ghanaian stock market, and from the US stock market to the Ghana cedi exchange rate. The values of a_{31} and a_{32} are 0.2128 and 0.0583 respectively, and that means the transmissions are stronger between the US stock market and the Ghanaian stock market than that between the US stock market and the Ghana cedi exchange rate. However, the reverse off-diagonal parameters a_{13} and a_{23} are not significant. This implies that news about shocks of the US stock exchange affects the volatility of the Ghana stock exchange and the Ghana cedi exchange rate but not vice versa. This one-way shock spillover indicates that there is a unidirectional past shock spillover between the US stock market and the Ghanaian stock market, and between the US stock market and the Ghana cedi exchange rate.

Moreover, we find evidence of bidirectional shock spillover between the US stock market and oil prices as the parameter a_{34} is significant, and its counterpart a_{43} is also significant. News about the US stock market affects the volatility of oil prices and vice versa. This two-way shock spillover between the US market and world price of oil indicates a bidirectional shock spillover effects between the two. Our evidence also suggests that there are shock spillovers from the international price of oil to the Ghanaian currency exchange rate since the value of a_{42} is statistically significant. However, we did not find significant evidence of shock spillover from oil prices to the Ghana stock market index. As shown in table 5.4.1, the coefficient representing this relationship, a_{41}, is insignificant.

We now focus on the off-diagonal parameters of matrix G which indicate the volatility spillover effects. As we can see from table 5.4.1, there is a bidirectional volatility spillover between international oil prices and the Ghana cedi exchange rate. The evidence is that the off-diagonal parameters g_{42} and g_{24} are both significant. The past volatility of oil prices affects the conditional variance of the Ghana cedi exchange rate and vice versa. However, the magnitudes of these volatilities are very small. The evidence that past volatility of the Ghana cedi exchange rate affects the conditional variance of oil prices is rather surprising as such a result is not expected. Note however, that although the coefficient explaining this relationship is significant at the 5% level of significance, it is not significant at the 1% level suggesting that the coefficient is not highly significant. There is also a unidirectional volatility spillover from oil prices to the US stock market. The diagonal parameter g_{43} is significant whilst its counterpart g_{34} is not significant.

With regards to the spillover effect of asymmetric shocks across the four variables, we consider the off-diagonal parameters of matrix D. As shown in table 5.4.1, the parameter d_{21} is significant indicating that there is an asymmetric response between the Ghana cedi exchange rate and the Ghanaian stock market. The coefficient of $(a_{21}^2 + d_{21}^2)$ is larger than the coefficient of a_{21}^2, suggesting that the reaction of the Ghana stock market to negative exchange rates shocks is larger than its response to positive shocks to the cedi exchange rate. There is also evidence of asymmetric spillovers from oil prices to the US stock market; from the Ghana stock market to the US stock market; and from the Ghana cedi exchange rate to oil prices, since the parameters d_{43}, d_{13}, and d_{24} are significant. The positive shock spillover from oil prices to the US stock market, a_{43}^2 (0.0065), is less than the negative shock spillover from the oil prices to the US stock market $(a_{43}^2 + d_{43}^2)$ (0.0240). This suggests that the reaction of the US stock market to a negative oil price shock is greater than its response to positive oil price shocks. This result is not surprising, as it supports the common view that markets respond more to negative shocks than they do to positive shocks. However, the evidence that there are asymmetric responses from the Ghana stock market to the US stock market and from the Ghana cedi exchange rate to oil prices, are not expected. Except for the asymmetries mentioned above, there are no other significant asymmetric effects present in the model.

Finally, the relationship between the return variables in the mean equation (the VAR) is captured in the R matrix in table 5.4.1. The results reveal that the returns of the Ghana stock market, the Ghana cedi exchange rate, and oil prices depend on their own previous values since R_{11}, R_{22}, and R_{44} are significant. However, the coefficient of R_{33} is statistically insignificant, indicating that the returns of the US stock market does not depend on its first lag. Also, return spillovers (in the mean equation) between the variables appear to be non-existent in this model since all the off-diagonal elements in matrix R are not significant.

Overall, the results from this model suggest that crude oil prices have significant shock, volatility, and asymmetric spillover effects on the Ghana currency exchange rates. However, crude oil prices were not found to have any effect on the Ghana stock market. An issue with this model is that some of the results that we found were rather surprising. E.g. the results that the Ghana stock market has an asymmetric effect on the US stock market; and the Ghana currency has a volatility spillover effect on the world oil price were not expected. These results will be examined again in the subsequent models using specifications that allow for exogeneity of some variables to determine if this can explain such anomalies.

In the second model for crude oil prices, we omit both stock market variables from the model and re-estimate the model with only oil prices and the exchange rates to determine whether the exclusion of the stock markets have any effect on the oil price-exchange rate relationship. In the literature, Ghosh (2011), Amano and Norden (1998), Chaudhuri and Daniel (1998), and Chen and Chen (2007) have also considered only oil prices and exchange rates in a bivariate analysis to model volatility spillover effects between oil prices and exchange rates. In this model, we use 1 to denote the Ghana currency exchange rate and 2 to denote the crude oil price. The model converges after 34 iterations and the results are reported in table 5.4.2. The diagnostic tests (reported at the bottom of the table) show that the model is free from both autocorrelation and ARCH effects.

Table 5.4. 2: Two-variable GARCH-BEKK Model for Endogenous Crude Oil Price

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6850*** (0.0443)	0.6885*** (0.0851)	0.8066*** (0.0468)	-0.0579 (0.1509)
(1,2)	-0.0030 (0.0074)	0.2633* (0.2435)	-0.4526 (0.2749)	0.4526 (0.4815)
(2,1)	0.0775 (0.1852)	0.0172*** (0.0095)	-0.0159 (0.0216)	0.0094 (0.0153)
(2,2)	0.1574*** (0.0569)	-0.2203*** (0.1093)	0.1222** (0.3392)	0.6165*** (0.1355)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{22}^2 + d_{22}^2$	0.4286	a_{22}^2	0.0485	1. Exchange rates
				2. World oil prices
Autocorrelation test in the mean equation				
MVLB-Q(12)	50.44 (0.3771)			
MVLB-Q(17)	84.75 (0.0825)			
MVLB-Q(24)	108.22 (0.1854)			
MVLB-Q(36)				
ARCH test in the variance equation				
MVARCH(6)	6.79 (0.6592)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

The results in table 5.4.2 show that when the Ghana stock market and the US stock market are dropped from the model, past shocks and past volatilities of the Ghana cedi exchange rate and the crude oil price have significant effects on their own conditional variances as the diagonal parameters of a_{11}, a_{22}, g_{11} and g_{22} are significant. This result is consistent with the four-variable model. Also, the diagonal element d_{22} is significant indicating the presence of asymmetric responses. From panel B, the own past negative shock, $(a_{22}^2 + d_{22}^2)$ is higher (0.4286) than the positive shock, a_{22}^2 (0.0485). In the cross-market transmissions, the results differ from the four-variable model in terms of volatility spillover. In the four-variable model, g_{42} was significant, indicating that oil price volatilities affect the conditional variances of the Ghana cedi exchange rates. In the two-variable model however, g_{21} is not significant indicating that oil price volatility does not spill over to the Ghana cedi exchange rate. Also, the significant volatility spillover effect from exchange rates to the crude oil price that was found in the four-variable model is not present in the two-variable model as g_{12} is not significant.

With regards to asymmetric responses, there are also significant differences between the two models. In the four-variable model, the Ghana cedi exchange rates have asymmetric effects on the crude oil price, and the crude oil price also has an asymmetric effect on the Ghana cedi exchange rates. However, no such relationships exist in the two-variable model. Note here that the unexpected result that the Ghanaian currency has volatility and asymmetric spillover effects on the world oil price disappear when the stock markets are dropped from the model. In terms of returns linkages, the two models produce similar results. In both models, the returns of the two variables depend on their own previous values but there are no significant cross-market return linkages. In general, some results are robust across the two models and this suggests that these inferences appear to be supported by the data. However, some results are not robust across the two specifications and this could be due to the exclusion of the stock markets. Hence, results that are not robust should be treated with caution.

In the two models that we have analysed, crude oil prices have been treated as endogenous because the full BEKK model treats all variables as such. In the next discussion, we shall analyse the crude oil price effects using the TBEKK models where crude oil prices are treated as exogenous.

Exogenous World Crude Oil Price Models

Firstly, we shall consider the four-variable TBEKK model which includes the same variables as the four-variable full BEKK model. The variables are also denoted with the same numbers as in the full BEKK. However, it should be noted that the matrices A, G and D are constrained to be a lower triangular. The model converges after 112 iterations and the results are reported in table 5.4.3. The diagnostic tests reveal that the model passes the autocorrelation and ARCH misspecification tests (see the lower portion of panel B in table 5.4.3).

Table 5.4. 3: Four-variable GARCH-TBEKK Model for exogenous crude oil prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6196** (0.0481)	0.8104*** (0.0916)	0.0869 (0.1096)	-0.3730 (0.1720)
(2,1)	0.0038** (0.0080)	-0.0089 (0.0129)	-0.0269*** (0.0140)	0.0020 (0.0175)
(2,2)	0.6614*** (0.0525)	0.7092*** (0.0576)	0.8626*** (0.0173)	0.0734 (0.1417)
(3,1)	-0.0504** (0.0251)	-0.0503** (0.0410)	-0.0938*** (0.0565)	-0.2357*** (0.0542)
(3,2)	0.0444 (0.0634)	-0.0168*** (0.0964)	0.0142 (0.0411)	-0.1181** (0.0823)
(3,3)	-0.0634 (0.0567)	-0.1522 *** (0.1046)	0.8624*** (0.0365)	0.5500 *** (0.0951)
(4,1)	0.0457 (0.0624)	0.0404 (0.0893)	0.1127 (0.1328)	0.1863** (0.1954)
(4,2)	0.0497 (0.1670)	0.5379*** (0.0078)	-0.2908 ** (0.1979)	-0.8493*** (0.2730)
(4,3)	0.1004 (0.1003)	0.4236 *** (0.1788)	0.0598 (0.0424)	0.1728 (0.2485)
(4,4)	0.1638*** (0.0545)	-0.0819*** (0.0843)	0.1710*** (0.1726)	0.5812 *** (0.1199)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{31}^2 + d_{31}^2$	0.0001**	a_{31}^2	0.0053	1. Ghana stock market
$a_{32}^2 + d_{32}^2$	0.0142**	a_{32}^2	0.0003	2. Exchange rates
$a_{33}^2 + d_{33}^2$	0.3257**	a_{33}^2	0.0232	3. US stock market
$a_{42}^2 + d_{42}^2$	1.0106***	a_{42}^2	0.2893	4. World crude oil price
$a_{44}^2 + d_{44}^2$	0.3646***	a_{44}^2	0.0067	
Autocorrelation test in the mean equation				
MVLB-Q(12)	164.07 (0.9288)			
MVLB-Q(17)	236.41 (0.9417)			
MVLB-Q(24)	357.66 (0.8286)			
MVLB-Q(36)	588.13 (0.3540)			
ARCH test in the variance equation				
MVARCH	95.64 (0.6048)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

From table 5.4.3, the parameters of matrix A show that the volatility of all the variables depend on their own past shocks as the elements a_{11}, a_{22}, a_{33}, and a_{44} are all significant indicating a strong ARCH process. The off-diagonal elements of matrix A also reveal that there are shock spillovers from the US stock market to both the Ghana stock market and the Ghana cedi exchange rate since a_{31} and a_{32} are both significant. There are also shock spillovers from the crude oil price to the Ghana cedi exchange rates. These results are consistent with the results in the four-variable full

BEKK model. With regards to the volatility spillovers, the parameters in matrix G show that all the variables derive their own conditional variances from their own past volatility (except the Ghana stock market) as the diagonal elements g_{22}, g_{33}, and g_{44} are all significant indicating strong GARCH effects. From the off-diagonal elements of matrix G, the Ghana cedi exchange rates and the US stock market both have volatility spillover effects on the conditional variance of the Ghana stock market. The crude oil price also has volatility spillover effect on the conditional variance of the Ghana cedi exchange rates. These results are also similar to the results in the full BEKK model except that the volatilities of the Ghana cedi exchange rate and the US stock market have no effect on the Ghana stock market in the full BEKK model.

From matrix D in table 5.4.3, the significant diagonal parameters of d_{33} and d_{44} indicate the presence of asymmetric responses of the US stock market and the crude oil price to their own past shocks. There are also significant cross-market asymmetric responses from the US stock market to the Ghana stock market and the Ghana cedi exchange rate. Asymmetric effects also spill over from the crude oil price to the Ghana stock market and the Ghana currency exchange rates. For all of the asymmetries, the effects of negative shocks are higher than positive shocks as indicated in panel B of table 5.4.3. These cross-market asymmetries were not found in the full BEKK model, and these represent differences in results from specifying crude oil prices as exogenous as compared to specifying them as endogenous.

In terms of return linkages in the mean equation, table 5.4.3 shows that the returns of all the variables depend on their previous values (except the US stock market) since R_{11}, R_{22}, and R_{44} are significant. These results are consistent with the full BEKK model. R_{21} and R_{31} are also significant indicating the existence of return spillovers from the exchange rate to the Ghana stock market, and from US stock market to the Ghana stock market. This result however, was not found in the full BEKK model since any cross-market return linkage was not reported in that model. Hence, the existence of cross-market return linkages in the TBEKK model also represents a difference in results between treating crude oil prices as endogenous and exogenous. In general, some results are robust across the two models whilst other results are not robust across the two specifications which could be a reflection of the specification of crude oil prices as either endogenous or exogenous. Also, the unexpected results that were obtained when all variables were treated as endogenous (e.g. the volatility spillover effects from the Ghana currency to the world oil price, and the asymmetric shock spillover from the Ghana stock market to the US stock market) are not found in the TBEKK model where crude oil prices are treated as exogenous.

In the next model, we omit the stock markets from the TBEKK model and re-estimate the model as we did in the full BEKK model. This enables us to check whether the interactions of the stock markets in the model have any effect in the crude oil price and the exchange rate relationship. Here, we use 1 to denote the exchange rate and 2 to denote the crude oil price. The model converges after 28 iterations, and there is no evident unmodeled autocorrelation and ARCH effects. The results are reported in table 5.4.4 below.

Table 5.4. 4: Two-variable GARCH-TBEKK Model for exogenous crude oil prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6962*** (0.0492)	0.7334*** (0.0731)	0.7926*** (0.0364)	-0.0664 (0.1665)
(2,1)	0.0619 (0.1637)	0.2391 (0.2857)	-0.4336** (0.2434)	0.4721 (0.4968)
(2,2)	0.1526*** (0.1525)	-0.2287*** (0.1098)	0.1568** (0.3331)	0.6043*** (0.1274)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{22}^2 + d_{22}^2$	04175	a_{22}^2	0.0233	1. Exchange rates
				2. World oil prices
Autocorrelation test in the mean equation				
MVLB-Q(12)	49.27 (0.4221)			
MVLB-Q(17)	83.27 (0.1004)			
MVLB-Q(24)	107.54 (0.1977)			
MVLB-Q(36)	171.08 (0.0613)			
ARCH test in the variance equation				
MVARCH(6)	6.98 (0.6388)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

In the bivariate TBEKK model, shocks from crude oil prices do not affect the volatility of the exchange rates as a_{21} is not significant (see table 5.4.4). However, oil price volatilities affect the conditional variance of the exchange rates because g_{21} is significant. The latter result is consistent with the four-variable TBEKK model, however, the former result is not consistent since there was shock spillover effects from crude oil prices to the Ghana cedi exchange rates in the four-variable TBEKK model because a_{42} was significant (see table 5.4.3). Another difference in results between the two models is that in the two-variable TBEKK model, crude oil prices have no asymmetric effects on the exchange rates, whereas this relationship is significant in the four-variable. Here, we can argue that the interactions of the stock markets in the model play important role in the asymmetric response between the crude oil prices and the Ghana cedi exchange rates. It can be noticed from these analyses that some results are robust across the two models suggesting that these inferences seem to be supported by the data. However, some results are not robust across the two specifications which could be due to the exclusion of the stock markets. Such results may need to be treated with caution.

From these results, we can observe that crude oil prices have some effects on the Ghana currency exchange rates, but their effects on the Ghana stock market is insignificant. In particular, oil price shocks and oil price volatilities affect the movements of the Ghana currency exchange rates. In terms of returns however, crude oil prices have no effect on any of the Ghanaian variables. In general, the oil price effects on the exchange rates are unaffected whether oil price is treated as an endogenous variable (as in the full BEKK model) or exogenous variable (as in the triangular BEKK model), although some of the oil price effects disappear when the stock markets are dropped from the models. The same can be said about the oil price and the Ghana stock market relationship except that oil prices have asymmetric effects on the Ghana stock market in the TBEKK model where the oil price is treated as exogenous.

Another aspect of this paper investigates the interactions between domestic oil prices, the Ghana currency exchange rates, and the Ghana stock market. Hence, we refer to the models that examined these interactions as the domestic oil price models. The next section analyses the results of these models.

5.4.2: Domestic Oil Price Models

In these models, domestic oil prices (diesel, petrol, and kerosene) are used to replace the world crude oil prices whilst all the other variables remain the same.

Because diesel, petrol, and kerosene are domestic variables, we do not deem it necessary to treat the domestic oil prices as exogenous as in the case of the world crude oil prices. However, the US stock market will be assumed to be exogenous to the domestic oil prices. Note that the US stock market was exogenous to the exchange rates and the Ghana stock market in the exogenous crude oil price model. The Ghanaian currency and the Ghana stock market can be influenced by information from a global stock market like the US, but news from these variables may not be significant enough to influence the US stock market. Hence, we shall first apply the full BEKK model where all the variables are treated as endogenous. We shall also apply the TBEKK model to treat the US stock market as exogenous to all the domestic variables and compare the results of the two models as we did in the crude oil price models. We shall estimate the domestic oil price effects for each of the three domestic oil prices by modelling them separately in the BEKK and the TBEKK models[11]. Here, we also examine four-variable models (which include the exchange rates, the Ghana stock market, the US stock market and a domestic oil price) and two-variable models (which include only the exchange rates and a domestic oil price).

Diesel Price Models

In the four –variable BEKK model with diesel prices, we use the numbers 1, 2, 3, and 4 to denote the Ghana stock market, the Ghana currency exchange rates, the price

[11] The TBEKK model is necessary here because of the exogeneity of the US stock market. Hence, if the US stock market is not included in any domestic oil price model, the TBEKK model will not be required. In the crude oil model, the US stock market was treated as endogenous to the world oil price although it was exogenous to the domestic Ghanaian variables. We bear in mind however, that the US stock market may also influence crude oil prices because economic activities in the US can affect world oil prices. However, the restriction was made to treat the world oil price as exogenous rather than the US stock market in that model because the crude oil price is our main variable of interest, and the aim was to determine the crude oil price effect when the crude oil price is treated as exogenous as compared to when it is endogenous.

of diesel, and the US stock market respectively. The model converges after 107 iterations, and there is no evident unmodeled autocorrelation and ARCH effects. The results are reported in table 5.4.5 below

Table 5.4. 5: Four-variable GARCH-BEKK Model for diesel prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.7264*** (0.0385)	0.7010*** (0.0594)	-0.2444 (0.0863)	0.1404 (0.0943)
(1,2)	-0.1360 (0.0718)	-0.0123** (0.0094)	0.0161 (0.0145)	0.0068 (0.0106)
(1,3)	-0.0719 (0.0460)	0.0022 (0.0056)	-0.0077** (0.0061)	0.1208*** (0.0185)
(1,4)	0.2116 (0.0320)	0.0363 (0.0339)	-0.2608 (0.0562)	-0.0114 (0.0449)
(2,1)	0.0036 (0.0063)	-0.0907 (0.1094)	0.2272** (0.1387)	-1.7589*** (0.4284)
(2,2)	0.6478*** (0.0482)	0.6621*** (0.0658)	0.8769*** (0.0144)	-0.1942 (0.2030)
(2,3)	0.0204 (0.0138)	-0.0035 (0.0118)	0.0105*** (0.0042)	-0.0206 (0.0386)
(2,4)	0.0073 (0.0186)	-0.1112** (0.0797)	0.0886*** (0.0415)	-0.0835 (0.1824)
(3,1)	0.0142*** (0.0024)	-0.1405*** (0.0773)	0.0895* (0.0814)	0.1581 (0.2342)
(3,2)	0.0186*** (0.0045)	-0.0004 (0.0265)	-0.0159 (0.0178)	0.0568 (0.0827)
(3,3)	0.8795*** (0.0073)	0.7020*** (0.0516)	0.5722*** (0.0246)	2.4898*** (0.1813)
(3,4)	0.0207 (0.0036)	0.0331 (0.0622)	-0.0019 (0.0343)	0.1838 (0.1675)
(4,1)	-0.0022 (0.0326)	-0.1069* (0.0888)	-0.0206 (0.1019)	0.0165 (0.1014)
(4,2)	0.0359 (0.0624)	-0.0373*** (0.0171)	0.0140*** (0.0086)	-0.0174 (0.0284)
(4,3)	0.0207 (0.0388)	-0.0019 (0.0049)	0.0012 (0.0034)	-0.0523*** (0.0119)
(4,4)	-0.0642 (0.0545)	-0.1909*** (0.0862)	0.7999*** (0.0563)	0.5419*** (0.0793)

Panel B: Asymmetric Shocks				
A+D: Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{13}^2 + d_{13}^2$	0.0146	a_{13}^2	0.0005	1. Ghana stock market
$a_{21}^2 + d_{21}^2$	3.1019	a_{21}^2	0.0082	2. Exchange rates
$a_{33}^2 + d_{33}^2$	6.6919	a_{33}^2	0.4928	3. Diesel prices
$a_{43}^2 + d_{43}^2$	0.002	a_{43}^2	0.0000	4. US stock market
$a_{44}^2 + d_{44}^2$	0.3301	a_{44}^2	0.0364	
Autocorrelation test in the mean equation				
MVLB-Q(12)	166.82 (0.905)			
MVLB-Q(17)	247.69 (0.852)			
MVLB-Q(24)	371.22 (0.671)			
MVLB-Q(36)	592.98 (0.3033)			
ARCH test in the variance equation				
MVARCH(6)	86.41 (0.832)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

Starting with the diagonal elements of matrices A, G, and D, the results in table 5.4.5 show that the volatilities of all the four variables depend on their own past shocks as

a_{11}, a_{22}, a_{33}, and a_{44} are all significant. Also, past volatilities of all the variables affect their own conditional variance (except the Ghana stock market) because g_{22}, g_{33}, and g_{44} are all significant. This implies there are strong ARCH and GARCH effects. In addition, diesel prices and the US stock market have asymmetric responses to their own past shocks whilst the Ghana stock market and the Ghana cedi exchange rate do not have such asymmetries. As shown in panel B, the negative shocks have higher effects than the positive shocks when asymmetric effects are significant.

In terms of cross-market effects, there are unidirectional shock spillovers from the Ghana stock market to the exchange rate and from diesel prices to the Ghana stock market since a_{12} and a_{31} are significant. Also, the parameters a_{24} and a_{42} are significant, suggesting that there are bidirectional shock spillover effects between the Ghana currency exchange rates and the US stock market. From the off-diagonal elements of matrix G, it can also be observed that there are unidirectional volatility spillovers from the Ghana stock market to diesel prices, and from the Ghana cedi exchange rate to the Ghana stock market and diesel prices as the parameters g_{13}, g_{21}, and g_{23} are significant. Also, the Ghana cedi exchange rate and the US stock market have a bidirectional relationship in terms of volatility spillover effects because g_{24} and g_{42} are both significant. These results are consistent with rational expectations but the results that there are spillover effects from the Ghana currency exchange rates and the Ghana stock market to the US stock market are rather surprising.

The off-diagonal elements of matrix D reveal the existence of asymmetric effects from the Ghana stock market to the diesel price, from the Ghana cedi exchange rate to the Ghana stock market, and from the US stock market to the diesel prices. From panel B, the impacts of the negative shocks are higher than the positive shocks for all the asymmetries. With regards to return linkages in the mean equation, the diagonal elements R_{11}, R_{22}, and R_{33} are significant implying that the returns of all the variables (except the US stock market) depend on their own previous values. However, the only return spillovers come from diesel prices to the Ghana stock market and the Ghana cedi exchange rates as the off-diagonal elements R_{31} and R_{32} are significant.

In the next model for diesel prices, the stock markets are dropped and the model is re-estimated with only the diesel price and the exchange rate. As in the crude oil price models, this is done to determine whether the exclusion of the stock market variables from the model influences the relationship between the diesel prices and the exchange rates. Here, 1 is used to denote the exchange rates whilst the diesel price is denoted by 2. After the estimation, the model converges after 96 iterations, and there is no evident unmodeled autocorrelation or ARCH effects. The results are reported in table 5.4.6 below.

Table 5.4. 6: Two-variable GARCH-BEKK Model for diesel prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6484*** (0.0463)	0.5797*** (0.0767)	0.8551 (0.0281)	-0.0771 (0.1729)
(1,2)	0.0161 (0.0184)	-0.0341*** (0.0194)	0.0040 (0.0054)	-0.0787*** (0.0436)
(2,1)	-0.0097 (0.0123)	0.0603 *** (0.0257)	-0.0413*** (0.0160)	0.1018** (0.0694)
(2,2)	0.7508*** (0.0174)	0.5343*** (0.0573)	0.6436*** (0.0226)	1.9086*** (0.1574)

Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{12}^2 + d_{12}^2$	0.0074	a_{12}^2	0.0016	1. Exchange rates
$a_{21}^2 + d_{21}^2$	0.0139	a_{21}^2	0.0036	2. Diesel prices
$a_{22}^2 + d_{22}^2$	3.9282	a_{22}^2	0.2855	
Autocorrelation test in the mean equation				
MVLB-Q(12)	54.58 (0.2387)			
MVLB-Q(17)	86.25 (0.0669)			
MVLB-Q(24)	112.88 (0.1149)			
MVLB-Q(36)	178.43 (0.0271)			
ARCH test in the variance equation				
MVARCH(6)	31.43 (0.9940)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

From panel A of table 5.4.6, the results show that the diagonals of matrix A are both significant whilst in matrix G, only g_{22} is significant. This implies the volatilities of both the exchange rates and diesel prices depend on their own past shocks whilst diesel prices also have their own conditional variance depending on their own past volatilities. The diagonal parameters of matrix D also shows that only d_{22} is significant. This implies that past shocks of diesel prices have asymmetric effects on their own volatilities, and the negative shocks appear to have greater effects than the positive shocks (see panel B). Thus, the effects of own past shocks and past volatilities are the same for both variables in the four-variable model and the two-variable model. This implies that the removal of the stock market variables has not changed the results for the relationship between exchange rates and diesel (in terms of own price effects). The results therefore, are robust across the two models.

However, there are significant differences between the models in terms of cross-market transmissions. From table 5.4.6, the off-diagonal elements a_{12} and a_{21} are both significant, suggesting that there are shock spillover effects between the two variables in both directions. Diesel price volatility also has a spillover effect on the exchange rates as g_{21} is significant, whilst significant asymmetric effects run from diesel prices to the exchange rates with negative shocks having a higher impact than positive shocks. These cross-market relationships between the exchange rates and diesel prices were not found in the four-variable model (although there was volatility spillover effect from exchange rates to diesel prices).

This result implies dropping the stock markets from the model produces more significant results for the diesel price effects on the exchange rates in terms of shock spillover and asymmetric effects. It is also evident that in the two-variable model, there are no return spillovers between the two variables as we can see in the off-diagonal elements of matrix R in the mean equation. In contrast, diesel price returns affect the returns of the Ghana cedi exchange rates in the four-variable model. In both models, the returns of the two variables depend on their own previous values as the diagonal parameters of matrix R are significant for the two variables in both models.

It is important to note that in the two models that have been analysed, all the variables are treated as endogenous. However, because the US stock market is an external variable which is not likely to be influenced by the macroeconomic variables in Ghana, it will also be prudent to treat the US stock market as exogenous to determine whether the exogeniety of the US stock market affects the interactions between the variables. Hence, in our next model, we shall estimate a TBEKK model where the effects of the domestic variables on the US stock market are restricted, whilst the US stock market is allowed to influence these variables. As in the full BEKK model, the Ghana stock market, the Ghanaian currency exchange rate, the price of diesel, and the US stock market are denoted by the numbers 1, 2, 3, and 4 respectively. The model converges after 133 iterations after estimation, and there is no evident unmodeled autocorrelation or ARCH effects. The results are reported in table 5.4.7 below.

Table 5.4. 7: Four-variable GARCH-TBEKK Model for diesel prices

Panel A: Return, shock, and volatility spillovers					
	Return(R): Mean Equation		A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.5661*** (0.0593)		0.5921*** (0.0706)	-0.0551 (0.2402)	0.3953 (0.1545)
(2,1)	0.0039** (0.0078)		-0.0191*** (0.0094)	-0.0045*** (0.0133)	-0.0028 (0.0137)
(2,2)	0.5739*** (0.0697)		0.6905*** (0.0678)	0.8831*** (0.0146)	-0.2313 (0.2127)
(3,1)	0.0295*** (0.0030)		-0.0245*** (0.0064)	-0.0009 (0.0048)	0.0273*** (0.0162)
(3,2)	0.0032 (0.0073)		-0.0175 (0.0152)	-0.0057 (0.0048)	-0.0346 (0.0341)
(3,3)	0.8655*** (0.0085)		0.7114*** (0.0669)	0.5548*** (0.0307)	3.2777*** (0.3321)
(4,1)	-0.0369 (0.0288)		0.0333 (0.0379)	-0.2199*** (0.0608)	-0.0671** (0.0496)
(4,2)	0.0330 (0.0613)		-0.0339 (0.0925)	0.0323** (0.0264)	0.3035*** (0.1129)
(4,3)	0.0343 (0.0497)		0.0640 (0.0678)	-0.0360 (0.0349)	0.3227 (0.2756)
(4,4)	-0.0050 (0.0555)		-0.1885*** (0.0857)	0.8484*** (0.0383)	0.5558 *** (0.0957)
Panel B: Asymmetric Shocks					
(A+D): Negative ARCH shocks			A: Positive ARCH shocks		Series Key
$a_{11}^2 + d_{11}^2$	0.5068	a_{11}^2		0.3506	1. Ghana stock market
$a_{31}^2 + d_{31}^2$	0.0013	a_{31}^2		0.0006	2. Exchange rates
$a_{33}^2 + d_{33}^2$	11.2494	a_{33}^2		0.5061	3. Diesel prices
$a_{41}^2 + d_{41}^2$	0.0056	a_{41}^2		0.0011	4. US stock market
$a_{42}^2 + d_{42}^2$	0.0933	a_{42}^2		0.0014	
$a_{44}^2 + d_{44}^2$	0.3444	a_{44}^2		0.0355	
Autocorrelation test in the mean equation					
MVLB-Q(12)	195.09 (0.4241)				
MVLB-Q(17)	272.52 (0.4798)				
MVLB-Q(24)	372.41 (0.6549)				
MVLB-Q(36)	579.79 (0.4479)				
ARCH test in the variance equation					
MVARCH(6)	97.96 (0.5389)				

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

From table 5.4.7, the diagonal elements of matrix A are all significant whilst matrix G's diagonal elements are also significant except for g_{11}. In matrix D, only d_{33} and d_{44} are significant. These results are all consistent with the evidence in the four-variable full BEKK model. From the off-diagonal elements of matrix A, the results show that diesel price shocks have a spillover effect on the Ghana stock market but such shocks have no impact on the Ghana currency exchange rates (a_{31} is significant but a_{32} is not significant). Diesel price volatility on the other hand, has no spillover effect on either the Ghana stock market or the Ghanaian cedi exchange rates as both g_{31} and g_{32} are statistically insignificant. Again, these findings are not different from the results reported in the full BEKK model. It can be argued that employing the TBEKK model does not affect the shock and volatility spillover effects of the price of diesel on the Ghana stock market and the Ghana currency exchange rates.

When we consider the cross-market asymmetric responses however, some differences can be noted between the models. In the TBEKK model, shocks to diesel prices and the US stock market have asymmetric effects on the Ghana stock market, and the US stock market shocks also have asymmetric effects on the Ghana currency exchange since d_{31}, d_{41}, and d_{42} are all significant. Such asymmetries were not found in the BEKK model. Note that in all the asymmetries, the negative shocks have higher impacts than the positive shocks (see panel B). Another noticeable difference is that the US stock market has a volatility spillover effect on the Ghana stock market in the TBEKK model as g_{41} is significant whilst in the BEKK, the US stock market did not have such effect on the Ghana stock market. In terms of return linkages in the mean equation, the significant parameters R_{11}, R_{22}, R_{31}, R_{33} in the TBEKK model are also reported in the BEKK model, but the BEKK model also has an additional significant parameter of R_{32}. This implies the returns of diesel prices affect the returns of Ghana currency exchange in the BEKK model but not in the TBEKK model. In general, it appears that the model improves if the US stock market is treated as exogenous because of the improved t-ratios and the absence of unexpected results in the restricted model.

The next domestic oil price variable that shall be considered in this paper is the petrol price. We estimate similar models for petrol prices as we did for the diesel prices.

Petrol Price Models

To estimate the petrol price models, we replace the price of diesel with the price of petrol in the diesel price models whilst maintaining all the other variables. Starting with the four-variable model, the petrol price is denoted by the number 3, whilst the other variables are denoted by the same numbers as in the diesel price models. After estimation, the four-variable BEKK model converges after 152 iterations and the model also passes all diagnostic tests. The results are reported in table 5.4.8, and the diagnostic test results are also reported at the bottom of this table.

Table 5.4. 8: Four-variable GARCH-BEKK Model for petrol prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.7022*** (0.0482)	0.7464*** (0.0689)	-0.0281 (0.0743)	-0.0571 (0.1161)
(1,2)	-0.1678 (0.0878)	-0.0115** (0.0093)	-0.0120 (0.0116)	-0.0011 (0.0084)
(1,3)	-0.0091 (0.0699)	0.0176*** (0.0068)	-0.0101*** (0.0059)	0.0630*** (0.0169)
(1,4)	0.0945 (0.0518)	0.0324 (0.0411)	-0.1501 (0.0508)	-0.0145 (0.0487)
(2,1)	0.0052 (0.0059)	0.1667 (0.1721)	0.1055*** (0.1091)	2.5438*** (0.8430)
(2,2)	0.5857*** (0.0673)	0.7249*** (0.0565)	0.8784*** (0.0138)	0.0684 (0.2326)
(2,3)	0.0023 (0.0109)	-0.0050 (0.0162)	0.0059 (0.0056)	0.0223 (0.0417)
(2,4)	0.0241 (0.0144)	-0.2550*** (0.0913)	-0.0410 (0.1476)	-0.5878 (0.2602)
(3,1)	0.0289*** (0.0042)	-0.2720*** (0.1042)	0.0402 (0.0617)	-0.0499 (0.2994)
(3,2)	0.0240*** (0.0060)	-0.0216 (0.0183)	-0.0028 (0.0093)	0.0248 (0.0452)
(3,3)	0.9073*** (0.0110)	0.7942*** (0.0739)	0.5754*** (0.0277)	1.9893*** (0.2169)
(3,4)	0.0108 (0.0040)	0.1148 (0.0725)	0.0969 (0.0912)	0.1129 (0.1479)
(4,1)	-0.0539 (0.0333)	0.0217 (0.0839)	0.0427 (0.1000)	0.1024 (0.1287)
(4,2)	0.0156 (0.0761)	-0.0311*** (0.0181)	0.0095 (0.0274)	-0.0063 (0.0305)
(4,3)	-0.0182 (0.0625)	-0.0255*** (0.0072)	0.0153** (0.0103)	-0.0497*** (0.0130)
(4,4)	-0.0751 (0.0631)	-0.1303** (0.0940)	-0.8070*** (0.0583)	0.5358*** (0.0899)

Panel B: Asymmetric Shocks				
A+D: Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{13}^2 + d_{13}^2$	0.0043	a_{13}^2	0.0003	1. Ghana stock market
$a_{21}^2 + d_{21}^2$	6.4987	a_{21}^2	0.0278	2. Exchange rates
$a_{24}^2 + d_{24}^2$	0.4105	a_{24}^2	0.0650	3. Petrol prices
$a_{33}^2 + d_{33}^2$	4.5881	a_{33}^2	0.6308	4. US stock market
$a_{43}^2 + d_{43}^2$	0.0031	a_{43}^2	0.0007	
$a_{44}^2 + d_{44}^2$	0.3041	a_{44}^2	0.0169	
Autocorrelation test in the mean equation				
MVLB-Q(12)	174.89 (0.8069)			
MVLB-Q(17)	260.31 (0.6844)			
MVLB-Q(24)	376.35 (0.6002)			
MVLB-Q(36)	481.53 (0.5817)			
ARCH test in the variance equation				
MVARCH(6)	79.43 (0.9358)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

From matrices A, G, and D in table 5.4.8, it can be observed that the interactions between the Ghana stock market, the Ghana cedi exchange rates, and the US stock market are similar to how they interact among themselves in the four-variable BEKK for diesel prices. This result is expected since the two models are similar: their only difference being the diesel prices and the petrol prices.

With regards to the interactions between petrol prices and the other variables, the results show that the Ghana stock market has a shock and volatility spillover effects on petrol prices as a_{13} and g_{13} are significant. d_{13} is also significant indicating that the Ghana stock market has asymmetric effects on the price of petrol. There are also shock spillover effects from petrol prices to the Ghana stock market since a_{31} is significant. This implies there is a feedback relationship between petrol prices and the Ghana stock market. However, there are no such spillover effects between petrol prices and the Ghana currency exchange rates. Also, a_{43}, g_{43}, and d_{43} are all significant suggesting that there are shock and volatility spillovers, as well as asymmetric effects from the US stock market to petrol prices. In all the asymmetries reported, negative shocks have higher impacts than positive shocks as shown in panel B of table 5.4.8.

In terms of return linkages in the mean equation, the results in matrix R are also similar to those in the four-variable BEKK model for diesel prices. In addition, we can see that there are return spillovers from petrol price returns to the returns of the Ghana stock market and the Ghana cedi exchange rates as the parameters R_{31} and R_{32} are both significant. In general, most of the results in this model are consistent with the four-variable BEKK model using diesel prices. However, some notable differences do exist. Firstly, there are shock spillovers from the Ghana stock market to petrol prices and volatility spillovers from the US stock market to petrol prices since a_{13} and g_{43} are significant (see table 5.4.8) whilst such results were not found in the model using diesel prices. Secondly, the US stock market has a shock spillover effect on diesel prices; and the Ghana stock market also has a volatility spillover effect on diesel prices as the coefficients of a_{43} and g_{13} (reported in table 5.4.5) are significant. However, these parameters are not significant in the four-variable BEKK using petrol prices as reported in table 5.4.8

To check whether the interactions of the stock markets have any influence on the petrol prices and the exchange rates relationship, the stock market markets are dropped from the model and the model is re-estimated with only two variables, which are petrol prices and the Ghana currency exchange rates. In the two-variable model, 1 is used to denote the exchange rates whilst the petrol price is denoted by 2. The model converges after 50 iterations and all the diagnostics suggest that the model is free from serial significant correlation and ARCH effects. The results of the model are presented in table 5.4.9.

Table 5.4. 9: Two-variable GARCH-BEKK Model for petrol prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6463*** (0.0650)	0.6326*** (0.0790)	0.8429*** (0.0334)	-0.1138 (0.1739)
(1,2)	0.0041 (0.0191)	0.0039** (0.0161)	-0.0032*** (0.0055)	0.0010 (0.0189)
(2,1)	-0.0288*** (0.0091)	0.0436 ** (0.0277)	-0.0261*** (0.0142)	0.0902* (0.0773)
(2,2)	0.7816*** (0.0158)	0.5751*** (0.0549)	0.6308*** (0.0245)	2.2549*** (0.2066)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{22}^2 + d_{22}^2$	5.4153	a_{22}^2	0.3307	1. Exchange rates
				2. Petrol prices
Autocorrelation test in the mean equation				
MVLB-Q(12)	53.83 (0.2612)			
MVLB-Q(17)	84.76 (0.0823)			
MVLB-Q(24)	96.96 (0.4533)			
MVLB-Q(36)	108.14 (0.3287)			
ARCH test in the variance equation				
MVARCH(6)	43.65 (0.8420)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

From table 5.4.9, the results show that the exchange rates have a shock and volatility spillover effect on petrol prices in the two-variable BEKK model as a_{12} and g_{12} are significant. Petrol prices are also found to have some effects on the exchange rates in terms of returns, shock, and volatility spillovers because R_{21}, a_{21}, and g_{21} are all significant. Thus, exchange rates and petrol prices have some feedback relationship in terms of shock and volatility spillovers. Such results were not found in the four-variable model except that the returns spillover from petrol prices to the exchange rates was significant (see table 5.4.8). These findings suggest that the petrol price-exchange rate relationship is stronger in the two-variable model than in the four-variable model since the coefficient estimates explaining this relationship are more significant in the two-variable model than in the four-variable model. Hence, it can be argued that the interaction of stock markets restricts the petrol price effects on the Ghana cedi exchange rates.

It can also be noted that there are some differences in results between the bivariate models using diesel and petrol prices. Firstly, there were no return spillover effects in the bivariate diesel price model whilst in the petrol price model, there are return spillovers from petrol prices to exchange rates. Secondly, the GARCH effects in matrix G suggests that petrol price volatility affects its own conditional variance and the conditional variance of the exchange rates (see matrix G of table 5.4.9), whereas the diesel price volatility did not have such effects (see matrix G of table 5.4.6). Considering the asymmetric effects, diesel prices and the exchange rates have a bidirectional relationship since d_{12} and d_{21} in table 5.4.6 are both significant. However, none of this result exists in the two-variable model using petrol prices.

In the final model of petrol prices, we estimate a four-variable TBEKK model as we did for the diesel price where the US stock market is treated as an exogenous variable. Here, the variables in the model are the same and are denoted by the same numbers as in the four-variable BEKK model for petrol prices. The model converges after 124 iterations and also passes the diagnostic tests for autocorrelation and unmodeled ARCH effects. The results and the diagnostic tests of this model are presented in table 5.4.10.

Table 5.4. 10: Four-variable GARCH-TBEKK Model for petrol prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.5491*** (0.0521)	0.6604*** (0.0727)	-0.0293 (0.1737)	0.3039 (0.1397)
(2,1)	0.0069*** (0.0070)	-0.0198** (0.0127)	-0.0067*** (0.0182)	0.0022 (0.0134)
(2,2)	0.5259*** (0.0498)	0.7463*** (0.0815)	0.8708*** (0.0177)	-0.2913** (0.2089)
(3,1)	0.0340*** (0.0029)	-0.0226*** (0.0082)	0.0012 (0.0068)	0.0266*** (0.0106)
(3,2)	0.0150*** (0.0079)	-0.0239*** (0.0128)	-0.0018 (0.0037)	-0.1739*** (0.0531)
(3,3)	0.8911*** (0.0093)	0.8547*** (0.0482)	0.5441*** (0.0229)	2.3896*** (0.2311)
(4,1)	-0.0508 (0.0314)	0.0301 (0.0388)	-0.1772*** (0.0558)	-0.0927*** (0.0470)
(4,2)	0.0574 (0.0615)	-0.0037 (0.1096)	0.0237 (0.0307)	0.2084*** (0.1009)
(4,3)	-0.0246 (0.0518)	0.0459 (0.0718)	-0.0172 (0.0338)	0.1420 (0.1847)
(4,4)	0.0085 (0.0553)	-0.2547*** (0.0677)	0.8734*** (0.0310)	0.4566 *** (0.0941)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{11}^2 + d_{11}^2$	0.5285	a_{11}^2	0.4361	1. Ghana stock market
$a_{22}^2 + d_{22}^2$	0.6418	a_{22}^2	0.5569	2.Exchange rates
$a_{31}^2 + d_{31}^2$	0.0012	a_{31}^2	0.0005	3. Petrol prices
$a_{32}^2 + d_{32}^2$	0.0308	a_{32}^2	0.0006	4. US stock market
$a_{33}^2 + d_{33}^2$	6.4278	a_{33}^2	0.7305	
$a_{41}^2 + d_{41}^2$	0.0095	a_{41}^2	0.0009	
$a_{42}^2 + d_{42}^2$	0.0434	a_{42}^2	0.0000	
$a_{44}^2 + d_{44}^2$	0.2734	a_{44}^2	0.0649	
Autocorrelation test in the mean equation				
MVLB-Q(12)	178.018 (0.7572)			
MVLB-Q(17)	266.05 (0.5902)			
MVLB-Q(24)	377.29 (0.5867)			
MVLB-Q(36)	592.14 (0.3117)			
ARCH test in the variance equation				
MVARCH(6)	86.52 (0.8294)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

If the results in the table above are compared to the results in the BEKK model in table 5.4.8, it can be noticed that some results are consistent across the two models in terms of petrol price effects. For example, shocks to petrol price returns have a spillover effect on the returns of the Ghana stock market and the exchange rates in both models since R_{31} and R_{32} are significant in both models. In both models, petrol price shocks also have a spillover effect on the Ghana stock market (a_{31} is significant) and there are no volatility spillover effects from petrol prices to the Ghana stock market and the exchange rates in either models (g_{31} and g_{32} are not significant). With regards to the effects of own market shocks, the results are also robust across both models (R_{11}, R_{22}, R_{33}, a_{11}, a_{22}, a_{33}, g_{44}, g_{22}, g_{33}, g_{44} d_{33}, d_{44} are all significant in the two models).

However, there are significant differences between the BEKK and TBEKK models in terms of petrol price effects on the Ghana stock market and the Ghana cedi exchange rates. The difference is most notable in matrices A and D. From matrix A in the TBEKK model (see table 5.4.10), there are significant shock spillover effects from petrol prices to both the Ghana stock market and the Ghana currency exchange rates (a_{31} and a_{32} are significant). In the BEKK model, however, petrol price shocks affect the Ghana stock market but not the exchange rates (see table 5.4.8). From matrix D in the TBEKK model, we can also notice that petrol prices and the US stock market have asymmetric effects on the Ghana stock market and the Ghana cedi exchange rates as d_{31}, d_{32}, d_{41}, and d_{42} are all significant. As shown in panel B of table 5.4.10, the negative shocks have higher impact than the positive shocks in the asymmetries. Again, such results were not found in the four-variable BEKK model. On the other hand, the US stock market have a shock, volatility, and asymmetric effects on the petrol prices in the BEKK model whilst such effects do not exist in the restricted TBEKK model.

The results of the two models also differ slightly in terms of how the US stock market affects the Ghana stock market and the Ghana cedi exchange rates. For example, the US stock market has no effect of any kind on the Ghana stock market in the BEKK model, whilst in the TBEKK model, the US stock market have volatility spillover and asymmetric effects on the Ghana stock market because g_{41} and d_{41} are significant. Also, the US stock market has a shock spillover effect on the Ghana cedi exchange rates in the BEKK model (a_{42} is significant) whilst in the TBEKK model, the effects of the US stock market on the Ghana cedi exchange rates are the asymmetric responses between the two, where negative shocks to the US stock market turn to have higher effects on the Ghana cedi exchange rates than positive shocks (d_{42} is significant and the coefficient of $a_{42}^2 + d_{42}^2$ is higher than a_{42}^2). This implies the results are sensitive to the model used. Comparing the two models, the TBEKK model is appropriate because it restricts the effects of all the domestic variables on the US stock market (which is an exogenous variable), and it also has a larger number of significant parameter estimates than the BEKK model. The TBEKK model provides inferences that are more consistent with theory because it does not yield surprising results.

We can also compare the TBEKK models for diesel and petrol prices where the US stock market is treated as exogenous in both models. The results in tables 5.4.7 and 5.4.10 suggest that the results are broadly consistent across the two domestic oil price models if the US stock market is exogenous. The only notable differences however, is that there are return spillover, shock spillover, and asymmetric spillover effects from petrol prices to both the exchange rates and the Ghana stock market, whilst diesel prices only affect the Ghana stock market for all the three spillover effects.

In the final group of models in this paper, we examine the spillover effects between kerosene prices, the Ghana stock market, and the US stock market. Hence, we refer to these models as the kerosene price models.

Kerosene Price Models

In the kerosene price models, an attempt has been made to estimate a four-variable BEKK specification and two-variable BEKK model in line with the diesel and petrol price models. However, the four-variable model for kerosene prices was not adequate because it did not pass the ARCH test although it passes the autocorrelation test. Several iterations were performed by increasing the ARCH and GARCH terms in the model in order to ensure that the model passes all diagnostic tests. However, the addition of the ARCH and GARCH terms did not achieve this goal as the model continued to fail the ARCH test. Instead, the addition of the ARCH and GARCH terms creates the problem of 'non-convergence' of the model if the ARCH and GARCH terms are increased beyond a certain point. Also, the higher ARCH and GARCH terms in the BEKK model complicates the parameterization of the A, G, and D matrices, making their interpretation difficult.

As a result, we drop the US stock market from the model to check if the adequacy of the model can be achieved. Hence, we re-estimate a three-variable GARCH-BEKK with the domestic variables namely; the Ghana stock market, the Ghana currency exchange rate, and kerosene prices. These variables are most important since our aim here is to examine the effects of domestic oil prices on the Ghana stock market and the Ghana cedi exchange rates. In the three-variable model, we use the numbers 1, 2, and 3 to denote the Ghana stock market, the Ghana currency exchange rates, and the price of kerosene respectively. The model achieved convergence after 106 iterations and it also passes the relevant diagnostic tests of serial correlation and unmodeled ARCH effects. The results of this model are presented in table 5.4.11 below.

Table 5.4. 11: Three-variable GARCH-BEKK Model for kerosene prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.6202*** (0.0432)	0.9355*** (0.0705)	-0.0748 (0.0718)	-0.4602 (0.2738)
(1,2)	-0.2351*** (0.0703)	0.0046 (0.0159)	-0.0073 (0.0185)	0.0670*** (0.0213)
(1,3)	0.1189*** (0.0423)	0.0350*** (0.0099)	0.0555*** (0.0089)	0.0197 (0.0257)
(2,1)	-0.0174*** (0.0003)	-0.3796*** (0.1164)	0.2316*** (0.1248)	-0.0158 (0.1905)
(2,2)	0.6680*** (0.0157)	0.4424*** (0.0734)	0.9112*** (0.0143)	0.1647** (0.1107)
(2,3)	0.0349*** (0.0026)	0.0117 (0.0233)	-0.0148** (0.0109)	0.0374 (0.0431)
(3,1)	0.0029 (0.0064)	-0.0144 (0.0868)	0.1915*** (0.0634)	0.0037 (0.1222)
(3,2)	0.0095** (0.0119)	0.1299*** (0.0259)	-0.0455*** (0.0125)	-0.0697*** (0.0406)
(3,3)	0.9105*** (0.0114)	0.7355*** (0.0703)	0.7158*** (0.0184)	-0.8077*** (0.1527)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{11}^2 + d_{11}^2$	1.0869	a_{11}^2	0.8752	1. Ghana stock market
$a_{12}^2 + d_{12}^2$	0.0045	a_{12}^2	0.0002	2. Exchange rates
$a_{22}^2 + d_{22}^2$	0.2228	a_{22}^2	0.1957	3. Kerosene prices
$a_{32}^2 + d_{32}^2$	0.0217	a_{32}^2	0.0169	
$a_{33}^2 + d_{33}^2$	1.1933	a_{33}^2	0.5409	
Autocorrelation test in the mean equation				
MVLB-Q(12)	95.51 (0.7993)			
MVLB-Q(17)	147.85 (0.6023)			
MVLB-Q(24)	199.84 (0.7779)			
MVLB-Q(36)	316.64 (0.6045)			
ARCH test in the variance equation				
MVARCH(6)	117.57 (0.2489)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

In broader terms, the results in table 5.4.11 are slightly different from the four-variable models for diesel and petrol prices in terms of the stock market, exchange rates, and domestic oil price relationships. Firstly, kerosene prices are found to have a shock, volatility, and asymmetric effects on the exchange rates since a_{32}, g_{32}, and d_{32} are all significant. In the four-variable BEKK models for petrol and diesel prices, the only significant spillover effect of domestic oil prices on the exchange rates was the returns. The other effects became significant after the stock markets were dropped in the two-variable models for the petrol and diesel price models. Also, kerosene price volatilities have a spillover effect on the Ghana stock market in this model (g_{31} is significant) whilst diesel and petrol prices only have shock spillover effects on the Ghana stock market in their respective four-variable BEKK models.

The evidence here also suggests that the shocks to the Ghana stock market and the Ghana stock market volatilities have spillover effects on kerosene prices as a_{13} and g_{13} are both significant. g_{23} is also significant indicating that the exchange rate volatilities have a spillover effect on the price of kerosene. This result is consistent with what was found in the diesel price models. On the contrary, the exchange rates have no effect of any kind on petrol prices in the petrol price models. With regards to return linkages in the mean equation, the parameters in matrix R show that the returns of kerosene prices depend on the past values of the Ghana stock market and the Ghana cedi exchange rate since R_{13} and R_{23} are both significant. However, the returns of kerosene prices do not appear to have any spillover effect on the returns of either the Ghana stock market or the Ghana cedi exchange rate.

Note that since the US stock market is not included in the kerosene price model, estimating a TBEKK model will not be required. However, it will still be prudent to determine whether the interaction of the Ghana stock market influences the kerosene price and the exchange rate relationship. Hence, the Ghana stock market is dropped from the model, and the model is re-estimated with only two variables, which are the price of kerosene and the exchange rate. In the two-variable model, the numbers 1 and 2 are used to denote the exchange rates and the kerosene prices respectively. The model converges after 46 iterations and it also passes the diagnostic tests of serial correlation and unmodeled ARCH effects. The results of the model are presented in table 5.4.12.

Table 5.4. 12: Two-variable GARCH-BEKK Model for kerosene prices

Panel A: Return, shock, and volatility spillovers				
	Return(R): Mean Equation	A: ARCH effects	G: GARCH effects	D: Asymmetries
(1,1)	0.5986*** (0.0554)	0.6387*** (0.0749)	0.8115 (0.0374)	-0.0599 (0.1790)
(1,2)	0.0264 (0.0166)	-0.0298 (0.0328)	-0.0012 (0.0083)	-0.0478 (0.0455)
(2,1)	-0.0759*** (0.0193)	0.0665*** (0.0217)	-0.0119* (0.0109)	0.0593 (0.0555)
(2,2)	0.7699*** (0.0180)	0.4128*** (0.0448)	0.7480*** (0.0175)	1.5404*** (0.1384)
Panel B: Asymmetric Shocks				
(A+D): Negative ARCH shocks		A: Positive ARCH shocks		Series Key
$a_{22}^2 + d_{22}^2$	2.5432	a_{22}^2	0.1704	1. Exchange rates
				2. Kerosene prices
Autocorrelation test in the mean equation				
MVLB-Q(12)	61.43 (0.0922)			
MVLB-Q(17)	95.58 (0.1539)			
MVLB-Q(24)	111.55 (0.1326)			
MVLB-Q(36)	173.71 (0.4633)			
ARCH test in the variance equation				
MVARCH	59.79 (0.8420)			

Note: constants are omitted in the above table to save space. Values in brackets are standard errors. ***, **, and * represent levels of significance at the 1%, 5%, and 10% significance levels respectively. MVLB-Q(12), (17), and (24) stand for the multivariate Ljung-Box Q-statistic for the standardized residuals up to 12 , 17, and 24 lags while MVARCH denotes the multivariate ARCH test.

It can be noticed from the table that some of the results are consistent with the three-variable model in terms of the diagonal parameters in the mean and the variance equations. The significant R_{11} and R_{22} suggest that the returns of the exchange rates and kerosene prices depend on their own previous values. The volatilities of both variables also depend on their own past shocks since a_{11} and a_{22} are significant indicating strong ARCH effects. The significant g_{22} also implies the past volatilities of kerosene prices affect their own conditional variances. In addition, the past shocks of kerosene prices have asymmetric effects on their own volatilities, and negative shocks have a higher impact than positive shocks (d_{22} is significant and the coefficient of $a_{22}^2 + d_{22}^2$ is higher than the coefficient of a_{22}^2). All of these results were also found in the three-variable model. However, in the three-variable model, the past volatilities of exchange rates affect their own conditional variances; whilst past exchange rate shocks also have asymmetric effects on their own volatilities. These results have not been found in the two-variable model.

With regards to cross-market effects, some results also appear to be different between the two models. From table 5.4.12, the exchange rates have no effect of any kind on the kerosene prices. In table 5.4.11 however, the exchange rates have returns spillover and volatility spillover effects on the kerosene prices. Also, in table 5.4.12, kerosene prices only have return spillover and shock spillover effects on the exchange rates as R_{21} and a_{21} are significant. Meanwhile, the kerosene prices have a shock spillover, volatility spillover, and asymmetric effects on the exchange rates in the three-variable model. In general, some results are robust across the two models and this suggests that these inferences are supported by the data. However, some results are not robust across the two specifications which could be due to the exclusion of the stock market. Hence, such results should be treated with caution.

The results that have been reviewed in the foregoing discussions show that domestic and world oil price movements have some influence on the Ghana stock market and the Ghana currency exchange rates. In some cases, the results depend on the type of model, i.e. whether the model is a two-variable, three-variable, or four-variable model; or whether restrictions are imposed on the model. From the discussions above, it can be noted that some of these models yielded results that are more consistent with theoretical expectations than others. This paper also attempted estimating VECH models in order to compare the results of those models with the results of the BEKK models that have been reported here. However, in all our estimations, we did not achieve convergence in the VECH models. Hence, we could not proceed to analyse the results of those models. Nevertheless, because the VECH does not guarantee positive semi definiteness whereas the BEKK provides this guarantee, we can be confident that the results that we obtained from the BEKK models are sufficient for the purpose of our study.

It is also important to identify our "preferred models" or "robust" results from the models we have analysed. With regards to the crude oil price models, our preferred models are the models that treat crude oil prices as exogenous on a priori grounds. Based on our assumption that economic activities in Ghana cannot influence world oil prices because of the relatively small size of the Ghanaian economy, the exogenous crude oil price models are most appropriate because they will not provide implausible results. For example, the exogenous crude oil price models will not accept the results that the Ghanaian currency exchange rate and the Ghana stock market affect the world crude oil price as it was found in the endogenous crude oil price model. However, the crude oil price effect on the exchange rate is not qualitatively different between the endogenous crude oil price models and the exogenous crude oil price models. In both groups of models, the world crude oil price has a shock and volatility spillover effect on the Ghana currency exchange rates. With regards to the crude oil price effect on the stock market, the results in the exogenous crude oil price model appear to suggest that crude oil price shocks have asymmetric effects on the Ghana stock market. This result however, was not found in the endogenous crude oil price model.

If we consider the effects of the US stock market shocks, the results from the models suggest that there are significant spillover effects from the US stock market to the Ghana stock market and the exchange rates in the exogenous crude oil price model than in the endogenous crude oil price – although the US stock market effect is not our main concern in this paper. Note that the US stock market is also exogenous to the exchange rates and the Ghana stock market in the exogenous crude oil price model. In the exogenous crude oil price model, the US stock market has all the spillover effects (i.e. returns, shock, volatility, and symmetric) on the Ghana stock market, whilst in the endogenous crude oil price model, the US stock market only has a shock spillover effect on the Ghana stock market. In general, the results in the exogenous crude oil price models (which include the spillover effects from crude oil prices to both the exchange rates and the Ghana stock market, and the spillover effects from the US stock market to the Ghana stock market) are more consistent with theoretical expectations than the results in the endogenous crude oil price models. The theoretical consistency of these results further justifies our preference for the models that treat the world crude oil prices as exogenous. These favoured results therefore, will be part of the main focus our discussions.

With regards to the domestic oil price models, our criterion for selecting the preferred models is based on the robustness of results (results that are repeated across the models). In this sense, the return spillover effects and the shock spillover effects from the diesel and petrol prices to the Ghana stock market are robust across the diesel and petrol price models. Also, return spillover and shock spillover effects from petrol and kerosene prices to the exchange rates are robust across the petrol and kerosene price models.

In terms of the US stock market effect, the significant asymmetric effects of the US stock market on the Ghana stock market and the exchange rate appear to be robust across the domestic oil price models. In particular, this result is very robust in the models that treat the US stock market as exogenous. This result is also consistent with the results in the exogenous crude oil price model, suggesting that the significant asymmetric effects of the US stock market on the Ghana stock market and the Ghana cedi exchange rates are robust. The robust results can also be justified on the basis of their consistency with theoretical expectations. Firstly, the robust results that have been stated above are all significant in the models that treat the US stock market as exogenous. These models should be preferred on a priori grounds because as in the case of the world oil prices, macroeconomic news in Ghana are not expected to have a significant influence on a global stock market such as the US. News from the US stock market on the other hand, can influence macroeconomic variables in Ghana. The models therefore, are expected to yield results that are theoretically justifiable. Also, the robust results such as the significant spillover effects from domestic oil prices to the Ghana stock market and the exchange rates, and the significant asymmetric effects from the US stock to the Ghana stock market and the exchange rate are consistent with theoretical expectations. For example, fuel plays an important role in national economic life, which means the prices of fuel can influence certain macroeconomic variables such as exchange rates and the stock market. The significant asymmetric effects of the US stock market on the exchange rates and the Ghana stock market are also consistent with the popular view that macroeconomic news are transmitted from global stock markets, and that negative shocks usually have a higher impact than positive shocks.

It is important to note that the criteria we used to select our preferred models or results are subject to some criticisms. In relation to the theoretical expectations, selecting models based on this criterion is subject to the criticism of trying to justify existing theories which can lead to bias in model selection. Besides, theories by themselves are usually faced with some limitations such as their reliance on restrictive assumptions that are usually questionable in reality. However, our preferred models that treat the US stock market and world oil prices as exogenous do not fall into this category. With regards to the selection of robust results, the problem with this criterion relates to the fact that “bad models” which yield inconsistent results may make it difficult to identify robust models. Hence, this is why we use theoretical criteria which are based primarily on exogeneity assumption as a useful guide in selecting the best models.

Another issue that needs to be considered is the comparison of world oil price effects and domestic oil price effects to determine whether there are any differences between the two. From the results of our preferred models, it can be noticed that exchange rates are influenced by both domestic and world oil prices in terms of shock, volatility, and asymmetric spillover effects. Both proxies of oil prices also have asymmetric effects on the Ghana stock market. However, there are some notable differences between the two oil price effects. Firstly, shocks to domestic oil price returns have a spillover effect on the exchange rates and the Ghana stock market. Secondly, domestic oil prices influence the Ghana stock market in terms shock and volatility spillover. The world crude oil prices were not found to have any of these effects on the Ghana stock market and the exchange rates. Hence, it can be stated that the spillover effects from domestic oil prices to the Ghana stock market and the Ghanaian currency are more significant than the spillover effects of world crude oil prices on the Ghana stock market and the Ghanaian currency.

In the next section, we shall discuss our favoured results from the preferred models further and identify some justifications for some of the results.

5.5. Discussion of favored Results

This section discusses the findings mainly from our preferred models which were reported in the previous section. The discussion will include some background information and theories that underpin these results. It will also include how the results compare with the findings of previous studies. The favoured results are summarised as follows:

Firstly, world crude oil prices have shock spillover, volatility spillover, and asymmetric effects on the Ghanaian currency exchange rate. Secondly, the world crude oil prices have asymmetric effects on the Ghana stock market. Furthermore, domestic oil price returns have a spillover effect on the returns of the Ghana stock market and the Ghanaian currency exchange rates, whilst domestic oil price shocks also have a spillover effect on the conditional variances of the Ghana stock market and the Ghana currency exchange rates. Finally, there are asymmetric effects from the US stock market to the Ghana stock market and the exchange rate.

The result that shocks to the US stock market spill over to the Ghana stock market and the Ghana currency exchange rates could be a reflection of the trade and FDI flows between the two countries. Ghana has a close relationship with the United States in terms of trade and investment. Essentially, Ghana receives significant amounts of FDI flows from the United States annually, whilst the US serves as one of Ghana's major export markets. Because of the substantial trade link between Ghana and the US, macroeconomic news from the US could have some impact on economic activities in Ghana. As noted by Phylaktis and Ravazzolo (2005), movements in the US stock market convey information about the performance of the US economy. A global centre such as the US also transmits news about global economic conditions. Hence, we infer that the influence of the US stock market on the Ghanaian stock market reflects the fact that investors in Ghana react to macroeconomic news from the US, and this transmission is consistent with the ‘global centre’ hypothesis that a global centre such as the US plays an important role in the transmission of macroeconomic news (Li, 2007). Besides, macroeconomic news from the US could affect export and import trade between the two countries, and this can have an impact on the Ghana currency exchange rate vis-à-vis the US dollar. Our results from the preferred models are consistent with the findings of Li (2007) and Li and Giles (2015). In their papers that investigated the shock spillover effects from developed markets to emerging markets, Li (2007) found evidence of shock spillover from the Hong Kong stock market to the two stock market indices in China, whilst Li and Giles (2015) found evidence that shocks to the US stock market have a spillover effect on a group of stock markets in Asia.

To explain the result that past shocks and past volatility of world crude oil prices affect the volatility and conditional variance of the Ghana cedi exchange rate, we first note that Ghanaian importers of crude oil are demanders of the US dollar. Since oil contracts in the world market are denominated in US dollars, oil importers in Ghana need to sell the Ghanaian cedi in order to obtain liquidity in US dollars. Therefore, as oil price increases, more US dollars must be bought, which also means selling more cedis. This increase in the demand for the US dollar raises its exchange rate at the expense of the Ghana cedi. In order words, an increase in the price of oil in the world market is likely to cause a depreciation of the Ghana cedi relative to the US dollar. Thus, it should not be surprising that news about shocks to world oil prices affect the volatility of the Ghana cedi exchange rate.

This result is consistent with the findings of Gosh (2011), Lizardo and Mollick (2011), Amano and Norden (2008), Chen and Chen (2007), Beckmann and Czudaj (2013) Tiwari (2013), Turhan (2014), Aloui et al (203), Aziz and Abu Bakar (2011) and Benassy-Quere et al (2007) . For example, Ghosh (2011) showed that an increase in the price of oil leads to a depreciation of the Indian currency vis-à-vis the US dollar. Also, Lizardo and Mollick (2011) revealed that the US dollar depreciates against the currencies of oil exporting countries following positive shocks to oil prices whilst the currencies of oil importing countries such as Japan depreciate against the US dollar as a result of such shocks. Chen and Chen (2007) also showed that oil prices have been the dominant source of exchange rate movements in the G7 countries during their sample period. Yet, the findings of studies such as Sari et al (2010), Wu et al (2012), Reboredo (2012), Reboredo and Rivera-Castro (2013) appear to be inconsistent with our results as they found a relatively weak relationship between oil prices and a range of currencies including those of net oil-exporting, net oil-importing, developed, and developing economies. However, these papers showed that the dependence of exchange rates on oil price movements increased after the financial crisis of 2008.

This paper also examined the relationship between world crude oil prices and the Ghana stock market index. The evidence from our favoured model suggests that the impact of oil price movements on the stock market in Ghana is rather weak in terms of shock and volatility spillovers. However, there are asymmetric shocks from oil prices to the Ghana stock market, with negative shocks having a higher impact than positive shocks. Lin et al (2014) found some interesting results in examining the link between oil prices and the Ghana stock market, and it is worthwhile comparing their results to ours. Firstly, Lin et al found significant asymmetric effects from oil prices to the Ghana stock market which is consistent with our findings. In terms of the shock and volatility spillover effects, their findings differ from the results we reported in this paper since they found significant shock and volatility spillover effects from crude oil prices to the Ghana stock market. This difference in results could be attributed to a number of factors such as the type of data and methodologies used. For example, Lin et al (2014) used weekly data from 2000 to 2010 whilst our paper used monthly data running from 1991 to 2015 which is a more extended period. Also, whilst we employed the BEKK models in our study, Lin et al (2014) used the VAR-GARCH, VAR-AGARCH, and the DCC-GARCH frameworks.

In the literature, several papers investigated the relationship between oil prices and exchange rates, and oil prices and stock markets. However, only a few papers adopted the approach of studying the dynamic interactions between these variables together in one empirical model as we did in this study. These papers are Basher et al (2012) and Ciner et al (2013). Whilst some of our results are similar to the results of these papers, some differences also exist in some respects. For example, consistent with the findings of this paper, Basher et al (2012) showed that the exchange rates respond to movements in crude oil prices. However, their results that oil price increases depress stock prices whilst emerging stock market price increases leads to an increase in crude oil prices may not support our findings given that we did not find significant shock and volatility spillovers from oil prices to the Ghana stock market. Perhaps, the results of Basher et al (2012) are significant because of their use of the MSCI emerging markets index as a proxy for emerging stock market in their study. This index includes stock markets from countries such as China, India, Russia, Brazil, South Africa, etc. These countries have become important oil consumers in the world propelled by their rapid economic growth in recent times.

Hence, it is not surprising that the emerging stock markets (as proxied in Basher et al) and oil prices have a significant bidirectional relationship.

In the case of Ciner et al (2013), their paper investigated the dynamic correlations between oil prices, exchange rates, stock markets, and other financial assets using data from the US and the UK. Unlike our paper, Ciner et al (2013) conducted their investigations within a time-varying framework over three different periods, namely; a specific sample period, during extreme price changes, and during crisis periods. They also include gold and bonds in their paper. Because Ciner et al (2013) adopted a time-varying approach, some of their results (e.g. correlations during crisis periods) cannot be easily compared to our results. Nevertheless, some comparisons can be drawn between their results and ours. For example, our study found a strong relationship between world crude oil prices and the US stock market whereas such relationship was not found in Ciner et al. However, their study found a significantly negative relation between oil prices and the US stock market only during crisis periods such as the 2007-2008 financial crises. Moreover, our results that crude oil price volatilities have a significant spillover effect on the Ghana currency exchange rates against the US dollar is somewhat, similar to their findings that oil prices and the US dollar have a significantly negative correlation. The differences in results between our paper and Ciner et al (2012) could be due to differences in approach, methodology, and the countries under consideration. For example, in our paper, we employed the GARCH-BEKK model whilst Ciner et al used the dynamic conditional correlation (DCC) approach with a GARCH specification. Also, Ciner et al included two other financial assets in their model which are gold and bonds, whereas in our models, such variables were not included. Moreover, whilst our study used data from Ghana, Ciner et al used data from the US and the UK.

With regards to the relation between domestic oil prices, the Ghana currency exchange rates, and the Ghana stock market, the results reported in our preferred models show that diesel, petrol, and kerosene prices have return spillover and shock spillover effects on the Ghana cedi and the Ghana stock market. Here, we argue that the effects of domestic oil price movements on the exchange rates and the stock market could be due to their effect on the cost of production. Domestic oil price rises have the potential to increase the cost of production for firms and the cost of goods and services for consumers. This reduces company profits, and hence, their stock prices. The increase in the cost of production may also repel foreign capital and cause capital flight from the domestic economy which may lead to a depreciation of the domestic currency. Note also that because Ghana still import significant amounts of refined petroleum products (see chapter 2), domestic oil prices are likely to reflect changes in the Ghana cedi exchange rates because the importers of refined petroleum products will need to convert their cedi into dollars to buy the products. Hence, the significant spillover effects from domestic oil prices to the exchange rates and the stock market in our preferred models is not surprising.

It should be noted that domestic oil prices have more spillover effects on the Ghana stock market than the spillover effects of world oil prices on the Ghana stock market. In particular, world oil prices did not have significant return spillover effects and shock spillover effects on the volatility of the Ghana stock market whereas domestic oil prices have such spillover effects on the Ghana stock market. This further underscores the argument that domestic oil prices are more relevant to the domestic economy than world oil prices from Ghana’s point of view.

In the literature, although several studies have investigated the relationship between crude oil prices and financial market variables such as stock markets and exchange rates, the studies that investigated the relationship between domestic oil prices and these variables have been very few. Some of the studies that investigated the relationship between domestic oil prices, exchange rates, and the stock market are Amano and Norden (1998), Nandha and Hammoudeh (2007), and Cong et al (2008). In these papers, domestic oil prices are determined by converting the world crude oil prices in US dollars into domestic currency using the bilateral exchange rate with the US dollar for the respective countries. Although our domestic oil price variables are measured differently from the proxies used by the previous papers, the results we reported here seem to support the findings of those papers. For example, Nandha and Hammoudeh (2007) showed that stock markets are more sensitive to oil prices expressed in local currencies than in the US dollar. Cong et al (2008) also noted that oil price shocks expressed in the local Chinese currency yield more significant impact on real stock returns than world oil price shocks expressed in the US dollar. These results are consistent with the results we reported in this study.

Nonetheless, it is important to note that the pricing of petroleum products is different across different countries because of government taxes and subsidies. As a result, the use of oil prices expressed in the local currency using the bilateral exchange rates may not be an accurate reflection of the prices consumers will actually pay for fuel. There is also the issue of exchange rate misalignment especially for developing countries. Besides, it can be argued that any evidence of significant relationship between exchange rates or stock market and world oil prices converted into domestic currency using the bilateral exchange rate with the US dollar could be a result of a common trend between the bilateral and effective exchange rates (Amano and Norden, 1998). Hence, the domestic oil price measures that we use in this paper are preferable in a study of this nature as they more accurately reflect what they are intended to, compared to the papers discussed above.

Also, the result that volatility spillovers from oil prices to the US stock market is expected given the impact of crude petroleum oil on economic activities in the US (e.g. see Hamilton 1996, 2003). Here, we argue that one of the channels through which oil price shocks are transmitted to the US stock market price is the reduction in the final demand for goods and services. Oil price increases reduce consumers' disposable incomes through their effect on the general price level. The consequent fall in the final demand for goods and services reduces company profits, and hence, their stock prices. Also, oil prices can affect stock prices in the US through their effect on current and expected future cash flows of firms. For example, increases in the price of oil tend to increase costs of production for US industries that use oil as inputs in production. The rising cost of production reduces the expected future cash flows of such companies, and consequently the value of their stocks. Because of the assumption that developed stock markets like that of the US are rational (see Jones and Kaul, 1996), it is reasonable for US stocks to react to events that significantly affect expected future cash flows.

Finally, because this paper is investigating the dynamic interactions among oil prices, exchange rates, and stock markets, we also obtained some results indicating the existence of shock and volatility spillovers between the Ghana cedi exchange rates and the Ghana stock market. This result was found in all our preferred models. Exchange rate shocks could be relevant to stock price movements in Ghana because of inflation expectations and portfolio adjustments. It has been argued that a depreciation of the nominal exchange rate creates expectations of inflation in the future. Inflation is also viewed as 'bad news' by the stock market because it tends to depress consumer spending and subsequently company profits. With regards to portfolio adjustments, a depreciation of the Ghanaian currency could discourage foreign investors from holding assets including stocks in the domestic currency, as that would reduce the returns on their investments. If foreign investors sell their holdings of Ghanaian stocks as a result of a depreciation of the currency, stock prices are supposed to drop. This result is analogous to the findings of other papers that studied the exchange rate-stock market relationship. Dimitrova (2005) showed that a depreciation of the US and UK currencies may depress the stock markets of those countries, whilst Cakan and Ejara (2013) found a similar result for eight out of twelve emerging markets. The exchange rate-stock market relationship has also been researched on Ghana by Boako et al (2015), Adjasi et al (2011), and Adjasi et al (2008), and the results of these papers are also consistent with our results in terms of return linkages, shock spillover, and volatility spillover effects across our preferred models.

5. 6. Conclusion

This chapter explored two lines of research; one investigating the dynamic interactions between the international price of oil, the Ghana cedi exchange rate, and the Ghana stock exchange index; and the other investigating the dynamic interactions among domestic oil prices, the Ghana currency exchange rates, and the Ghana stock market. In doing so, we employed a series of GARCH-BEKK models for each stream of research which also includes the US stock market. Hence, the paper developed different classes of models for crude oil prices and domestic oil prices. Our GARCH-BEKK models estimate shock spillover, volatility spillover, and asymmetric shocks to determine whether these markets have causal relationships between them.

Because of the relative size of the Ghana stock market and the Ghanaian economy in general, the Ghana stock market and the Ghana currency exchange rates are not expected to influence the crude oil prices. Hence, we treat crude oil price as exogenous in one class of models. In another class of models, crude oil prices are also treated as endogenous in order to determine whether the treatment of crude oil prices will change the main results. We do not expect the domestic variables in Ghana to influence a global market like the US stock market. Therefore, the US stock market is treated as exogenous in some of the domestic oil price models, whilst it is also endogenous in other models for comparison purposes. The domestic oil price models are our third class of models. To treat the crude oil prices and the US stock market as exogenous variables, we employed the triangular BEKK model by applying some restrictions to the variables. This approach is a novel contribution of this chapter. In the models where all variables are endogenous, we used the full

BEKK model. We also conducted some robustness checks to determine whether the interactions of the US stock market and the Ghana stock market have any influence on the oil price and the exchange relationship. Therefore, the stock markets were dropped in the models, and the models re-estimated.

The findings from the various models suggest that the crude oil price effect on the Ghana cedi exchange rate is unchanged regardless of whether crude oil prices are treated as exogenous or endogenous. However, with regards to the crude oil price and the Ghana stock market relationship, some differences appear to exist between the two groups of models – the crude oil price has an asymmetric effect on the Ghana stock market in the exogenous crude oil price model, whilst in the endogenous crude oil price model, the crude oil price has no significant effect of any kind on the Ghana stock market. Hence, the model that treats the crude oil price as exogenous seems to yield results that are more theoretically consistent than the models that treat the crude oil price as endogenous. We also prefer the exogenous crude oil price model on a priori grounds because the model restricts the effects of the Ghana stock market and the Ghana currency exchange rates on the world oil price which is also consistent with theoretical expectations. I.e. economic activities in Ghana are not expected to have a significant impact on the world oil price movements. For the domestic oil price effects, we selected our favoured results based on the robustness of the results. The favoured results were also significant in the models that treated the US stock market as an exogenous variable (for diesel and petrol prices) which we prefer a priori.

In our favoured models/results, we found significant evidence of shock, volatility, and asymmetric spillover effects from crude oil prices to the Ghana cedi exchange rate.

This result is consistent with theory and some empirical evidence. For example, papers such as Gosh (2011), Lizardo and Mollick (2011), Beckmann and Czudaj (2013), Amano and Norden (2008), Chen and Chen (2007), Tiwari (2013), Turhan (2014), and Aloui et al (203) found evidence suggesting that crude oil price fluctuations have significant effects on exchange rate movements. However, our results also contradict the findings of other papers such as Sari et al 2010, Wu et al (2012), Reboredo (2012) and Reboredo and Rivera-Castro (2013) who found weak relationship between crude oil prices and exchange rates. We noted that the crude oil price-exchange rate relationship for the Ghanaian currency comes from the demand for US dollars following oil price shocks. Since oil prices in the world market are denominated in US dollars, oil importers in Ghana will have to exchange their cedis for US dollars in order to import oil. Hence, when the oil price increases, more dollars will be demanded by Ghanaian importers to purchase oil and this puts a downward pressure on the Ghanaian currency against the US dollar. Thus, the result is important because it has helped to strengthen our belief that oil price shocks affect the volatility of the exchange rates of oil importing countries, and this effect is similar for both developed and developing countries. For the crude oil price-stock market relationship, the only significant result is the asymmetric effects from crude oil prices to the Ghana stock market. To some degree, this result is consistent with the findings of Lin et al (2014) who found significant shock, volatility, and asymmetric spillover effects from crude oil prices to the Ghana stock market. Masih et al (2011), Basher and Sadorsky (2006), Chen (2010), and Lee and Zeng (2011) also found significant spillover effects from oil prices to the stock market for other countries.

With regards to the relationship between domestic oil prices, exchange rates and the Ghana stock market, our favoured results suggest that the price of important domestic fuel such as diesel, petrol, and kerosene have some effects on the Ghanaian currency and the Ghana stock market. Domestic oil price returns have a spillover effect on the returns of the Ghana cedi exchange rate and the Ghana stock market, whilst shocks to domestic oil prices also have a spillover effect on the volatilities of the Ghana stock market and the exchange rate. We argue that this effect could be due to the increase in the cost of production of goods and services and the cost of doing business in Ghana as a result of increases in domestic fuel prices.

Although there are some consistent results between the domestic oil price effects and the world oil price effects (e.g. the shock spillover effects from both crude oil prices and domestic oil prices to the Ghana currency exchange rates), some differences can be noticed between the two oil price effects. Firstly, shocks to domestic oil price returns have a spillover effect on the exchange rates and the Ghana stock market. Also, domestic oil prices have a shock and volatility spillover effect on the Ghana stock market. These results were not found in the world crude oil price models. Hence, it can be stated that that domestic oil price movements have stronger effects on the Ghana stock market than the world oil price movements do. This result supports the findings of Nandha and Hamomoudeh (2007) that stock markets are more sensitive to oil prices expressed in local currency than in the US dollars. In general, the results from the domestic oil price models are preferable on a priori grounds to the results from the world oil price models within the context of Ghana. The government subsidies and regulations of domestic oil prices that have been in place in Ghana for several years means domestic oil prices are most likely to have direct and significant influence on economic activities than the world oil prices.

On the relationship between the Ghana stock market and the US market, this study found strong evidence that there are shock spillovers from the US stock market to the Ghana stock market. The results also show that shocks to the US stock market spill over to the Ghana currency exchange rate. This result is not surprising given the close ties between Ghana and the US in terms of trade and FDI flows. The influence of the US stock market on the Ghana stock market is in line with the 'global centre' hypothesis that a global centre such as the US plays a key role in transmitting macroeconomic news. This result also reaffirms the findings of Li (2007), and Li and Giles (2015). These papers showed that past shocks to developed markets such as the US and Hong Kong usually spillover to emerging or developing markets.

Besides the results we reported, this paper has also made contributions to the existing literature in a number of ways. Firstly, this paper sheds more light on the debate by treating crude oil price as both endogenous and exogenous. In so doing, we discovered that the treatment of crude oil prices is not important in the relationship between oil prices and exchange rates for a small country like Ghana. The main results are unchanged regardless of whether crude oil prices are treated as endogenous or exogenous. Secondly, this paper is among the first to investigate the effects of domestic fuel prices on the exchange rates and the stock market. Although papers such as Amano and Norden (1998), Nandha and Hammoudeh (2007), and Cong et al (2008) conducted similar studies, our study differs from those papers to the extent that we used specific fuel prices such as diesel, petrol, and kerosene as proxies of domestic oil prices whilst the previous papers used world oil prices converted into domestic currencies using the bilateral exchange rates as their proxies for domestic oil prices. Hence, our proxies are a better reflection of the domestic price of oil than the proxies used by the previous papers. Besides, it can be argued that any evidence of significant relationship between exchange rates or stock market and oil prices converted into domestic currency using the bilateral exchange rates could be a result of a common trend between the bilateral exchange rate and the effective exchange rate (Amano and Norden, 1998). In the literature, we have not found any paper that used the proxies we used in this paper for Ghana or any country in studying the exchange rates, stock market, and oil price relationship. Also, although there is a large body of literature discussing the oil price-exchange rate relationship for developed and developing countries, there is still insufficient literature about this topic on Africa. For Ghana, such study has not yet been conducted. This chapter therefore, represents another contribution of our work to the extent that it is the first such paper on Ghana. Finally, this paper discovered that the spillover effects of domestic oil prices on the exchange rate and the stock market in Ghana are more significant than the spillover effects of world crude oil prices on the exchange rate and the stock market.

The results in this paper have some important implications for policy makers and investors. Firstly, the significant shock spillover effect from oil prices to the Ghana currency exchange rate implies oil prices do have a role in exchange rate movements in Ghana. Thus, the government must consider events in the world oil market when modelling the Ghana cedi movement. This result is also important for Ghanaian investors who hold diversified portfolios overseas. During turbulent times in the world oil market, internationally diversified portfolio investors in Ghana will need to evaluate their alternatives in an effort to protect their investments from exchange rate risk emanating from disturbances in the oil market. The investors can use hedging strategies such as currency forwards, futures, and options. They can also invest in hedged overseas assets such as hedged exchange-traded funds

(ETFs), or maybe, avoid investing in overseas assets altogether. However, it must be noted that the use of currency futures and options as hedging strategies may not result in the desired outcome for investors who trade in oil futures contracts. Potentially, such investors will have to direct their investments to other commodities or assets.

The results also underscore the importance of domestic fuel prices in exchange rates and stock price movements. The result that the Ghana stock market is influenced by domestic oil price shocks could be a benefit to diversification for an investor who is linked to the local oil market. During economic crises, investors can use the oil market as a safe haven to protect themselves from potential losses from their portfolios of investment in the stock market.

Since the government recently abolished petroleum subsidies, the effects of domestic and world oil prices on the Ghana stock market and the Ghanaian currency are likely to become even stronger in the years ahead. This is apparent given that Ghana continues to import large amount of refined petroleum products despite becoming an oil producer. Therefore, we propose some measures the government can adopt to lessen the adverse effects of both domestic and world oil prices on the exchange rates and the stock market. Firstly, the government could consider reducing the taxes on fuel and petroleum products to reduce the final price consumers pay for those products. This will be particularly relevant when the import price of refined petroleum products increase and importers seek to pass the higher prices onto consumers. However, this may still not be sufficient to lessen the impact of higher oil import prices on the exchange rate since oil importers will demand more foreign currency to import oil. Secondly, investment is needed to expand the capacity of the Tema Oil Refinery whilst measures aimed at ensuring that the crude oil Ghana produces is refined domestically are also required. This will reduce the country's dependence on the importation of refined petroleum products. The government should also consider measures aimed at promoting energy efficiency and oil-saving. Such measures should include energy conservation and the use of alternative fuels such as solar energy. Energy diversity is particularly needed in the agricultural and transport sectors.

The result that shocks to the Ghana cedi exchange rate influences the Ghana stock market also have some implications to policy makers and investors. From a policy perspective, we recommend that the Bank of Ghana should avoid procedures and programs that result in depreciations in the Ghana cedi if it seeks to boost stock prices on the Ghana stock market. For so many years, Ghana has not been able to maintain a stable exchange rate for a sustained period. To boost investor confidence and attract foreign investors, policy makers need to intervene during periods of high or abnormal volatility in the Ghana currency. For example, when the cedi is depreciating, the Bank of Ghana can respond by raising interest rates. This will attract foreign capital and help the domestic currency to gain strength. The result also implies any attempt to temporarily maintain an overvalued currency can have serious short-term effects on the stock market. This is more so if the exchange rate is suddenly allowed to float, or if it suffers a shock. For investors, an appreciation or depreciation of the Ghana cedi exchange rate could be a signal that stock market returns are likely to increase or decline, and this can help them to make informed decisions about where to direct their investments.

This chapter also identifies some avenues for future research in order to enhance our understanding of the interactions between oil prices, exchange rates, and stock markets. Firstly, the main limitation of this paper is that the data that was used for the domestic oil prices had some missing values, as the data was not reported in full from the source. As a result, we had to use an interpolation method to generate the missing values before working with the data. Therefore, future research should re-examine this topic when a more complete set of data becomes available.

Secondly, a possible extension of this study is to find out whether oil price shocks and oil price volatility have any spill over effects on other macroeconomic or financial variables such as interest rates, bond returns, and CPI inflation. Thus, future research can include these variables to examine the dynamic interactions in a multivariate GARCH approach.

Also, besides the GARCH-BEKK model, another method that is suitable for a study of this nature is the Diebold-Yilmaz specification. Therefore, as an alternative, future research can consider other methods such as the Diebold-Yilmaz procedure.

Chapter 6: Conclusion

This thesis examined the macroeconomic effects of domestic and international crude oil price movements in Ghana. It also examined the shock and volatility spillover effects of domestic and crude oil prices on the exchange rate and the stock market in Ghana. This study is motivated by the growing importance of crude oil and petroleum products in the Ghanaian economy. Petroleum products form a significant percentage of Ghana's energy mix, whilst Ghana's oil dependence continues to rise. As of 2014, oil consumption accounted for about 52% of total energy consumption in Ghana. Despite becoming an oil producer in 2011, Ghana continues to import refined petroleum products in large quantities to meet local needs. This implies oil price shocks will have different impacts on various sectors of the economy. For example, increases in oil prices will benefit the oil sector whilst households and firms suffer, as such shocks lead to rises in cost of production and increase in the costs of goods and services. Therefore, it is prudent to examine the effects of domestic and international crude oil price movements on macroeconomic variables in Ghana.

In our investigations, we employed several estimation methods including; structural VAR, VAR with exogenous variable, forecast scenarios, the autoregressive distributive lag (ARDL), the standard VAR/VECM, BEKK, and TBEKK models. These methods were employed in an attempt to treat crude oil prices as both exogenous and endogenous whilst treating domestic oil prices as endogenous. Because of the relatively small size of the Ghanaian economy, we noted that economic activities in Ghana are unlikely to affect world crude oil prices whereas world crude oil prices can affect economic activities in Ghana. Hence, we treated crude oil prices as exogenous to account for any model misspecification as a result of the treatment of crude oil prices. In doing so, we are able to determine whether the treatment of crude oil prices is important when examining the crude oil price-macro economy relationship. However, the models that treat crude oil prices as exogenous are our preferred models a priori because of the reason given above. By so doing, this study has made some contributions to the literature; firstly, we examined the crude oil price effect by treating crude oil prices as both exogenous and endogenous within the context of a small developing country. Also, some of the methods we employed in this study such as the VAR with exogenous variable and the forecast scenarios have never been used to examine oil price effects. This study is the first to employ such methods in the oil price literature. We also examined the link between domestic oil prices, economic growth, and financial variables which is rarely found in the literature.

In general, our findings show that the treatment of crude oil prices is not important in examining the relationship between oil prices and GDP growth rate in Ghana. The effects of international crude oil price shocks on GDP growth rate is statistically insignificant either in the short run or in the long run, and this result is unaffected by the treatment of crude oil prices. Surprisingly, this result contradicts the findings of Jumah and Pastuszyn (2007) and Tweneboah and Adam (2008) who conducted a similar study on Ghana, and Fofana et al (2009), Rafiq et al (2009), and Park et al (2011) who conducted similar studies on other developing countries. All of these studies found significantly negative effects of crude oil price shocks on economic growth. However, whilst the oil price effect on the economy is statistically insignificant according to the t-ratios in the VAR, our forecast scenarios show that the effects of oil price shocks on the economy are non-negligible. Our simulations show that a temporary oil price shock reduces economic growth, although the effect is transitory, becoming zero after about one and a half or two years. The simulations from the asymmetric VAR also suggest that a negative oil price shock stimulates economic growth, and this extra growth declines slowly, becoming zero after about 10 years. Thus, although the oil price effect is not statistically significant according to the t-ratios of the VAR, the results could still be useful in understanding the crude oil price-macro economy relationship in Ghana.

With regards to the relationship between domestic oil prices and economic growth, we used the prices of diesel, petrol, and kerosene as the proxies for domestic oil prices. Our findings suggest that all the domestic oil prices have statistically insignificant effect on GDP growth rate in the short run. In the long run however, diesel and petrol prices have a significantly negative effect on GDP growth. We noted that this result could be attributed to the fact that oil consumption in Ghana mostly come from transportation and transport related activities. Therefore, whilst the domestic oil price pass-through effect is not immediate, the domestic oil price shocks will eventually feed through to the GDP growth rate over time through transportation or transport related activities. We also noted that the differences in results between using domestic oil prices and world crude oil prices could be due to the government's subsidies on petroleum products and price controls that existed in Ghana for several years, although this has not been formally tested.

This thesis also found some interesting results with respect to the spillover effects of oil prices on the exchange rate and the stock market in Ghana. In the crude oil price models, we discovered in our multivariate GARCH estimates that there are shock and volatility spillover effects from crude oil prices to the Ghana currency exchange rates, and this result is unchanged regardless of whether the crude oil price is treated as exogenous or endogenous. The crude oil price also has asymmetric effect on the exchange rate in both models. This result supports both economic theory and some empirical evidence (e.g. Gosh 2011, Lizardo and Mollick 2011, Beckmann and Czudaj (2013), Amano and Norden 2008, Chen and Chen 2007, Tiwari 2013, Turhan 2014, Aloui et al 203). These studies found evidence suggesting that crude oil price fluctuations cause exchange rate movements of the US dollar and the currencies of other countries. Although our results are robust in this sense given that we used the Ghana currency exchange rate vis-à-vis the US dollar, they also contradict the findings of other papers (e.g. Sari et al 2010, Wu et al 2012, Reboredo 2012, Reboredo and Rivera-Castro 2013). For the crude oil price and the Ghana stock market relationship, some difference appears to exist between the exogenous and the endogenous crude oil price models. When the crude oil price is treated as endogenous, the crude oil price has no effect of any kind on the Ghana stock market. But when the crude oil price is treated as exogenous, the crude oil price has an asymmetric effect on the Ghana stock market. This result is our preferred result a priori because of the treatment of crude oil prices as exogenous. To some degree, this result is consistent with the findings of Lin et al (2014) who found significant shock, volatility, and asymmetric spillover effects from crude oil prices to the Ghana stock market. Masih et al (2011), Basher and Sadorsky (2006), Chen (2010), and Lee and Zeng (2011) also found significant spillover effects from oil prices to the stock market for other countries.

It is worthwhile noting that crude oil prices did not have significant effect on the exchange rate in the VAR and VECM models whilst in the multivariate GARCH models, the crude oil price effects on the exchange rates are significant. This conflicting result could be due to the types of data we used in the different models. In the VAR and VECM models, annual data was used, whereas in the multivariate GARCH models, we used monthly data. Monthly data are high frequency data compared to annual data. As it is generally known, the use of high frequency data such as monthly data can capture more information than annual data which are low frequency data. In particular, monthly data can capture interactions that may only last a few weeks or months. As a result, it is possible for the relationship between two variables to vary with different data frequencies.

The results from our domestic oil price models also suggest that the prices of diesel, petrol, and kerosene have return spillover and shock spillover effects on the exchange rate and the stock market in Ghana. There are also volatility spillover effects from the domestic oil prices to the Ghana currency exchange rate and the Ghana stock market, although this result is not robust across all the domestic oil price models. The notable difference between the domestic oil price models and the crude oil price models lies in how the two oil price series affect the Ghana stock market. Domestic oil prices have a return spillover, shock spillover, and volatility spillover effects (in some models) on the Ghana stock market whereas crude oil prices only have an asymmetric effect on the Ghana stock market. Hence, domestic oil price movements have stronger effects on the Ghana stock market than the world oil price movements do. Given that the domestic oil prices also have a long run effect on economic growth, it can be stated that domestic oil prices are more important determinants of economic activities in Ghana than international crude oil prices do.

From the investigations, this study has made some innovations to the literature. Firstly, we discovered that the crude oil price effects on GDP growth and the exchange rate are unaffected by the treatment of the crude oil price – the effects are the same regardless of whether the crude oil price is treated as exogenous or endogenous. Secondly, the crude oil price and the Ghana stock market relationship is related to the treatment of the crude oil price– the crude oil price has no effect on the stock market when it is treated as endogenous whilst asymmetric effects exist when the crude oil price is treated as exogenous. Also, domestic oil prices have greater effects on economic activities and the stock market than international crude oil prices do.

The implication of the results in this thesis is that the government's petroleum tax policies should adequately reflect its motives because whilst increases in the petroleum tax will generate extra revenue to the government, it will drive up the prices of domestic petroleum products which may have an adverse effect on financial sector variables, and a long term effect on the economy. This is particularly important given that the government has recently slashed fuel subsidies. This result can also be beneficial to other countries in the West African sub-region with similar characteristics to Ghana. For example, countries like Nigeria, Cameroon, Guinea, Togo, the Ivory Coast, etc. have similar level of economic development as Ghana. They are also similar to Ghana with regards to petroleum subsidies and petroleum tax policies.

Key limitations

One of the limitations of this study is that we used annual data in examining the oil price-macro economy relationship. Although quarterly data is usually ideal for a study of this nature, we could not obtain such data for Ghana. Also, the data which was used to examine the domestic oil price effects on economic growth was relatively short due to the limited data that was available.

Besides, this study used monthly data to examine the volatility spillovers between oil prices, exchange rates, and the stock market. However, when measuring volatilities, it is usually preferable to use high frequency data such as daily data as such data are able to capture more information about variables than monthly data. Again, we were unable to obtain daily data for all the variables for Ghana. Also, the monthly data for the domestic oil price series have missing values in some periods. As a result, the author had to use an interpolation method to obtain the missing values.

Finally, as we noted previously, the government recently abolished subsidies on fuel consumption to align domestic oil prices with international crude oil prices. Potentially, this may change the domestic oil price effects on the economy in the post subsidy period. This implies the relations between oil prices and the macroeconomic variables may differ from some of the findings we reported in this study in the future, especially given that our study did not include the post subsidy period.

Future research

Firstly, future research should re-examine the domestic oil price effects on macroeconomic activities in Ghana when more data becomes available that allows for longer sample periods to be investigated. When full data are available in daily price series, future research can also investigate the volatility spillover effects of domestic and crude oil prices on the exchange rate and the stock market in Ghana again. Besides, future research should examine the sectoral effects of oil price shocks in Ghana focusing on the agricultural, industrial, and services sectors. Finally, since the government withdrew all subsidies in 2015, there is a need to re-examine the macroeconomic effects of the oil price on the Ghanaian economy during the post-subsidy era as more data becomes available. This is relevant because the withdrawal of subsidies could change the economy's response to oil price shocks.

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Appendices

APPENDIX A: Summary of empirical literature review

Appendix A1: Summary of the literature on oil prices and the economy for developed countries

Study	Methodology	Data	Main Findings
Hamilton (1983)	-OLS regression - F-test	Quarterly US GNP and the West Texas crude oil prices from 1948 to 1972	- This study shows that seven out of eight US economic recessions preceded oil price shocks
Svensson (1984)	-Optimization -Production functions	Parametric equations for a small open economy	- The results indicated that temporary oil price increases deteriorates the trade balance, while permanent oil price increases have an ambiguous effect on the trade balance.
Hamilton (1996)	-Granger-causality test -Impulse response functions	Quarterly US GDP growth, oil prices, treasury bills rate, inflation rate, and import price changes from 1948 to 1973	- The evidence from this study shows that oil price hikes produce negative effects on US economic performance
Hooker (1996)	-VAR -Granger causality -Structural stability test	Quarterly time series data of real GDP, oil price, treasury bills rate, the GDP deflator, Unemployment, and import price deflator of the US from 1948 to1994.	- Oil prices Granger cause several US macroeconomic variables up to 1973. - The oil price-macro economy relationship changed after the 1973 oil shock. From 1973 to 1994, oil price do not appear to have a causal effect on US macroeconomic variables.

Rotemberg and Woodford (1996)	-simulations	Monthly series of US output and crude oil prices from 1948 to 1980. Parameter values	- This study observed that oil price increase is predicted to contract output
Bernanke, Gertler, and Watson (1997)	-VAR -quandt test -chow split-sample test -simulation	Monthly series of oil price, output, federal funds rate, and prices from January 1965 to December 1995	- The results of this study indicated that a significant part of oil price shocks on the economy comes from the tightening of monetary policy. - Also, the Quandt test and the chow-split test suggest that there is instability in the link between oil and the macro economy for the sample period
Hooker (1997)	-VAR - Granger causality	Quarterly data of GDP, oil price, unemployment, and federal funds rate, GDP deflator and the ratio nominal to real imports of the US from 1960:2 to 1997:2	- Oil prices partly affect the economy indirectly by inducing monetary policy responses - The oil price-macro economy relationship broke down in the 1980s following falling oil prices and market collapses. - The break down in relationship was due misspecification of oil price rather a weakened relationship
Backus and Crucini (2000)	-Simulations	Parameter values for oil prices, GDP, and terms of trade of OECD from 1972 to 1987	- This study observed that the price of oil was largely responsible for the increase in volatility in terms of trade since the Bretton Woods.

Hamilton (2003)	-VAR -Impulse response function -OLS -Simulation	Quarterly GDP growth of the US and oil prices from 1949 to 1980. Parameter values	- The evidence from this study shows that oil prices have strong and significant effect on the economy. - The study also observed that rising oil prices are much more important in predicting GDP growth than declining oil prices. - It also identifies that the relation between oil prices and the US economy is non-linear
Leduc and Sill (2004)	-VAR -simulation	Quarterly series of oil prices, GDP, CPI, Federal funds rate of the US from 1972 to 2004. Orphanides' 1979:3 to 1995:4 parameter estimates	- There is evidence that monetary policy plays a significant role in determining how of oil price shocks affect the economy
Barsky and Kilian (2004)	-Statistical observation	Monthly and quarterly series of oil prices and US real GDP from 1971 to 2003	- The study revealed that oil price shocks are neither necessary nor sufficient in explaining stagflation in the US economy
Aguiar-Conraria and Wen (2005)	-VAR -Simulation	Quarterly series of US macroeconomic variables and the West Texas Intermediate (WTI) crude oil prices from 1950 to 1978. Parameter values	- The evidence from this study shows that the deep recession in 1975 was due to the oil crisis in the early 1970s. - The study also argued that standard models are not able to provide a quantitative explanation to the US recessions experienced in the mid-1970s.

Carlstrom and Fuert (2006)	-Simulation -Impulse response function	Parameter values	- The simulation result from this study demonstrates that interest rates will increase and output decline following oil price shocks. - The findings also suggest that if interest rates were expected to be kept constant, output would actually grow in response to oil price shocks.
Zhang (2008)	-Granger causality test	Quarterly series of Japanese macroeconomic variables and oil prices from 1957 to 2006	- The evidence from this study revealed that oil price shocks Granger-causes economic growth in Japan. - The study also found that the relationship between oil prices and growth is non-linear
Kilian (2009)	-Structural VAR	Monthly data of global crude oil production, the index of global real economic activity, and the real price of oil from 1973:1 to 2007:12	- Oil price increases caused by oil supply disruptions cause a temporary decline in real GDP and have little effect on the price level. - Aggregate oil demand shocks have a delayed recessionary effect on output - Precautionary oil demand shocks reduce real output and raise consumer prices

Hamilton (2009a)	-Literature survey -Statistical analysis	Monthly and quarterly data of various years of world oil supply, world oil demand, US real GDP	- Evidence suggests that demand-driven oil price shocks have positive impact on economic activities whilst oil supply shocks have negative effect on economic activities.
Kilian and Lewis (2011)	-VAR	Monthly data series from 1967 to 2008	- This study found no evidence that the US real economic activity and CPI inflations were significantly affected by monetary policy response to oil price shocks. - This study also concluded that the combined direct and indirect effect of oil price shock on the US economy is insignificant.
Segal (2011)	Observation	Annual data of petroleum expenditure as a share of GDP for US, OECD, and World from 1970 to 2010, and analysis of the findings of previous literature	- The most important channel through which oil prices affect output is monetary policy. - High oil prices have not reduced output growth in recent years because they no longer pass through to core inflation
Cavalcanti and Jalles (2013)	-Structural VAR -Impulse response functions -Variance decompositions	Quarterly series of oil prices and macroeconomic variables of the US and Brazil	- The study estimated that the contribution of oil shocks to output volatility in the US is decreasing over time. - Variance decomposition analysis show that oil price shocks account for only a small part of the volatility in Brazilian inflation and output growth rate

Appendix A2: Summary of the literature on oil prices and the economy for developing countries

Study	Methodology	Data	Main Findings
Chang and Wong (2003)	-Cointigration -VAR -Impulse response functions -Variance decompositions	Quarterly series of Singapore macroeconomic variables and oil prices from 1978 to 2000	- The findings from this study revealed that oil price shocks have only a marginal impact on Singapore macroeconomic performance
Soderling (2005)	-Computable general equilibrium (CGE) model -Simulation	Parameter values. Annual series of Gabon GDP from 2000 to 2007	- This study observed that the Gabonese economy is vulnerable to fluctuations in oil prices.
Jumah and Pastuszyn (2007)	-Cointegration -VECM Granger Causality	Annual time series of oil prices, real GDP, interest rates, and CPI of Ghana	- Oil price shocks have negative effect on real output by impacting positively on the price level - Monetary policy is initially eased in response to oil price increases in order to lessen the negative consequences on growth
Adam and Tweneboah (2008)	-Cointegration -VECM	Quarterly data of world oil price and GDP, CPI, interest rates, and exchange rates of Ghana from 1971:1 to 2006:4	- Results indicate that there is a long run relationship all among the variables. - Unexpected oil price increase leads to an increase in the price level and decline in output - A one standard deviation shock to oil prices leads to a 0.02% decline in output after about four quarters.

Fofana et al (2009)	-Simulation	Parameter estimates for South Africa	- This study observed that the South African GDP falls as oil price increases. - The study also observed that the current account balance worsens in the wake of oil price shocks.
Kpodar and Djiofack (2009)	-Computable general equilibrium model (CGE) -Simulation	Parameter values	- The estimations from this study show that the rise in oil prices lead to a drop in household incomes in Mali. - The impact of rising oil prices is slightly more on urban households than rural households.
Rafiq et al (2009)	-VAR -Granger causality -Impulse response functions -Variance decompositions	Quarterly time series of macroeconomic indicators of Thailand and international oil prices	- The result of this study supports the evidence that oil price volatility has significantly negative impact on growth, investment, and employment.
Guivarch et al (2009)	-Simulations	Default parameter values. Observed oil prices from 2001 to 2007	- The estimated result from the simulations in this study suggests that the Indian economic growth rate is predicted to decease in the wake of oil price hikes
Limin Du et al (2010)	-Multivariate VAR -Granger causality test -Impulse response functions	Monthly time series of China's macro economy from 1995 to 2008	- The findings of this study reveal that there is a negative relationship between world oil prices and macroeconomic growth and inflation in China. - The study also shows that the relation between oil price and growth is non-linear. - It concluded that economic activity in China does not affect oil price

Ozlale and Pekkurnaz (2010)	-SVAR -Impulse response functions	Monthly series of macroeconomic variables of Turkey and Brent crude oil prices from 1999 to 2008	- The evidence shows that in the short run, oil price shocks significantly affect the current account balance in Turkey. - The findings revealed that unexpected increase in oil prices cause the change in the current account to fall.
Carton et al (2010)	-Simulation -Dynamic stochastic general equilibrium model	Parameter values	- Findings from this study show that fixed money supply regime generates volatility of consumption in the ECOWAS region following oil price shocks, whilst fixed exchange rate regime insulates the economy from such shocks.
Ali Ahmed and Wadud (2011)	-SVAR -EGARCH -Impulse response functions	Monthly data series of Malaysia macroeconomic variables and oil prices from 1986 to 2009	- Results suggest that rising oil prices leads to a fall in industrial production. - Conditional volatility of oil prices leads to a significant fall in Malaysian aggregate industrial output - There is asymmetric effect of oil price volatility on conditional output volatility.

Qianqian (2011)	-Cointegration -VECM	Monthly series of China's macroeconomic data and oil prices from 1999 to 2008	- Cointegration test shows that there exist a long-run equilibrium relationship between oil prices and China's output. - VECM results show that rising international oil prices would cause China's net exports and output to decline
Aydin and Acar (2011)	-Dynamic Computable General Equilibrium model (DCGE) -Simulation	Simulated data. Yearly series oil prices, macroeconomic variables, and carbon emission in Turkey from 2004 to 2020	- Simulation results show that oil price shocks have significant effects on macroeconomic variables and carbon emission in Turkey.
Park et al (2011)	-Structural VAR -Impulse response function	Monthly series of oil prices and macroeconomic variables of Korea from 1997 to 2008	- The evidence show that there is negative response of industrial production to oil price shocks.
BianlingOu et al (2012)	-Structural dynamic factor model	Monthly time series of China's macroeconomic indicators and oil prices from 1997 to 2011	- The result shows that China's industrial production responds negatively to oil price shocks.
Dagher et al (2012)	-Dynamic Stochastic general equilibrium (DSGE) model -Simulation	Parameter values specific to Ghana data and Low income countries (LICs).	- The study found that oil windfalls increase macroeconomic volatility in Low Income Countries.
Hassan and Zaman (2012)	-ARDL -Granger causality	Annual time series of Pakistan macroeconomic indicators and oil prices from 1975 to 2010	- Evidence show that there is a large negative relationship between oil prices and trade balance in Pakistan. - Increases in oil prices leads to a significant deterioration of the trade balance. - Granger causality test show that there is unidirectional causality running from oil prices to trade balance

Cantah and Asmah (2015)	-ARDL Cointegration -ECM	Annual data of various macroeconomic variables from 1967 to 2012	- There exist a long run relationship between oil prices and economic growth in Ghana. - Oil prices have a negative impact on economic growth in both long run and short run which is reinforced by government fuel subsidies.

Appendix A3: Summary of the literature on oil prices and exchange rates for developed countries

Study	Methodology	Data Type	Main Findings
Amano and van Norden (1998)	- Cointegration - VECM - Granger causality	Monthly series of US dollar exchange rates and US real price of oil from 1972:02 to 1993:01	- The result of this study shows a uni-directional relationship, with causality running from oil price to the US dollar real exchange rate. - VECM regression shows that increases in oil prices lead to appreciation of the US dollar.
Amano and Norden (1998)	-Cointegration -Granger causality	Monthly data of the exchange rates of the US, UK, and German currencies, and the US price of WTI crude oil converted into domestic currency from 1973:01 to 1993:06	- Cointegration exists between oil prices and the three currencies. - Oil price granger-causes the real exchange rates whereas there is no evidence of the reverse.
Chaudhuri and Daniel (1998)	-Cointegration -Granger causality	Monthly series of real exchange rates of 16 OECD countries and oil prices from 1973 to 1996	- Cointegration test reveals that there exist a long run relationship between oil prices and OECD currencies exchange rates. - The study estimated that the non-stationarity of oil prices accounted for the non-stationarity of the US dollar real exchange rate during the post Bretton Woods era.

Benassy-Quere et al (2007)	-Cointegration -VECM -Granger causality	Monthly data of crude oil prices and the US dollar exchange rates from January 1974 to November 2004	- There is a long run relationship between oil prices and the US dollar - Causality runs from oil prices to the US dollar - A 10% rise in oil price coincides with a 4.3% depreciation of the US dollar in the long run, all things being equal.
Chen and Chen (2007)	-Cointegration -DOLS -FMOLS -PMG	Monthly data of world crude oil prices and the exchange rates of G7 countries from 1972:1 to 2005:10	- There is cointegration relationship between oil prices and exchange rates of the G7 countries. - A rise in real oil prices depreciates the real exchange rates in the long run.
Zhang et al (2008)	-Cointegtration -VAR -Granger causality -ARCH models	Daily observations of the WTI crude oil price and the US dollar exchange rates from 4th January 2000 to 31st May 2005.	- There is evidence of a long run relationship between oil prices and the US dollar - There is unidirectional mean spillover effect from the US dollar exchange rate to international oil price. - Volatility spillover effect is very weak in either direction. i.e. the price volatility magnitudes of the US dollar and oil price are not transferred to each other.
Lizardo and Mollick (2010)	-Cointegration -VAR	Monthly series of oil prices and the exchange rates of the US, and other 20 developed countries from 1970 to 2008	- Findings prove that there exist a long run relationship between oil prices and the exchange rates of all the countries except Norway. - Oil price increase causes a depreciation of the US dollar and the Japanese yen.

Sari et al (2010)	-ARDL bound test - generalised forecast error variance decomposition - generalised impulse response functions	Daily data of four precious metals (gold, silver, platinum, and palladium), oil prices, and USD/euro exchange rate from 4th January 1999 to 19th October 2007.	- There was no evidence of long run relationship between the variables. - Exchange rates and oil price returns do not have considerable linkages with each other
Aziz and Baker (2011)	-Cointegration -PMG	Monthly series of oil prices, interest rates, and exchange rates for a panel of 8 countries from 1980 to 2008	- There was evidence from cointegration test that a long run relationship exist between the price of oil and exchange rates in the oil-importing countries. - It was shown that increases in oil prices lead to the depreciation of real exchange rates in the oil importing countries. - There was no evidence of a long run relationship between oil prices and the exchange rates of oil exporting countries.
Aloui et al (2013)	-Copular-GARCH approach	Daily data of crude oil prices and US dollar exchange rates from 4th January 2000 to 17th February 2011	- The effect of oil price shocks on the US dollar exchange rate is symmetric and significant. - The rise in the price of oil is associated with the depreciation of the of the dollar
Wu et al (2012)	-Dynamic copula GARCH models	Daily data of WTI crude oil price and the US dollar index returns from 2nd January 1990 to 28th December 2009	- The dependence structure between crude oil prices and the US dollar index returns is low or zero.
Reboredo (2012)	-Correlations -copula models	Daily data of WTI crude oil prices and the US dollar exchange rates from 4th January 2000 to 15th June 2010	- Oil price-exchange rate dependence is generally weak - The dependency between oil prices and exchange rate rose substantially in the aftermath of the global financial crisis of 2008.

Beckmann and Czudaj (2013)	- Markov-switching - vector error correction model	Monthly data of the US dollar exchange rate index, US consumer price index, and US treasury bills rate from January 1974 to November 2011	- In nominal terms, effective depreciation of the dollar triggers an increase in oil prices. - An increase in oil prices leads to a real depreciation of the dollar
Ciner et al (2013)	-Dynamic conditional correlations - GARCH	Daily observations of the prices of bonds, equities, gold, currencies, and oil from the UK and US between January 1990 and June 2010.	- The correlation between oil prices and the US dollar became negative since 2003 - The results is consistent with the argument that oil can be used as a hedge against potential declines in the US dollar in more recent data - Correlation between oil prices and the UK pound sterling became stronger after the 2008 financial crisis.
Uddin et al (2013)	-Wavelet analysis	Monthly data from May 1983 to May 2013 and quarterly data from 1983Q3 to 2013Q1 of WTI crude oil price and the real exchange rates of Japan and the US.	- The strength of the relationship between the return on the real effective exchange rate and oil price growth differ and deviate over time. - The co-movement between changes in the real exchange rate and changes in the price of oil is concentrated on the short term frequency scale.
Reboredo and Rivera-Castro (2014)	-Wavelet multi-resolution analysis	Daily observations of WTI crude oil prices and the US dollar exchange rates from 4th January 2000 to 7th October 2011.	- Oil price changes had no effect on the exchange rate and vice versa in the period before the 2008 financial crisis. - There was evidence of contagion and negative interdependence between oil prices and exchange rates from the onset of the global financial crisis of 2008.

Turhan et al (2014)	-Consistent dynamic conditional correlation analysis	Daily observations of Brent crude oil prices and the exchange rates of G20 countries vis-à-vis the US dollar from 2nd January 2000 to 17th April 2013	- Relations between oil prices and the exchange rates of G20 countries are strongly negatively correlated. - Correlations between oil prices and exchange rates are stronger for developed countries during the 2003 Iraq invasion. - During the 2008 financial crisis, correlations were stronger for all countries
Jiang and Gu (2016)	-Multifractal detrended cross-correlation analysis	Daily data of WTI oil prices and bilateral exchange rates between the US dollar other currencies of major oil exporting and oil importing countries including Canada, Mexico, Norway, UK, Japan, Australia, and the EU from 4th January 2000 to 31st December 2014.	- The value of Hurst exponent depends on the source and size of oil price fluctuations. - When oil prices fluctuate violently, exchange rates may change correspondingly but experience inverse movements in the future - When there are slight movements of oil price, exchange rates may not show a sudden inverse movement in the future. - Hurst exponent of oil price and exchange rate is asymmetric. - When positive oil supply shock occurs, the scale of the shock may not influence the oil price-exchange rate dependence. - When negative oil supply shock occurs, the relation between oil price and exchange rate is affected by the scale of the shock.

Yang et al (2017)	-Wavelet coherence analysis	Daily data of WTI crude oil spot price and the nominal exchange rate of the US dollar from 1st January 1999 to 31st December 2014 for oil exporting countries (Brazil, Canada, Mexico, Russia) and oil importing countries (EU, India, Japan, and South Korea)	- The degree of co-movement between oil prices exchange rates differs over time. - There are strong links between oil prices and exchange rates around the year 2008 for all countries. - There is negative relationship between oil prices and exchange rates of oil exporting countries. - The relationship between oil prices and the exchange rates of oil importing countries is uncertain.

Appendix A4: Summary of the literature on oil prices and exchange rates of developing countries

Study	Methodology	Data	Main Findings
Dawson (2007)	-Cointegration -VAR -VECM	Monthly series of oil prices, trade balance, and real exchange rates of the Dominican peso from 1991 to 2005	- There was evidence of the existence of long run relationship between oil prices and the Dominican peso - VECM estimates reveal that the Dominican peso depreciates as the price of crude oil increases.
Huang and Guo (2007)	-Cointegration test -SVAR -Variance decomposition	Monthly data series of world oil prices and the Chinese RMB from 1990 to 2005	- There was no evidence of long run relationship between oil prices and the RMB. - VAR estimations show that shocks to the real prices of oil lead to a slight appreciation of the Chinese real RMB exchange rate. - Positive real oil supply shocks generate depreciation of the real exchange rate whereas positive real oil demand shocks causes an appreciation of the real exchange rate
Narayan et al (2008)	-GARCH/EGARCH	Daily price of oil prices and the Fiji dollar exchange rate from 2000 to 2006	- The study evidenced that a rise in oil prices leads to an appreciation of the Fiji dollar against the US dollar

Ghosh (2011)	-GARCH/EGARCH	Daily price data of crude oil prices and the Indian exchange rate from July 2, 2007 to November 28, 2008.	- Results from GARCH estimations show that increases in the price of oil lead to the depreciation of the Indian currency against the US dollar. - Shocks to the prices of oil have a permanent effect on the volatility of the Indian currency. - Exchange rate volatility is affected in a similar way by positive and negative oil price shocks. (i.e. oil price shocks have symmetric effect on Indian currency exchange rates)
Dogan (2012)	-Cointegration -SVAR	Monthly series of oil prices and the exchange rate of Turkey from 2001 to 2011	- Cointegration test revealed that there was no long run relationship between oil prices and the Turkish currency exchange rate. - Results from VAR estimation show that an increase in real oil price has led to a fall in the real exchange rate.
Selmi et al (2012)	-GARCH	Quarterly series of oil prices and exchange rates of Morocco and Tunisia from 1972 to 2010	- The shocks to real prices of oil have significantly negative effect on real exchange rates volatility in both Morocco and Tunisia. - There is asymmetric relationship between oil price shocks and exchange rate volatility in Morocco.
Jain and Ghosh (2013)	-ARDL cointegration -Granger causality -Generalised forecast error variance decomposition analysis.	Daily data of Indian currency exchange rate vis-à-vis the US dollar, world oil prices, and the price of precious metals (gold, silver, and platinum) from 2nd January 2009 to 30th December 2011	- There is a long run relationship among oil prices, exchange rates, and the prices of precious metals. - The rupee-US dollar exchange rate Granger causes international crude oil prices

Tiwari et al (2013)	-Wavelet framework -Granger causality	Monthly observations of WTI world oil prices and the real effective exchange rate of the Romanian currency from 1986M2 to 2009M3.	- Oil prices have a strong influence on the Romanian real effect exchange rate both in the short-time horizons and long-time horizons. - Positive shocks to oil price have a more powerful impact on the real effective exchange rate in the short term than negative shocks. - In the long run, both the positive and negative shocks in oil price returns cause real effective exchange rate fluctuations in Romania.
Tiwari et al (2013)	-Causality test -Wavelet analysis	Monthly data of the Indian currency exchange rate and the WTI crude oil price from April 1993 to December 2010.	- Causality between the rupee exchange rate and oil price is frequency dependent. - At lower time scales (high frequency), no causality is found - At higher time scales (low frequency), there is unidirectional causality from exchange rates to oil prices.
Turhan et al (2013)	-VAR	Daily time series data of crude oil prices and the exchange rates of the countries included in the J.P. Morgan Emerging Market Bond Index Plus (EMBI+) vis-à-vis the US dollar from March 1, 2003 to February 6, 2010	- Evidence from the study show that a rise in oil prices leads to a substantial appreciation of the currencies of emerging economies against the US dollar. - It was noted that the relationship between oil prices and exchange rates became more evident after the financial crisis of 2008
Kin and Courage (2014)	-GARCH	Monthly data of nominal exchange rates and nominal interest rates of South Africa, and Brent crude oil prices from 1994 to 2012	- Oil prices have a significant impact on nominal exchange rates - Increases in oil prices lead to a depreciation of the South African Rand exchange rate

Appendix A5: Summary of the related empirical literature on oil prices and stock markets for developed countries

Study	Methodology	Type of data	Main findings
Jones and Kaul (1996)	-Dividend valuation model	Quarterly series of oil prices and stock market returns of the US, UK, Canada, and Japan from 1970 to 1991	- The volatility in oil prices have a detrimental effect on output and stock returns in the US, UK, Canada, and Japan during the post-war period. - The US and Canadian stock markets react rationally to oil price shocks, whereas the UK and Japanese stock markets overreact to innovations in oil prices as measured by rational cash flow models.
Papapertrou (2001)	-Cointegration test -VAR -Impulse response functions -Variance decompositions	Monthly series of oil prices and macroeconomic variables of Greece from 1989 to 1999.	- There was no evidence of long run relationship between oil prices and the Greek economy. - Findings show that about 1.9% of real stock returns variability of the Greek stock market is attributed to oil price changes. - The VAR regressions revealed that positive oil price shocks depress real stock returns.

Al-rjoub and Am (2005)	-VAR -Impulse Response functions -Variance decompositions -Mixed Dynamic model -Granger causality	Monthly series of crude oil prices and the S&P 500 stock index returns from 1985 to 2004	- The VAR result show that oil shock negatively affects the S&P 500 stock index returns. - Granger causality test reveal that oil prices Granger cause movements in the stock market index. - Oil price shocks have an immediate negative effect on the stock market.
Kilian and Park (2007)	-VAR -Impulse response functions -Variance decompositions	Monthly observations of world crude oil production, crude oil prices, and stock returns of the US from 1973 to 2006.	- Evidence from the study show that the effect of oil price shocks to US real stock returns vary significantly, depending on the underlying causes of the oil price shock. - Oil price shocks caused by precautionary oil demand shocks account for large declines in US stock prices than oil price shocks caused by shocks to oil supply.
Driesprong et al (2008)	-OLS regressions	Monthly observations of oil prices and stock market returns of a group of 18 developed countries from 1973 to 2003.	- Result from this study shows that in all the 18 countries, the impact of oil prices on stock market returns is negative (except Hong Kong where the effect is positive and insignificant). - A fall in the price of oil in one month leads to a higher stock market return the next month.

Cong et al (2008)	-Cointegration -VAR	Monthly series of Chinese macroeconomic variables and the Brent crude oil price from 1996 to 2007	- There was no evidence of cointegration relationship between oil price and Chinese stock market returns. - From the VAR, estimations, oil price shocks do not appear to have statistically significant impact on Chinese stock market returns. - The study demonstrates that increases in oil price volatility have no significant impact on stock returns. - Oil price shocks measured in the Chinese currency yield more statistically significant effects on real stock returns than world oil price shocks expressed in US dollars
Apergis and Miller (2009)	-Cointegration test -VAR -Variance decomposition	Monthly observations of stock market returns in 8 developed countries and oil prices from 1981 to 2007	- There was no cointegration relationship between oil prices and stock market returns. - VAR result shows that international stock market returns do not react significantly to oil market shocks.
Chen (2010)	-TVTP Markov-switching model	Monthly data of the S&P 500 stock price index and the world average crude oil price index from 1957M:1 to 2009M:5	- The dynamic phases of stock returns are affected by changes in oil prices - Higher oil prices raises the probability of switching from a bull market to a bear market

Filis (2010)	-Cointegration -VECM -Multivariate VAR	Monthly time series data of stock market index, industrial production, and CPI of Greece and world oil prices from 1996:1 to 2008:6	- Findings suggest that oil price shocks have a negative and significant effect on the Greek stock market. - Oil prices and the stock market exercise a positive and significant long run effect on Greek CPI
Filis et al (2011)	-DCC-GARCH-GJR	Monthly data of oil prices and stock market indices of three oil exporting countries (Canada, Brazil, and Mexico) and three oil importing countries (US, Germany, and the Netherlands) from January 1987 to September 2009.	- Time-varying correlations of oil and stock prices do not differ for oil importing and oil exporting countries - Precautionary demand shocks cause a negative correlation between oil prices and stock market prices - Aggregate demand-side shocks cause a positive correlation between oil prices and stock market prices - Supply-side shocks do not affect the relation between oil prices and stock prices
Lee and Zeng (2011)	-Quantile regressions -OLS estimates -F-test	Monthly price series of stock market returns of G7 countries and crude oil prices from 1968 to 2009.	- Oil price shocks have negatively significant effect on stock market returns in the US, France, Japan, and the UK. - Negative shocks to oil prices increase real stock market returns when the stock market performs better.

Talukdar and Sunyaeva (2012)	-Cointegration -Impulse response -Variance decompositions	Monthly series of oil prices and stock market returns from a panel of 11 OECD countries from 1986 to 2010	- There was no evidence of long run relationship between oil prices and international stock market returns - Real stock market returns of the net oil importing countries are affected negatively in the wake of oil price shocks, compared to the net oil exporting countries. - Variability in real stock returns is greatly caused by oil price shocks when the economy is in a steady state.
Ciner et al (2013)	-Dynamic conditional correlations - GARCH	Daily observations of the prices of bonds, equities, gold, currencies, and oil from the UK and US between January 1990 and June 2010.	- There was a large positive correlation between oil prices and the UK stock market in the 1990s. The relationship switched to negative in the decade after. - Correlation between oil prices and the US stock is stronger only during crisis periods such as the Gulf war 1 and the 2008 financial crises periods.
Antonakakis and Filis (2013)	DCC-GARCH	Monthly time series data from 1988:1 to 2011:12 from the stock markets of the US, UK, Germany, Canada, and Norway and crude oil prices.	- The effects of oil price changes on stock market correlations are not constant overtime - The effect depends on whether the country is oil importing or oil exporting. - Aggregate demand and precautionary demand shocks exert a negative effect on stock market correlations whilst supply-side oil price shocks tend to have no effect

Wang et al (2013)	-SVAR -Granger causality	Monthly oil price series and stock indices in a group of 16 major oil importing and major oil exporting countries from 1999 to 2011	- Oil price shocks have a strong explanatory power on the variability of stock return in oil exporting countries than oil importing countries. - In both oil importing and oil exporting countries, oil supply uncertainties can reduce stock returns. - Oil demand uncertainty has a negative impact on stock returns.
Boldanov et al (2015)	Diag-BEKK	Daily closing prices of Brent crude oil and the stock market indices of three oil exporting countries (Canada, Russia, and Norway) and three oil importing countries (US, China, and Japan, from January 2000 to December 2014.	- Correlation between oil prices and stock market volatilities changes over time. - Correlations are nearly always positive for oil importing countries (except the 2004-2005 period) - Correlations are negative for oil exporting countries during crises periods such as wars in the Middle East. - Time-varying correlations between oil prices and stock markets are different for oil exporting countries and oil importing countries. - Correlations are positive for all markets during aggregate demand or precautionary demand oil shocks. - During supply-side events, correlations become negative.

Antonakakis et al (2017)	-Diebold-Yilmaz dynamic connectedness measure	Monthly observations of oil prices and the stock market indices of major oil exporting and oil importing countries (Canada, China, Spain, Italy, Norway, Russia, France, Germany, Japan, UK, and US) from 1995:09 to 2013:07	- The oil price-stock market connectedness varies across time. - Aggregate demand shocks, supply-side shocks, and oil-specific demand shocks are the net transmitters of oil price shocks to the stock market during specific periods - The oil price and stock market connectedness may differ not only between oil exporting countries and oil importing countries, but also within each group of countries.

Appendix A6: Summary of the related empirical literature on oil prices and emerging stock markets

Study	Methodology	Data	Main Findings
Basher and Sadorsky (2006)	-International multifactor mode	Daily closing prices of 21 emerging stock markets and international crude oil prices from December 31st 1992 to October 31st 2005	- The study evidenced that oil price risk has positive and significant effect on excess emerging stock market returns.
Nandha and Hammoudeh (2007)	-International Multifactor Model	Weekly series of oil prices measured in local currencies and US dollars, and stock index returns of 15 countries from the Asia-pacific region from May 4th 1994 to June 30th 2004	- The study demonstrates that realized stock returns are conditionally sensitive to oil prices measured in local currency than oil prices measured in US dollar. - When oil prices are measured in US dollars, stock return sensitivity becomes non-existent in all the countries except Sri Lanka.
Al-Fayoumi (2009)	-Cointegration -VECM -Variance decompositions	Monthly series of oil prices, interest rates, industrial production, and stock market indices of Tunisia, Turkey, and Jordan from 1997 to 2008.	- In all three countries, oil prices have no effect on stock market returns. - Stock market returns are rather influenced by local macroeconomic variables
Masih et al (2011)	-Cointegration -VAR -Impulse response functions -Variance decompositions	Monthly observations of oil prices and macroeconomic variables of Korea from 1988 to 2005.	- There was no evidence of cointegration relationship. - VAR result shows that oil price changes have negative effects on Korean stock market index.

Aloui et al (2012)	-International multifactor model	Daily closing price series of 25 emerging stock markets and oil prices from September 29th 1997 to November 2nd 2007.	- The study found that stock markets in developing countries are conditionally sensitive to oil risk. - There is asymmetric oil sensitivity of stock returns which is particularly significant when oil prices are rising.
Basher et al (2012)	-Cointegration -SVAR -Impulse response functions -Variance decompositions	Monthly series of global oil production, oil prices, and proxies of world economic activity, world exchange rates, emerging stock market index, and world interest rates from 1988 to 2008	- There was no evidence of cointegration relationship. - VAR result reveals that positive oil price shocks reduce emerging market stock prices. - Oil prices react positively to positive shocks to emerging stock market prices.
Ngei et al (2012)	-Cointegration -VECM	Monthly series of stock market returns of India and China, and the price of oil from 2000 to 2011	- There exist long run relationship between oil prices and the stock markets in Indian and China. - Result from VECM regressions show that there is negative causality relationship from oil prices to both the Indian and Chinese stock markets
Gupta and Modise (2013)	-SVAR -Impulse response functions -Variance decompositions	Monthly observations of crude oil prices, world oil production, and the stock index returns of the South African stock exchange from 1973 to 2011.	- Oil price shocks caused by aggregate oil demand shocks have a positive effect on the returns of the Johannesburg Stock Exchange, whilst oil price shocks due to shocks to oil supply has negative impact on stock returns.

Lin et al (2014)	-VAR -GARCH -DCC	Weekly observations of the stock market indices of Ghana and Nigeria, and Brent crude oil prices from 7th January 2000 to 31st December 2010.	- There are significant volatility spillovers and interdependence between oil prices and the stock market indices of Ghana and Nigeria. - Volatility spillover between the oil market and the stock market are stronger for Nigeria than in the case of Ghana. - There is a stronger correlation between oil market returns and the Nigerian stock market returns than the correlation between oil market returns and the Ghana stock market returns. - Volatility spillover effect only runs from oil prices to the Ghana stock market with no feedback, i.e. unidirectional relationship.
Arnold et al (2015)	-Wavelet Coherence method	Daily data of the stock market returns of South Africa, Egypt, Nigeria, Morocco, Kenya, and the West African Economic and Monetary Union and OPEC oil prices from 6th January 2003 to 3rd October 2012	- The results show that the co-movement between oil prices and the African stock markets is relatively low, except for South Africa

APPENDIX B: Exogenous crude oil price models

Appendix B1: Lag Selection Criteria for the Structural VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	38.74764	NA	1.22e-07*	-1.730648*	-1.517371*	-1.654126*
1	61.61615	38.70055*	1.38e-07	-1.621341	-0.341678	-1.162209
2	78.17888	23.78239	2.27e-07	-1.188661	1.157388	-0.346919
3	105.7653	32.53785	2.37e-07	-1.321298	2.091136	-0.096946
4	128.4252	20.91682	3.91e-07	-1.201292	3.277527	0.405670

Appendix B2: Serial correlation LM test for the Structural VAR model

Null hypothesis: No serial correlation at lag h			
Lag	LRE* stat	df	Prob.
1	23.26640	25	0.5620
2	22.64048	25	0.5985
3	18.61787	25	0.8151
4	34.14800	25	0.1048
5	27.00616	25	0.3556
6	25.49034	25	0.4352
7	24.69138	25	0.4798
8	13.38766	25	0.9714
9	41.51893	25	0.0202
10	14.12950	25	0.9594
11	11.72914	25	0.9886
12	7.731798	25	0.9996

Appendix B3: Heteroscedasticity test for the Structural VAR model

Joint test:		
Chi-sq	df	Prob.
302.0927	300	0.4552

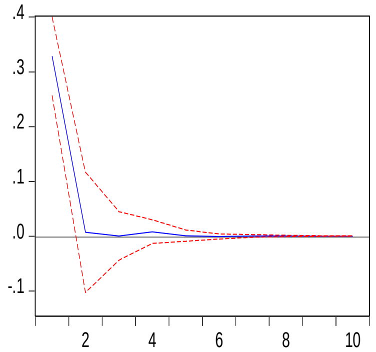
Appendix B4: Normality test For the Structural VAR model

Component	Skewness	Chi-sq	df	Prob.*
1	0.866486	5.130450	1	0.0235
2	1.974364	26.63711	1	0.0000
3	-0.080385	0.044155	1	0.8336
4	0.628100	2.695814	1	0.1006
5	0.124357	0.105675	1	0.7451
Joint		34.61320	5	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	5.677935	12.25103	1	0.0005
2	11.38487	120.1061	1	0.0000
3	2.710604	0.143073	1	0.7052
4	4.339347	3.064494	1	0.0800
5	3.850903	1.236893	1	0.2661
Joint		136.8016	5	0.0000
Component	Jarque-Bera	Df	Prob.	
1	17.38148	2	0.0002	
2	146.7433	2	0.0000	
3	0.187228	2	0.9106	
4	5.760308	2	0.0561	
5	1.342568	2	0.5111	
Joint	171.4148	10	0.0000	

Appendix B5: Orthogonalised impulse response functions for short run restrictions

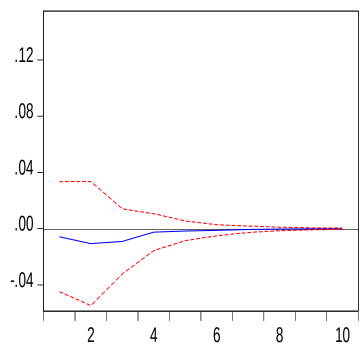
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLCOP to DLCOP



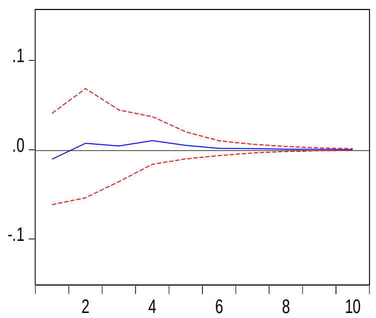
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLRNOGDP to DLCOP



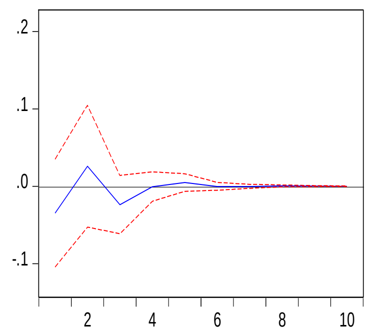
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLCPI to DLCOP



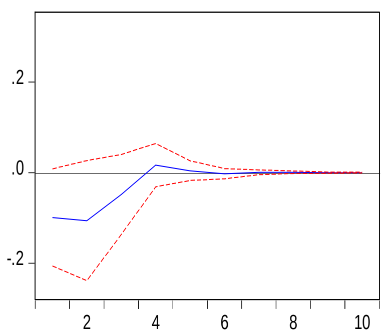
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLIR to DLCOP



Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

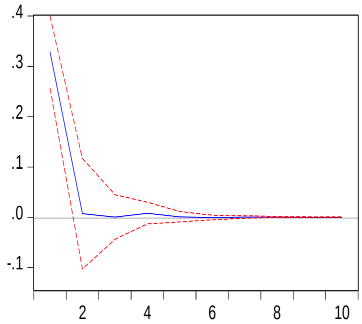
Response of DLEXR to DLCOP



Appendix B6: Orthogonalised impulse response functions for long run restrictions

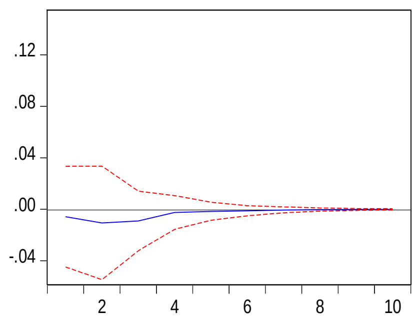
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLCOP to DLCOP



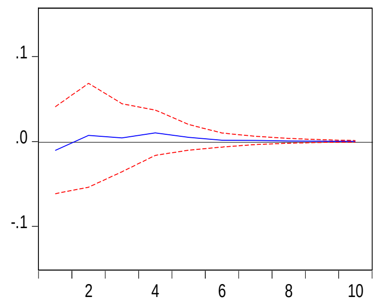
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLRNOGDP to DLCOP



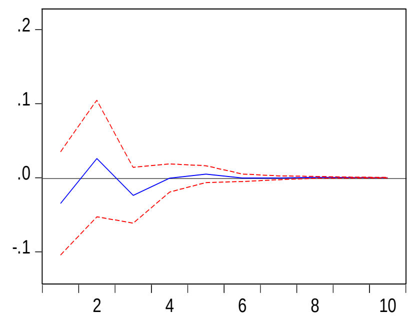
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLCPI to DLCOP



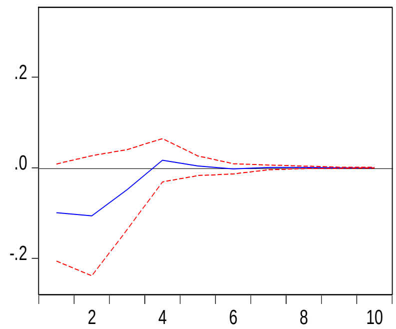
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLIR to DLCOP



Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

Response of DLEXR to DLCOP



Appendix B7: Contemporaneous Coefficients in the short run SVAR mode

	Coefficient	Std. Error	z-Statistic	Prob.
a_{21}	0.014452	0.059759	0.241841	0.8089
a_{31}	0.043682	0.059706	0.731608	0.4644
a_{41}	0.081822	0.087004	0.940444	0.3470
a_{51}	0.227565	0.138434	1.643854	0.1002
a_{32}	0.831923	0.154061	5.399960	0.0000
a_{52}	-0.765994	0.457493	-1.674329	0.0941
a_{43}	-0.761495	0.172523	-4.413872	0.0000
a_{53}	-1.109032	0.399355	-2.777062	0.0055
a_{54}	-0.256044	0.241886	-1.058529	0.2898
Log likelihood	44.58296			
LR test for over-identification:				
Chi-square(1)	0.016857		Probability	0.8967

Appendix B8: Contemporaneous Coefficients in the long run SVAR model

	Coefficient	Std. Error	z-Statistic	Prob.
f_{11}	0.349414	0.038124	9.165150	0.0000
f_{21}	-0.024025	0.032157	-0.747101	0.4550
f_{31}	0.018117	0.052899	0.342477	0.7320
f_{41}	-0.044846	0.028375	-1.580456	0.1140
f_{51}	-0.263773	0.066345	-3.975783	0.0001
f_{22}	0.207709	0.022663	9.165150	0.0000
f_{32}	-0.310975	0.040535	-7.671744	0.0000
f_{42}	-0.095156	0.025950	-3.666846	0.0002
f_{52}	-0.131361	0.058034	-2.263524	0.0236
f_{33}	0.143727	0.015682	9.165150	0.0000
f_{43}	0.059516	0.022879	2.601344	0.0093
f_{53}	0.124334	0.054575	2.278201	0.0227
f_{44}	0.142176	0.015513	9.165150	0.0000
f_{54}	0.014881	0.052837	0.281640	0.7782
f_{55}	0.342264	0.037344	9.165150	0.0000
Log likelihood	44.59139			

Appendix B9: Lag Selection Criteria for the Five-Variable VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	41.39240	NA	2.12e-06	-1.712431	-1.371187*	-1.589995*
1	59.64581	30.89039*	1.91e-06*	-1.827990*	-0.804260	-1.460685
2	70.29793	15.84162	2.60e-06	-1.553740	0.152477	-0.941564
3	75.40182	6.543447	4.97e-06	-0.994965	1.393739	-0.137919
4	98.20835	24.56088	4.14e-06	-1.344018	1.727173	-0.242101
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Appendix B10: Serial correlation LM test for the Five-Variable VAR model

Null hypothesis: No serial correlation at lag h			
Lag	LRE* stat	Df	Prob.
1	16.60302	16	0.4117
2	15.07879	16	0.5189
3	11.15324	16	0.7999
4	22.18029	16	0.1375
5	11.50498	16	0.7773
6	21.78271	16	0.1503
7	15.58739	16	0.4821
8	5.347036	16	0.9937
9	18.21490	16	0.3115
10	10.74374	16	0.8250
11	8.875063	16	0.9185
12	6.625581	16	0.9798

Appendix B11: Heteroscedasticity test for the Basic Five-Variable VAR model

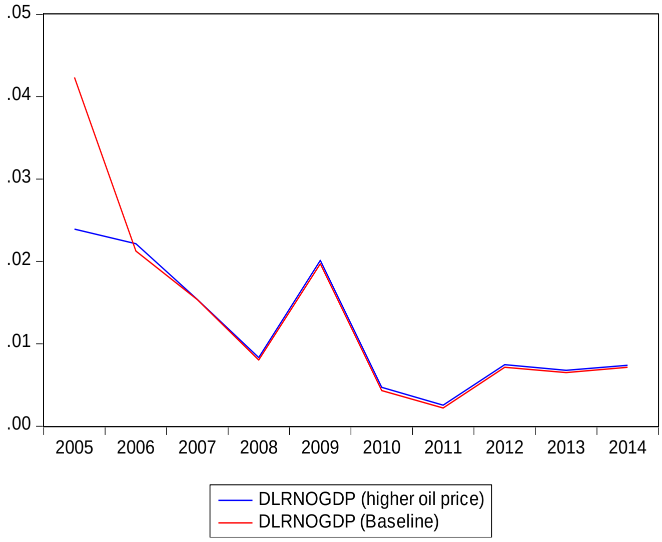
Joint test:		
Chi-sq	df	Prob.
115.9448	100	0.1315

Appendix B12: Normality test For the Basic Five-Variable VAR model

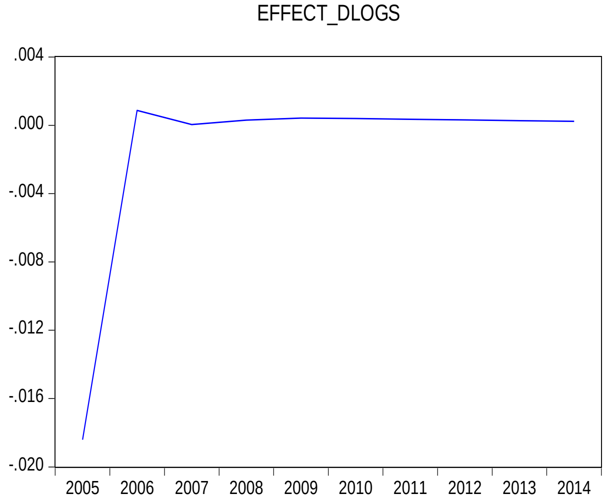
Component	Skewness	Chi-sq	Df	Prob.*
1	1.063986	7.924457	1	0.0049
2	0.327050	0.748731	1	0.3869
3	0.587627	2.417140	1	0.1200
4	0.684633	3.281052	1	0.0701
Joint		14.37138	4	0.0062
Component	Kurtosis	Chi-sq	Df	Prob.
1	8.256090	48.34635	1	0.0000
2	3.260390	0.118655	1	0.7305
3	3.546950	0.523519	1	0.4693
4	6.001385	15.76455	1	0.0001
Joint		64.75307	4	0.0000
Component	Jarque-Bera	Df	Prob.	
1	56.27080	2	0.0000	
2	0.867386	2	0.6481	
3	2.940659	2	0.2298	
4	19.04560	2	0.0001	
Joint	79.12445	8	0.0000	

Appendix B13a: Impact of Higher oil piece on non-oil GDP growth rate, 2005 to 2014 [DLCPI DLIR DLEXR DLRNOGDP]

(a)
Comparative forecast of oil price shock on growth rate

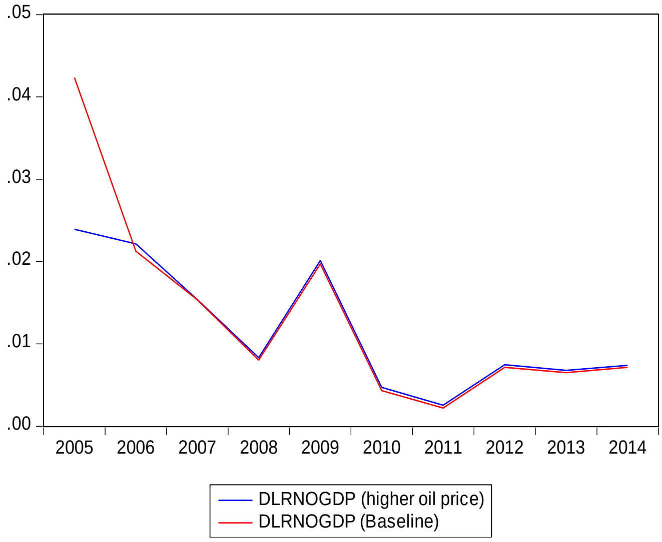


(b)
Net Effect of oil price shock on growth rate

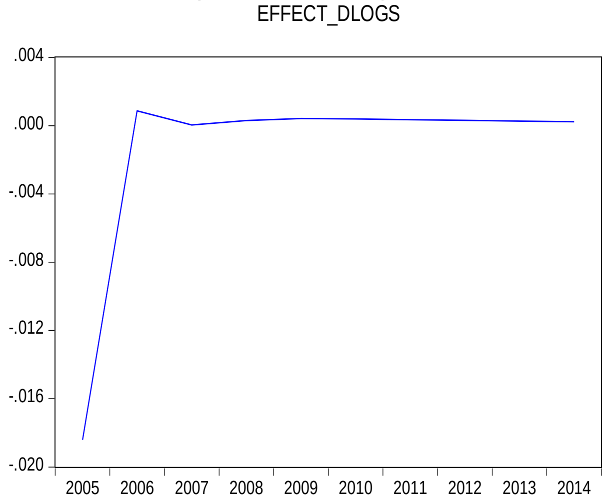


Appendix B13b: Impact of higher oil price on non-oil GDP growth rate, 2005 to 2014 [DLIR DLEXR DLRNOGDP DLCOP]

(a)
Comparative forecast of oil price shock on growth rate

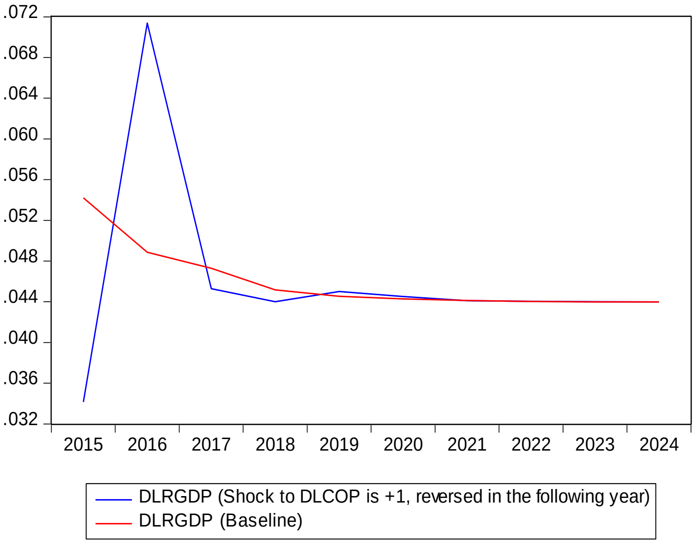


(b)
Net Effect of oil price shock on growth rate

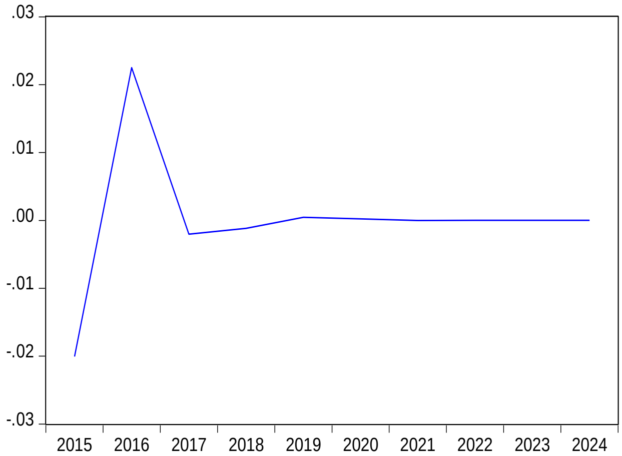


Appendix B14a: Impact of oil price shock on non-oil GDP growth rate, 2015 to 2024 [DLCPI DLIR DLEXR DLRNOGDP]

(b)
Comparative forecast of oil price shock on growth rate

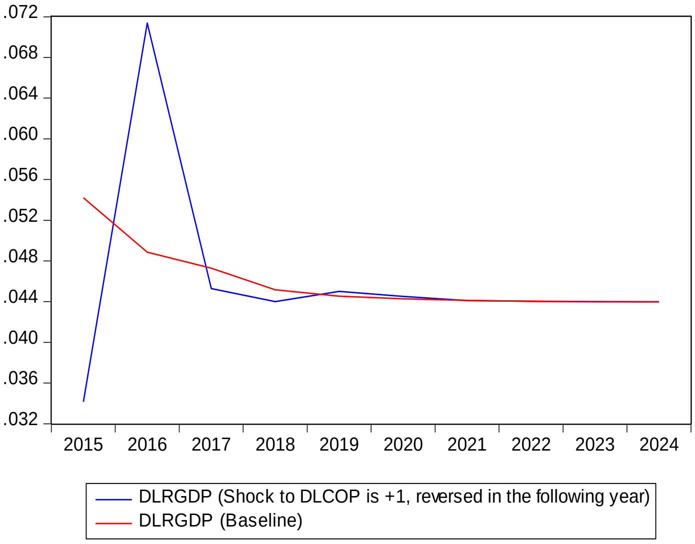


(b)
Net Effect of oil price shock on growth rate

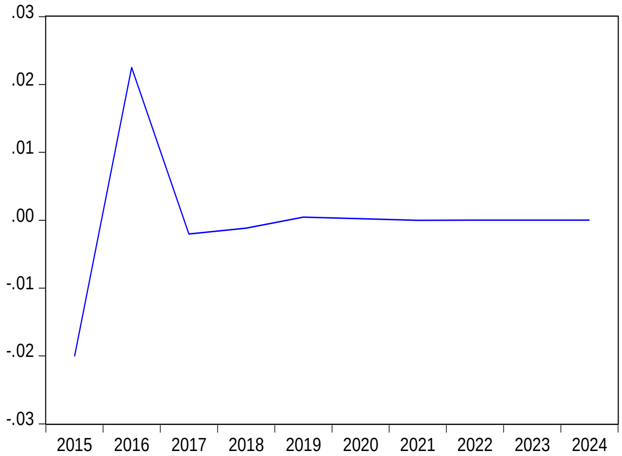


Appendix B14b: Impact of oil price shock on non-oil GDP growth rate, 2015 to 2024 [DLIR DLEX RNOGDP DLCPI]

(a)
Comparative forecast of oil price shock on growth rate



(b)
Net Effect of oil price shock on growth rate

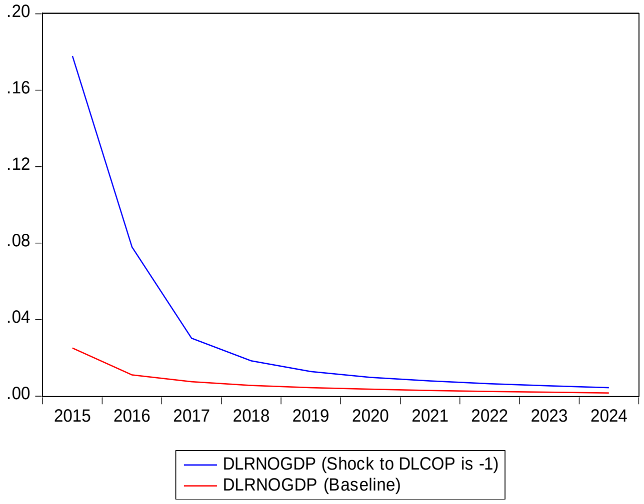


Appendix B15a: Impact of negative shock to oil price growth rate [DLCPI DLIR DLEX DLRNOGDP]

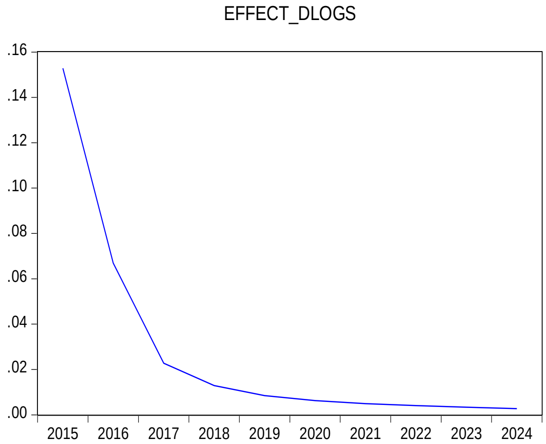
Comparative forecast of a negative oil price shock on growth rate

Net effect of a negative oil price shock on growth

(a)



(b)

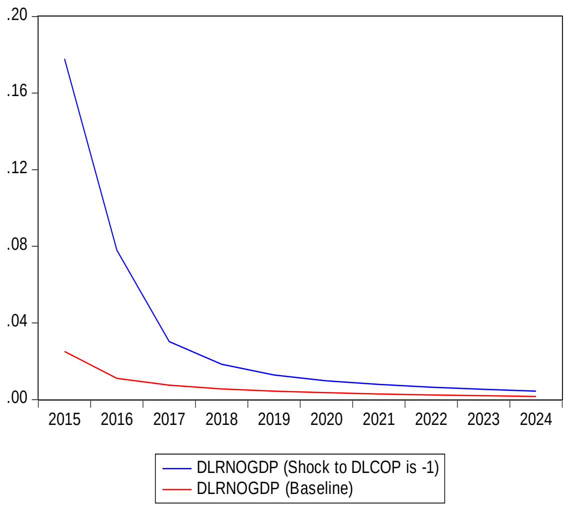


Appendix B15b: Impact of negative shock to oil price growth rate [DLIR DLEXR DLRNOGDP DLCPI]

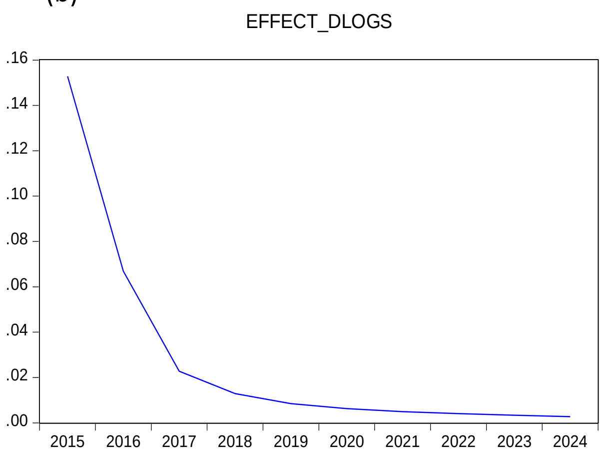
Comparative forecast of a negative oil price shock on growth rate

Net effect of a negative oil price shock on growth

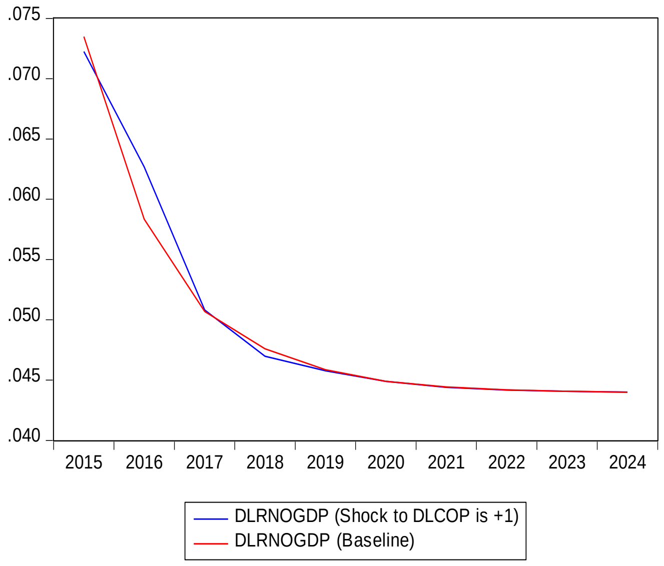
(a)

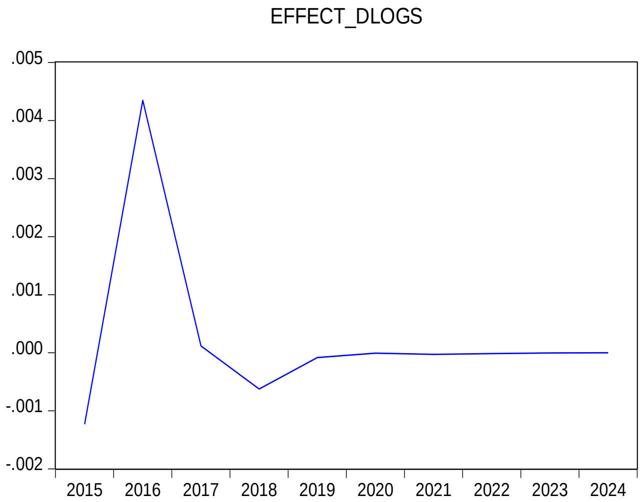


(b)

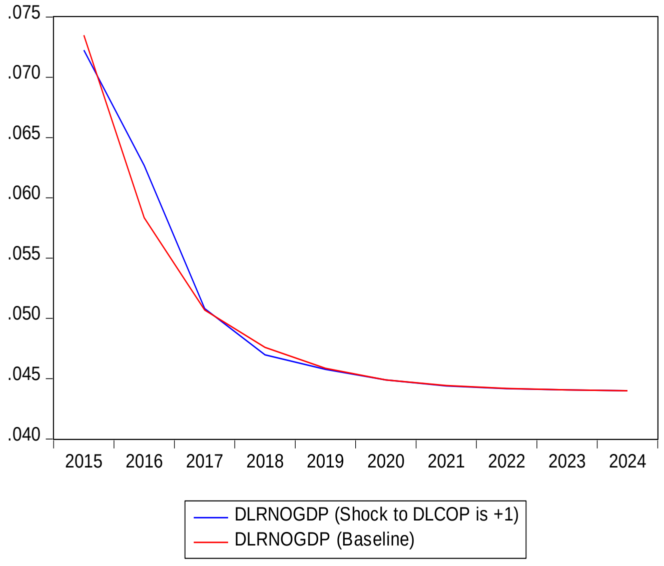


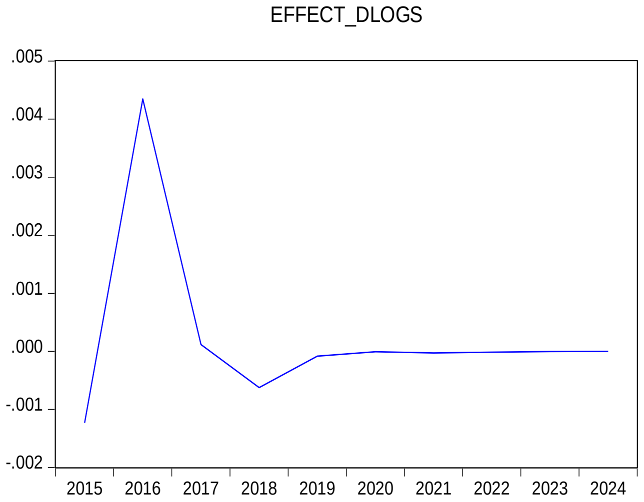
Appendix B16a: Impact of positive shock to oil price growth rate [DLCPI DLIR DLEXR DLRNOGDP]





Appendix B16b: Impact of positive shock to oil price growth rate [DLIR DLEXR DLRNOGDP DLCPI]





Appendix B17: Lag Selection Criteria for the Two-Variable Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	26.32044	NA*	0.016280	-1.280023	-1.193834	-1.249358
1	28.26438	3.580947	0.015495	-1.329704	-1.200421	-1.283706
2	30.09025	3.267338	0.014842	-1.373171	-1.200793*	-1.311840*
3	30.65516	0.981160	0.015198	-1.350271	-1.134800	-1.273608
4	32.35986	2.871072	0.014661*	-1.387361*	-1.128795	-1.295365
5	33.19660	1.365208	0.014811	-1.378768	-1.077108	-1.271440

Appendix B18: Serial correlation LM test for the Basic Two-Variable VAR model

Lag	LRE* stat	df	Prob.
1	0.356044	1	0.5507
2	0.063044	1	0.8017
3	2.006396	1	0.1566
4	1.206182	1	0.2721
5	0.234936	1	0.6279
6	0.657363	1	0.4175
7	0.017788	1	0.8939
8	0.017945	1	0.8934
9	1.109459	1	0.2922
10	1.111354	1	0.2918
11	0.755720	1	0.3847
12	0.017391	1	0.8951

Appendix B19: Normality test For the Basic Two-Variable VAR model

Component	Skewness	Chi-sq	Df	Prob.*
1	1.245551	10.60122	1	0.0011
Joint		10.60122	1	0.0011
Component	Kurtosis	Chi-sq	Df	Prob.
1	8.994748	61.39238	1	0.0000
Joint		61.39238	1	0.0000
Component	Jarque-Bera	df	Prob.	
1	71.99360	2	0.0000	
Joint	71.99360	2	0.0000	

Appendix B20: VAR results for the five-variable model with GDP

	DLRGDP	DLCPI	DLIR	DLEXR
DLRGDP(-1)	0.151645	-0.389635	0.373151	-0.491888
	(0.22231)	(0.28820)	(0.39363)	(0.62690)
	[0.68213]	[-1.35196]	[0.94797]	[-0.78463]
DLCPI(-1)	-0.163130	0.390801	0.281532	0.136231
	(0.17724)	(0.22977)	(0.31382)	(0.49980)
	[-0.92041]	[1.70087]	[0.89711]	[0.27257]
DLIR(-1)	-0.074504	-0.184192	-0.362386	-1.015672
	(0.10091)	(0.13082)	(0.17867)	(0.28456)
	[-0.73833]	[-1.40803]	[-2.02822]	[-3.56933]
DLEXR(-1)	0.044041	-0.019022	0.113570	0.274655
	(0.06112)	(0.07924)	(0.10823)	(0.17237)
	[0.72052]	[-0.24005]	[1.04936]	[1.59344]
C	0.073181	0.187686	-0.083586	0.208228
	(0.05155)	(0.06683)	(0.09128)	(0.14537)
	[1.41956]	[2.80840]	[-0.91572]	[1.43238]
DLCOP	-0.014042	-0.031735	-0.107344	-0.295523
	(0.06470)	(0.08388)	(0.11457)	(0.18246)
	[-0.21701]	[-0.37834]	[-0.93696]	[-1.61967]
R-squared	0.153082	0.307149	0.156799	0.296646
Adj. R-squared	0.035454	0.210920	0.039688	0.198958
Sum sq. resids	0.587798	0.987847	1.842829	4.674179
S.E. equation	0.127780	0.165651	0.226251	0.360331
F-statistic	1.301409	3.191848	1.338890	3.036673

Standard errors in ( ) & t-statistics in [ ]

Appendix B21: results for the two-variable equation model with GDP

	DLRGDP
DLRGDP(-1)	0.261832
	(0.16100)
	[1.62627]
DLRGDP(-2)	0.214089
	(0.16115)
	[1.32849]
C	0.024188
	(0.02188)
	[1.10535]
DLCOP	-0.007205
	(0.06302)
	[-0.11433]
R-squared	0.151218
Adj. R-squared	0.082397
Sum sq. resids	0.588993
S.E. equation	0.126169
F-statistic	2.197285

Standard errors in ( ) & t-statistics in [ ]

Appendix B22: ADF unit root test results for Engle and Granger test with GDP

Null Hypothesis: Residuals have a unit root				
Exogenous: None				
Lag Length: 0 (Automatic - based on SIC, maxlag=9)				
			t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic			-2.526538	0.0127
Test critical values:	1% level		-2.619851	
	5% level		-1.948686	
	10% level		-1.612036	
*MacKinnon (1996) one-sided p-values.				

Note: * indicate significance at 10% level
** indicate significance at 5% level
*** indicate significance at 1% level
Critical values are taken from MacKinnon (2010)

Appendix B23: Engle and Granger cointegration test output results with GDP

Null hypothesis: Series are not cointegrated					
Automatic lags specification based on Schwarz criterion (maxlag=9)					
Dependent	tau-statistic	Prob.*	z-statistic	Prob.*	
LRGDP	-3.693030	0.1673	-18.85089	0.2615	
LCOP	-5.126322	0.0086	-33.11131	0.0086	
LCPI	-5.183072	0.0075	-33.68193	0.0072	
LIR	-4.083714	0.0836	-24.28450	0.0895	
LEXR	-4.943609	0.0133	-31.81409	0.0127	

Appendix B24: Serial correlation LM test for the ARDL model

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 12 lags			
F-statistic	0.899020	Prob. F(12,23)	0.5611
Obs*R-squared	13.72946	Prob. Chi-Square(12)	0.3183

Appendix B25: Heteroscedasticity test for the ARDL model

Heteroskedasticity Test: ARCH			
F-statistic	0.222404	Prob. F(1,40)	0.6398
Obs*R-squared	0.232233	Prob. Chi-Square(1)	0.6299

Appendix B26: Results of ARDL bound test with total GDP

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	Lower bound	Upper bound
F-statistic	10.63977	10%	2.2	3.09
		5%	2.56	3.49
		1%	3.29	4.37

Appendix B27: ARDL model (1, 1, 1, 0, 0) long run results with total GDP

Dependent variable: LRNOGDP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCOP	0.413776	0.316423	1.307669	0.1995
LCPI	-0.380956	0.304341	-1.251741	0.2190
LIR	-0.865572	0.318604	-2.716767	0.0102
LEXR	0.554314	0.238939	2.319894	0.0263

APPENDIX C: Endogenous crude oil price models

Appendix C1: Lag Selection Criteria for the Five-Variable VECM Model

Lag	LogL	LR	FPE	AIC	SC	HQ
1	48.27199	NA	2.10e-07*	-1.193435	-0.127050*	-0.810825*
2	66.51543	27.13126	3.13e-07	-0.846945	1.285826	-0.081725
3	99.03139	40.01965*	2.47e-07	-1.232379*	1.966778	-0.084549
4	120.2719	20.69587	4.16e-07	-1.039584	3.225959	0.490856

Appendix C2: Serial correlation LM test for the Five-Variable VECM model

Lag	LRE* stat	Df	Prob.
1	24.20964	25	0.5073
2	22.62155	25	0.5997
3	24.98726	25	0.4631
4	25.70022	25	0.4237
5	30.09817	25	0.2206
6	25.16006	25	0.4534
7	17.94304	25	0.8448
8	17.38017	25	0.8675
9	20.94768	25	0.6955
10	18.53417	25	0.8189
11	19.81464	25	0.7565
12	11.98685	25	0.9867

Appendix C3: Heteroscedasticity test for the Five-Variable VECM model

Joint test:			
Chi-sq	df	Prob.	
561.0249	525	0.1340	

Appendix C4: Normality test For the Five-Variable VECM model

Component	Skewness	Chi-sq	df	Prob.*
1	1.395951	13.64076	1	0.0002
2	0.666165	3.106430	1	0.0780
3	-0.145286	0.147757	1	0.7007
4	0.606150	2.571927	1	0.1088
5	-0.150375	0.158288	1	0.6907
Joint		19.62516	5	0.0015
Component	Kurtosis	Chi-sq	df	Prob.
1	7.971481	43.25234	1	0.0000
2	4.039747	1.891879	1	0.1690
3	3.317377	0.176274	1	0.6746
4	3.743695	0.967895	1	0.3252
5	3.906741	1.438813	1	0.2303
Joint		47.72720	5	0.0000
Component	Jarque-Bera	df	Prob.	
1	56.89310	2	0.0000	
2	4.998309	2	0.0822	
3	0.324031	2	0.8504	
4	3.539821	2	0.1703	
5	1.597100	2	0.4500	
Joint	67.35236	10	0.0000	

Appendix C5: Lag Selection Criteria for the Two-Variable VECM Model

Lag	LogL	LR	FPE	AIC	SC	HQ
1	23.13554	NA	0.001252*	-1.007134*	-0.834756*	-0.945803*
2	25.36122	3.982786	0.001377	-0.913748	-0.568993	-0.791087
3	27.36727	3.378616	0.001535	-0.808804	-0.291671	-0.624812
4	31.25441	6.137586	0.001556	-0.802864	-0.113354	-0.557541
5	38.09319	10.07821*	0.001357	-0.952273	-0.090386	-0.645620

Appendix C6: Serial correlation LM test for the Two-Variable VECM model

Lag	LRE* stat	df	Prob.
1	6.417581	4	0.1701
2	2.064714	4	0.7239
3	4.816452	4	0.3067
4	3.382609	4	0.4960
5	6.482322	4	0.1659
6	6.394563	4	0.1716
7	2.033407	4	0.7296
8	1.683098	4	0.7938
9	2.103865	4	0.7167
10	0.710776	4	0.9500
11	2.586370	4	0.6292
12	1.875395	4	0.7587

Appendix C7: Heteroscedasticity test for the Two-Variable VECM model

Joint test:		
Chi-sq	df	Prob.
26.57117	27	0.4871

Appendix C8: Normality test For the Two-Variable VECM model

Component	Skewness	Chi-sq	Df	Prob.*
1	1.042825	7.612390	1	0.0058
2	0.183755	0.236361	1	0.6268
Joint		7.848751	2	0.0198
Component	Kurtosis	Chi-sq	Df	Prob.
1	8.819737	59.27135	1	0.0000
2	3.476658	0.397605	1	0.5283
Joint		59.66895	2	0.0000
Component	Jarque-Bera	Df	Prob.	
1	66.88374	2	0.0000	
2	0.633967	2	0.7283	
Joint	67.51771	4	0.0000	

Appendix C9: VECM results for the five-variable model with GDP

	D(LRGDP)	D(LCOP)	D(LCPI)	D(LIR)	D(LEXR)
ECT	0.020835	0.135063	-0.021757	-0.052801	0.111322
	(0.01959)	(0.04599)	(0.02563)	(0.03424)	(0.05200)
	[1.06377]	[2.93647]	[-0.84877]	[-1.54218]	[2.14064]
D(LRGDP(-1))	0.122322	0.128966	-0.371740	0.403117	-0.703820
	(0.22208)	(0.52152)	(0.29065)	(0.38821)	(0.58966)
	[0.55079]	[0.24729]	[-1.27901]	[1.03839]	[-1.19360]
D(LCOP(-1))	0.028920	0.349551	-0.053104	-0.046135	-0.053343
	(0.08315)	(0.19525)	(0.10882)	(0.14534)	(0.22076)
	[0.34782]	[1.79024]	[-0.48802]	[-0.31742]	[-0.24163]
D(LCPI(-1))	-0.242031	-0.224625	0.462763	0.438562	-0.323968
	(0.19049)	(0.44733)	(0.24930)	(0.33298)	(0.50577)
	[-1.27059]	[-0.50215]	[1.85628]	[1.31707]	[-0.64055]
D(LIR(-1))	0.026399	0.393799	-0.279833	-0.579933	-0.438645
	(0.13658)	(0.32073)	(0.17875)	(0.23875)	(0.36264)
	[0.19329]	[1.22780]	[-1.56553]	[-2.42904]	[-1.20959]
D(LEXR(-1))	0.059941	0.041914	-0.034938	0.087071	0.351041
	(0.06352)	(0.14918)	(0.08314)	(0.11105)	(0.16867)
	[0.94359]	[0.28097]	[-0.42025]	[0.78410]	[2.08126]
C	0.086031	0.093090	0.175252	-0.121669	0.290237
	(0.05263)	(0.12360)	(0.06888)	(0.09201)	(0.13975)
	[1.63455]	[0.75316]	[2.54422]	[-1.32240]	[2.07685]
R-squared	0.182620	0.232114	0.318508	0.206823	0.398197
Adj. R-squared	0.042497	0.100476	0.201681	0.070850	0.295031
Sum sq. resids	0.567298	3.128448	0.971652	1.733500	3.999316
S.E. equation	0.127313	0.298972	0.166618	0.222550	0.338033
F-statistic	1.303286	1.763276	2.726316	1.521059	3.859769

Standard errors in ( ) & t-statistics in [ ]

Appendix C10: VECM results for the two-variable model with GDP

	D(LRGDP)	D(LCOP)
ECT	-0.020986	0.181955
	(0.02157)	(0.04769)
	[-0.97291]	[3.81509]
D(LRGDP(-1))	0.327296	0.174112
	(0.15087)	(0.33359)
	[2.16934]	[0.52194]
D(LCOP(-1))	-0.024578	0.003365
	(0.06253)	(0.13826)
	[-0.39305]	[0.02434]
C	0.032424	0.079598
	(0.02127)	(0.04703)
	[1.52418]	[1.69232]
R-squared	0.134957	0.279591
Adj. R-squared	0.066665	0.222717
Sum sq. resids	0.600377	2.935020
S.E. equation	0.125696	0.277916
F-statistic	1.976158	4.915938

Standard errors in ( ) & t-statistics in [ ]

APPENDIX D: Domestic Oil Price Models

Appendix D1: Lag Selection Criteria for the Five-Variable VECM (Diesel Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	98.63191	NA	4.36e-09*	-5.078063*	-3.899359*	-4.708908*
2	109.3067	13.98760	1.33e-08	-4.090114	-1.732708	-3.351804
3	130.7242	20.67897	2.56e-08	-3.843046	-0.306936	-2.735580
4	166.6633	22.30704	3.35e-08	-4.597467	0.117346	-3.120847

Appendix D2: Lag Selection Criteria for the Five-Variable VECM (Petrol Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	90.74106	NA	7.52e-09*	-4.533866	-3.355163*	-4.164711*
2	102.8685	15.89111	2.08e-08	-3.646102	-1.288696	-2.907792
3	121.1283	17.63015	4.97e-08	-3.181260	0.354850	-2.073795
4	170.8495	30.86147	2.51e-08	-4.886175*	-0.171362	-3.409554

Appendix D3: Lag Selection Criteria for the Five-Variable VECM (Kerosene Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	84.93065	NA	1.12e-08*	-4.133149*	-2.954445*	-3.763993*
2	95.23837	13.50666	3.52e-08	-3.119887	-0.762481	-2.381577
3	115.8756	19.92561	7.14e-08	-2.819007	0.717103	-1.711541
4	151.0497	21.83223	9.85e-08	-3.520672	1.194141	-2.044051

Appendix D4: Serial correlation LM test for the Five-Variable VECM (Diesel Price Model)

Lag	LRE* stat	df	Prob.
1	7.344306	25	0.9998
2	14.11904	25	0.9596
3	20.21407	25	0.7355
4	24.37534	25	0.4978
5	22.79415	25	0.5896
6	19.74674	25	0.7600
7	33.92606	25	0.1095
8	17.89554	25	0.8468
9	32.76094	25	0.1372
10	14.18273	25	0.9585
11	23.51753	25	0.5474
12	22.65949	25	0.5974

Appendix D5: Serial correlation LM test for the Five-Variable VECM (Petrol Price Model)

Lag	LRE* stat	df	Prob.
1	13.86247	25	0.9641
2	19.33068	25	0.7810
3	17.41368	25	0.8662
4	21.65994	25	0.6553
5	21.21957	25	0.6803
6	18.57885	25	0.8169
7	36.95754	25	0.0583
8	24.04649	25	0.5167
9	27.79184	25	0.3175
10	14.30949	25	0.9561
11	28.90333	25	0.2680
12	23.78216	25	0.5320

Appendix D6: Serial correlation LM test for the Five-Variable VECM (Kerosene Price Model)

Lag	LRE* stat	df	Prob.
1	14.66575	25	0.9489
2	15.06875	25	0.9398
3	21.40249	25	0.6700
4	25.57235	25	0.4307
5	26.50088	25	0.3813
6	18.44025	25	0.8231
7	23.60199	25	0.5425
8	30.05252	25	0.2223
9	41.22759	25	0.0217
10	16.26500	25	0.9067
11	21.20330	25	0.6812
12	31.17829	25	0.1832

Appendix D7: Heteroscedasticity test for the Five-Variable VECM (Diesel Price Model)

Joint test:		
Chi-sq	df	Prob.
193.7444	180	0.2291

Appendix D8: Heteroscedasticity test for the Five-Variable VECM (Petrol Price Model)

Joint test:		
Chi-sq	df	Prob.
207.5637	210	0.5346

Appendix D9: Heteroscedasticity test for the Five-Variable VECM (Kerosene Price Model)

Joint test:		
Chi-sq	df	Prob.
226.5443	240	0.7242

Appendix D10: Normality test For the Five-Variable VECM (Diesel Price Model)

Component	Skewness	Chi-sq	df	Prob.*
1	3.271900	57.09510	1	0.0000
2	0.290661	0.450579	1	0.5021
3	0.604606	1.949594	1	0.1626
4	0.180873	0.174480	1	0.6762
5	0.429590	0.984254	1	0.3212
Joint		60.65400	5	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	16.06092	227.4503	1	0.0000
2	3.524127	0.366278	1	0.5450
3	2.804922	0.050741	1	0.8218
4	2.893513	0.015119	1	0.9021
5	3.688098	0.631306	1	0.4269
Joint		228.5138	5	0.0000
Component	Jarque-Bera	Df	Prob.	
1	284.5454	2	0.0000	
2	0.816857	2	0.6647	
3	2.000334	2	0.3678	
4	0.189599	2	0.9096	
5	1.615559	2	0.4458	
Joint	289.1678	10	0.0000	

Appendix D11: Normality test For the Five-Variable VECM (Petrol Price Model)

Component	Skewness	Chi-sq	df	Prob.*
1	3.146701	52.80920	1	0.0000
2	0.608667	1.975871	1	0.1598
3	-0.293615	0.459785	1	0.4977
4	-0.214189	0.244676	1	0.6208
5	0.420001	0.940806	1	0.3321
Joint		56.43034	5	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	15.37202	204.0892	1	0.0000
2	2.840774	0.033804	1	0.8541
3	3.467242	0.291087	1	0.5895
4	3.107460	0.015397	1	0.9012
5	3.748872	0.747746	1	0.3872
Joint		205.1772	5	0.0000
Component	Jarque-Bera	Df	Prob.	
1	256.8984	2	0.0000	
2	2.009675	2	0.3661	
3	0.750872	2	0.6870	
4	0.260073	2	0.8781	
5	1.688552	2	0.4299	
Joint	261.6076	10	0.0000	

Appendix D12: Normality test For the Five-Variable VECM (Kerosene Price Model)

Component	Skewness	Chi-sq	Df	Prob.*
1	2.539952	34.40723	1	0.0000
2	-1.035891	5.723045	1	0.0167
3	0.159059	0.134933	1	0.7134
4	1.267678	8.570713	1	0.0034
5	0.283912	0.429898	1	0.5120
Joint		49.26582	5	0.0000
Component	Kurtosis	Chi-sq	Df	Prob.
1	12.33669	116.2316	1	0.0000
2	3.695699	0.645330	1	0.4218
3	4.449831	2.802679	1	0.0941
4	5.519344	8.462792	1	0.0036
5	2.748650	0.084236	1	0.7716
Joint		128.2266	5	0.0000
Component	Jarque-Bera	Df	Prob.	
1	150.6388	2	0.0000	
2	6.368375	2	0.0414	
3	2.937611	2	0.2302	
4	17.03350	2	0.0002	
5	0.514133	2	0.7733	
Joint	177.4924	10	0.0000	

Appendix D13: Lag Selection Criteria for the Two-Variable VECM (Diesel Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	25.40622	NA	0.000784*	-1.476291*	-1.287698*	-1.417226*
2	29.12046	6.403867	0.000802	-1.456583	-1.079398	-1.338454
3	32.72312	5.714564	0.000831	-1.429181	-0.863403	-1.251986
4	36.34710	5.248526	0.000868	-1.403248	-0.648878	-1.166989

Appendix D14: Lag Selection Criteria for the Two-Variable VECM (Petrol Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	22.81238	NA	0.000937*	-1.297406*	-1.108813*	-1.238341*
2	25.69145	4.963915	0.001016	-1.220100	-0.842915	-1.101970
3	29.27204	5.679560	0.001054	-1.191175	-0.625398	-1.013981
4	33.97580	6.812333	0.001022	-1.239710	-0.485340	-1.003451

Appendix D15: Lag Selection Criteria for the Two-Variable VECM (Kerosene Price Model)

Lag	LogL	LR	FPE	AIC	SC	HQ
1	15.68385	NA	0.001532*	-0.805782*	-0.617190*	-0.746718*
2	18.91467	5.570383	0.001621	-0.752736	-0.375551	-0.634606
3	22.17737	5.175315	0.001720	-0.701887	-0.136110	-0.524693
4	24.35122	3.148346	0.001985	-0.575946	0.178424	-0.339687

Appendix D16: Serial correlation LM test for the Two-Variable VECM (Diesel Price Model)

Lag	LRE* stat	df	Prob.
1	5.052048	4	0.2820
2	0.579553	4	0.9653
3	6.177299	4	0.1863
4	0.864951	4	0.9295
5	3.929669	4	0.4156
6	4.382289	4	0.3567
7	0.266295	4	0.9919
8	5.004541	4	0.2868
9	4.479509	4	0.3450
10	3.573993	4	0.4667
11	14.44326	4	0.0060
12	0.804845	4	0.9378

Appendix D17: Serial correlation LM test for the Two-Variable VECM (Petrol Price Model)

Lag	LRE* stat	df	Prob.
1	0.190776	4	0.9957
2	1.693333	4	0.7919
3	5.569648	4	0.2337
4	3.267490	4	0.5141
5	2.092267	4	0.7188
6	2.637172	4	0.6203
7	2.764861	4	0.5979
8	3.960588	4	0.4114
9	3.813511	4	0.4318
10	5.355071	4	0.2528
11	14.35483	4	0.0062
12	1.607197	4	0.8075

Appendix D18: Serial correlation LM test for the Two-Variable VECM (Kerosene Price Model)

Lag	LRE* stat	df	Prob.
1	2.826676	4	0.5872
2	0.520718	4	0.9715
3	6.647911	4	0.1557
4	0.917534	4	0.9220
5	5.965986	4	0.2017
6	2.035123	4	0.7293
7	1.870357	4	0.7596
8	7.993422	4	0.0918
9	4.032257	4	0.4017
10	5.569633	4	0.2337
11	16.49746	4	0.0024
12	0.654742	4	0.9568

Appendix D19: Heteroscedasticity test for the Two-Variable VECM (Diesel Price Model)

Joint test:		
Chi-sq	df	Prob.
23.09701	18	0.1869

Appendix D20: Heteroscedasticity test for the Two-Variable VECM (Petrol Price Model)

Joint test:		
Chi-sq	df	Prob.
9.946819	18	0.9336

Appendix D21: Heteroscedasticity test for the Two-Variable VECM (Kerosene Price Model)

Joint test:		
Chi-sq	df	Prob.
10.86976	18	0.8998

Appendix D22: Normality test For the Two-Variable VECM (Diesel Price Model)

Component	Skewness	Chi-sq	df	Prob.*
1	3.184887	54.09870	1	0.0000
2	0.356576	0.678114	1	0.4102
Joint		54.77681	2	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	15.89348	221.6557	1	0.0000
2	3.072337	0.006977	1	0.9334
Joint		221.6627	2	0.0000
Component	Jarque-Bera	df	Prob.	
1	275.7544	2	0.0000	
2	0.685091	2	0.7100	
Joint	276.4395	4	0.0000	

Appendix D23: Normality test For the Two-Variable VECM (Petrol Price Model)

Component	Skewness	Chi-sq	df	Prob.*
1	3.083244	50.70076	1	0.0000
2	0.093410	0.046536	1	0.8292
Joint		50.74729	2	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	15.27283	200.8299	1	0.0000
2	2.490343	0.346334	1	0.5562
Joint		201.1762	2	0.0000
Component	Jarque-Bera	df	Prob.	
1	251.5306	2	0.0000	
2	0.392870	2	0.8217	
Joint	251.9235	4	0.0000	

Appendix D24: Normality test For the Two-Variable VECM (Kerosene Price Model)

Component	Skewness	Chi-sq	df	Prob.*
1	3.087510	50.84118	1	0.0000
2	0.609436	1.980863	1	0.1593
Joint		52.82204	2	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	15.42154	205.7263	1	0.0000
2	3.482838	0.310844	1	0.5772
Joint		206.0372	2	0.0000
Component	Jarque-Bera	df	Prob.	
1	256.5675	2	0.0000	
2	2.291707	2	0.3180	
Joint	258.8592	4	0.0000	

Appendix D25: VECM results of diesel price effect in the five-variable model with GDP

	D(LRGDP)	D(LDIESEL)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.048308	-0.024011	0.057124	0.058078	0.040714
	(0.01641)	(0.03509)	(0.01057)	(0.03260)	(0.03156)
	[-2.94436]	[-0.68430]	[5.40671]	[1.78130]	[1.28989]
D(LRGDP(-1))	-0.175943	-0.100323	0.184956	0.594113	0.027358
	(0.20112)	(0.43011)	(0.12951)	(0.39967)	(0.38691)
	[-0.87482]	[-0.23325]	[1.42811]	[1.48653]	[0.07071]
D(LDIESEL(-1))	0.098081	-0.126449	-0.156872	-0.080008	-0.058958
	(0.08640)	(0.18478)	(0.05564)	(0.17170)	(0.16622)
	[1.13513]	[-0.68430]	[-2.81939]	[-0.46597]	[-0.35469]
D(LCPI(-1))	-0.243387	0.119638	0.285356	-0.461769	-0.481633
	(0.22508)	(0.48135)	(0.14494)	(0.44728)	(0.43300)
	[-1.08134]	[0.24855]	[1.96880]	[-1.03240]	[-1.11231]
D(LIR(-1))	0.031025	0.083305	-0.018647	-0.103249	-0.055882
	(0.09724)	(0.20796)	(0.06262)	(0.19324)	(0.18707)
	[0.31905]	[0.40058]	[-0.29780]	[-0.53431]	[-0.29872]
D(LEXR(-1))	-0.042979	0.305460	0.108772	0.357782	0.336127
	(0.06745)	(0.14425)	(0.04344)	(0.13404)	(0.12977)
	[-0.63717]	[2.11750]	[2.50418]	[2.66916]	[2.59027]
C	0.133373	0.206234	0.134327	-0.013625	0.244883
	(0.04534)	(0.09697)	(0.02920)	(0.09011)	(0.08723)
	[2.94143]	[2.12679]	[4.60049]	[-0.15121]	[2.80734]
R-squared	0.328359	0.409907	0.696375	0.300368	0.245635
Adj. R-squared	0.167165	0.268284	0.623505	0.132457	0.064588
Sum sq. resids	0.211917	0.969221	0.087876	0.836855	0.784296
S.E. equation	0.092069	0.196898	0.059288	0.182960	0.177121
F-statistic	2.037044	2.894364	9.556413	1.788847	1.356744

Standard errors in ( ) & t-statistics in [ ]

Appendix D26: VECM results of petrol price effect in the five-variable model with GDP

	D(LRGDP)	D(LPETROL)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.071470	-0.067452	0.075992	0.078969	0.051203
	(0.02208)	(0.05614)	(0.01687)	(0.04536)	(0.04405)
	[-3.23732]	[-1.20147]	[4.50565]	[1.74090]	[1.16250]
D(LRGDP(-1))	-0.161705	-0.313466	0.108624	0.574543	-0.002124
	(0.18838)	(0.47905)	(0.14392)	(0.38706)	(0.37584)
	[-0.85839]	[-0.65435]	[0.75477]	[1.48437]	[-0.00565]
D(LPETROL(-1))	0.118960	0.049703	-0.063287	-0.064965	-0.014564
	(0.07964)	(0.20252)	(0.06084)	(0.16363)	(0.15889)
	[1.49372]	[0.24542]	[-1.04018]	[-0.39701]	[-0.09166]
D(LCPI(-1))	-0.207001	0.026422	0.170864	-0.498383	-0.521949
	(0.20442)	(0.51983)	(0.15617)	(0.42002)	(0.40783)
	[-1.01263]	[0.05083]	[1.09409]	[-1.18658]	[-1.27981]
D(LIR(-1))	0.062422	0.228209	-0.036898	-0.124890	-0.062557
	(0.09650)	(0.24539)	(0.07372)	(0.19827)	(0.19252)
	[0.64688]	[0.92998]	[-0.50052]	[-0.62989]	[-0.32494]
D(LEXR(-1))	-0.077690	0.014392	0.123916	0.380103	0.341550
	(0.06890)	(0.17521)	(0.05264)	(0.14157)	(0.13746)
	[-1.12758]	[0.08214]	[2.35416]	[2.68497]	[2.48469]
C	0.128843	0.261233	0.131869	-0.015556	0.240802
	(0.04532)	(0.11525)	(0.03462)	(0.09312)	(0.09042)
	[2.84286]	[2.26663]	[3.80862]	[-0.16705]	[2.66314]
R-squared	0.366390	0.140485	0.596851	0.294402	0.234619
Adj. R-squared	0.214323	-0.065799	0.500095	0.125058	0.050927
Sum sq. resids	0.199918	1.292818	0.116680	0.843992	0.795750
S.E. equation	0.089424	0.227404	0.068317	0.183738	0.178410
F-statistic	2.409404	0.681028	6.168623	1.738489	1.277245

Standard errors in ( ) & t-statistics in [ ]

Appendix D27: VECM results of kerosene price effect in the five-variable model with GDP

	D(LRGDP)	D(LKEROSENE)	D(LCPI)	D(LIR)	D(LEXR)
ECT	-0.085492	-0.004421	0.096743	0.083891	0.040760
	(0.02785)	(0.08525)	(0.01896)	(0.05626)	(0.05453)
	[-3.07000]	[-0.05186]	[5.10119]	[1.49103]	[0.74744]
D(LRGDP(-1))	-0.148406	-0.070524	0.129098	0.560905	-0.038523
	(0.19438)	(0.59507)	(0.13238)	(0.39273)	(0.38064)
	[-0.76350]	[-0.11851]	[0.97524]	[1.42823]	[-0.10121]
D(LKEROSENE(-1))	0.029688	-0.137711	-0.099833	-0.048732	0.039809
	(0.06726)	(0.20590)	(0.04580)	(0.13589)	(0.13170)
	[0.44141]	[-0.66882]	[-2.17960]	[-0.35862]	[0.30226]
D(LCPI(-1))	-0.191662	-0.114004	0.220555	-0.475633	-0.534156
	(0.21128)	(0.64681)	(0.14389)	(0.42687)	(0.41374)
	[-0.90715]	[-0.17625]	[1.53285]	[-1.11422]	[-1.29106]
D(LIR(-1))	0.030013	0.089416	-0.020463	-0.087251	-0.020691
	(0.09730)	(0.29786)	(0.06626)	(0.19658)	(0.19053)
	[0.30847]	[0.30019]	[-0.30883]	[-0.44384]	[-0.10860]
D(LEXR(-1))	-0.036801	0.324353	0.118081	0.347828	0.295636
	(0.07042)	(0.21558)	(0.04796)	(0.14228)	(0.13790)
	[-0.52259]	[1.50454]	[2.46222]	[2.44471]	[2.14387]
C	0.138579	0.258635	0.134389	-0.014025	0.242002
	(0.04596)	(0.14071)	(0.03130)	(0.09287)	(0.09001)
	[3.01500]	[1.83803]	[4.29331]	[-0.15102]	[2.68868]
R-squared	0.325641	0.173497	0.659034	0.273849	0.215208
Adj. R-squared	0.163794	-0.024863	0.577203	0.099573	0.026858
Sum sq. resids	0.212775	1.994176	0.098683	0.868575	0.815931
S.E. equation	0.092255	0.282431	0.062828	0.186395	0.180658
F-statistic	2.012036	0.874655	8.053526	1.571354	1.142597

Standard errors in ( ) & t-statistics in [ ]

Appendix D28: VECM results of diesel price effect in the two-variable model with GDP

	D(LRGDP)	D(LDIESEL)
ECT	-0.025056	0.126596
	(0.02290)	(0.04500)
	[-1.09409]	[2.81342]
D(LRGDP(-1))	0.081210	-0.323391
	(0.18404)	(0.36160)
	[0.44126]	[-0.89433]
D(LDIESEL(-1))	0.047408	-0.060459
	(0.08877)	(0.17441)
	[0.53406]	[-0.34664]
C	0.063552	0.320894
	(0.03499)	(0.06874)
	[1.81650]	[4.66819]
R-squared	0.057051	0.300723
Adj. R-squared	-0.043979	0.225800
Sum sq. resids	0.297521	1.148554
S.E. equation	0.103081	0.202533
F-statistic	0.564693	4.013782

Standard errors in ( ) & t-statistics in [ ]

Appendix D29: VECM results of petrol price effect in the two-variable model with GDP

	D(LRGDP)	D(LPETROL)
ECT	-0.016885	0.069208
	(0.01354)	(0.02695)
	[-1.24682]	[2.56804]
D(LRGDP(-1))	0.086745	-0.174754
	(0.18314)	(0.36445)
	[0.47365]	[-0.47950]
D(LPETROL(-1))	0.072084	-0.085476
	(0.08631)	(0.17175)
	[0.83519]	[-0.49767]
C	0.056312	0.303651
	(0.03483)	(0.06932)
	[1.61655]	[4.38048]
R-squared	0.071829	0.228986
Adj. R-squared	-0.027618	0.146377
Sum sq. resids	0.292858	1.159702
S.E. equation	0.102270	0.203514
F-statistic	0.722281	2.771930

Standard errors in ( ) & t-statistics in [ ]

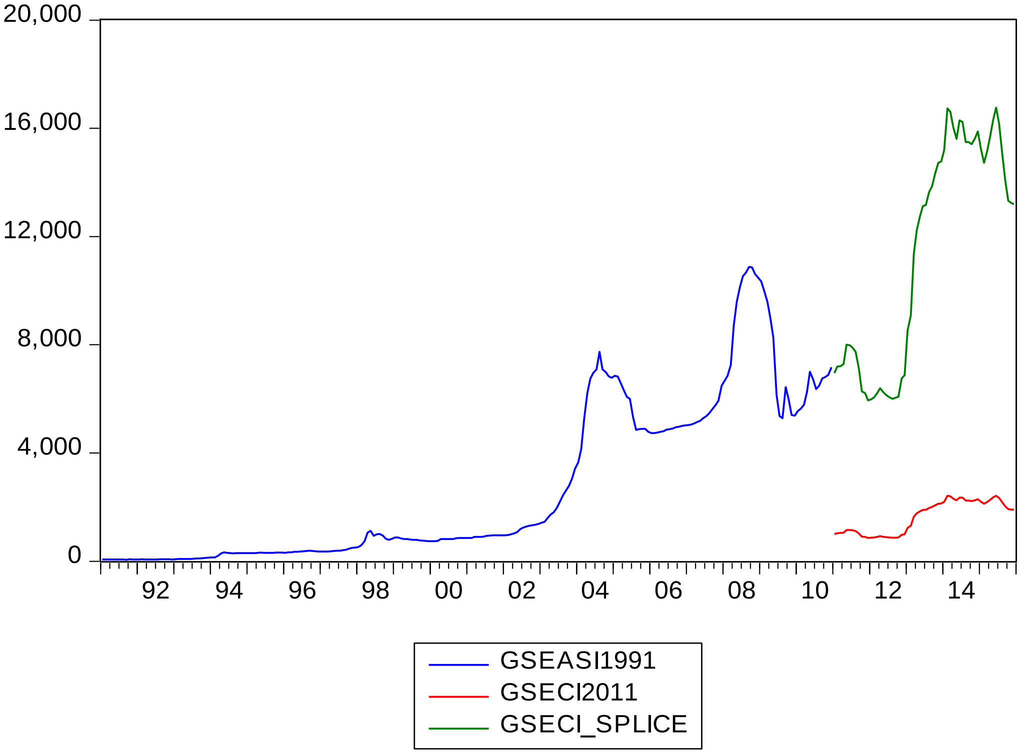
Appendix D30: VECM results of kerosene price effects in the two-variable model with GDP

	D(LRGDP)	D(LKEROSENE)
ECT	-0.021667	0.144101
	(0.02468)	(0.06335)
	[-0.87801]	[2.27467]
D(LRGDP(-1))	0.093310	-0.216346
	(0.18418)	(0.47281)
	[0.50664]	[-0.45758]
D(LKEROSENE(-1))	-0.008203	-0.040748
	(0.06406)	(0.16445)
	[-0.12806]	[-0.24779]
C	0.079641	0.311453
	(0.03273)	(0.08402)
	[2.43349]	[3.70707]
R-squared	0.050368	0.181590
Adj. R-squared	-0.051379	0.093903
Sum sq. resids	0.299629	1.974650
S.E. equation	0.103446	0.265562
F-statistic	0.495032	2.070893

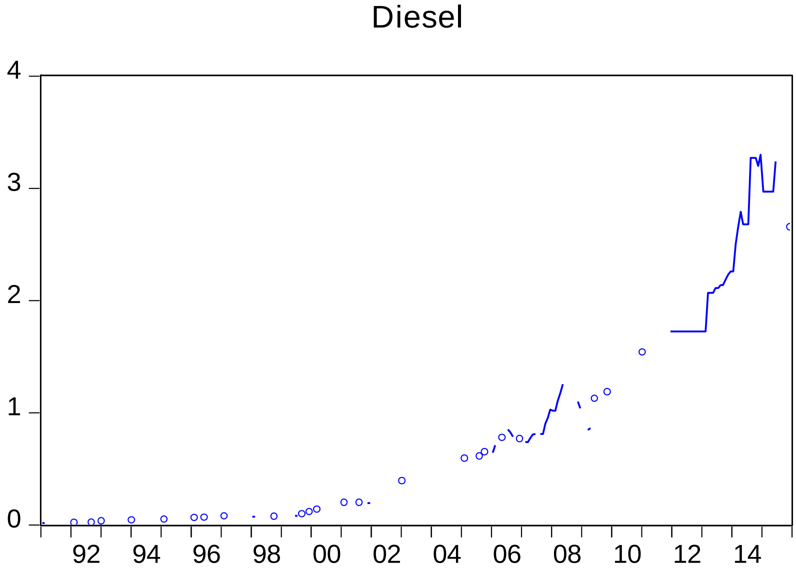
Standard errors in ( ) & t-statistics in [ ]

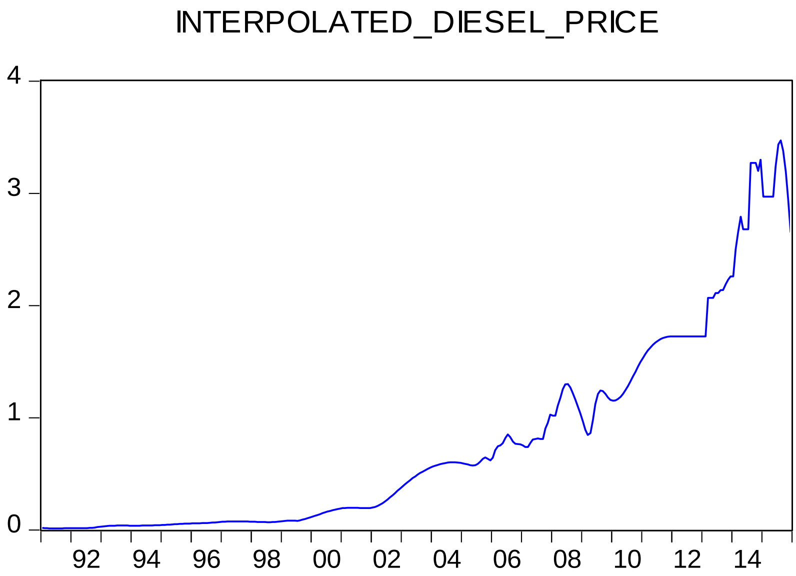
APPENDIX E: Interpolated Data

Appendix E1: Spliced Series of the Ghana Stock Market Index, January 1991 to December 2014

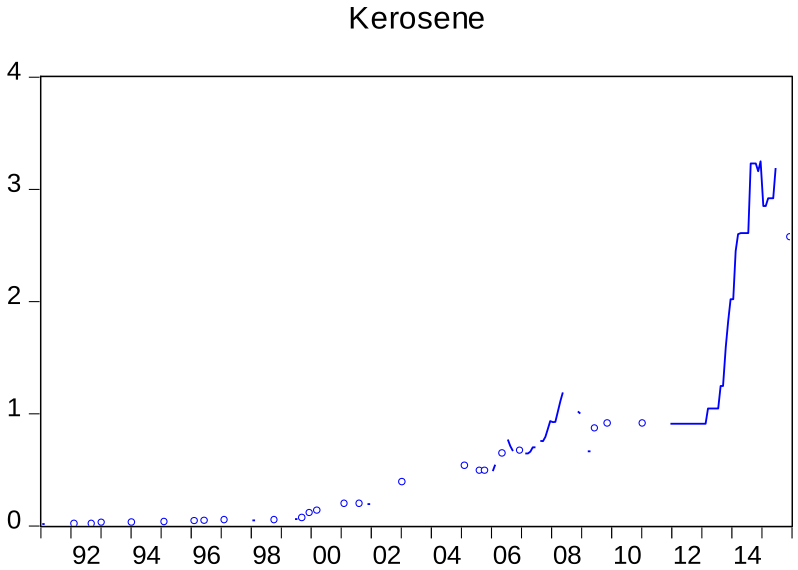


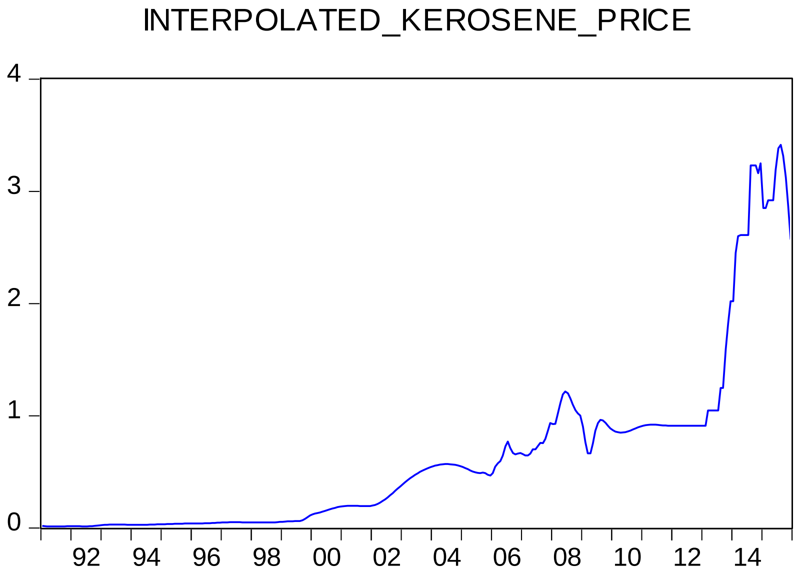
Appendix E2: Interpolated diesel price



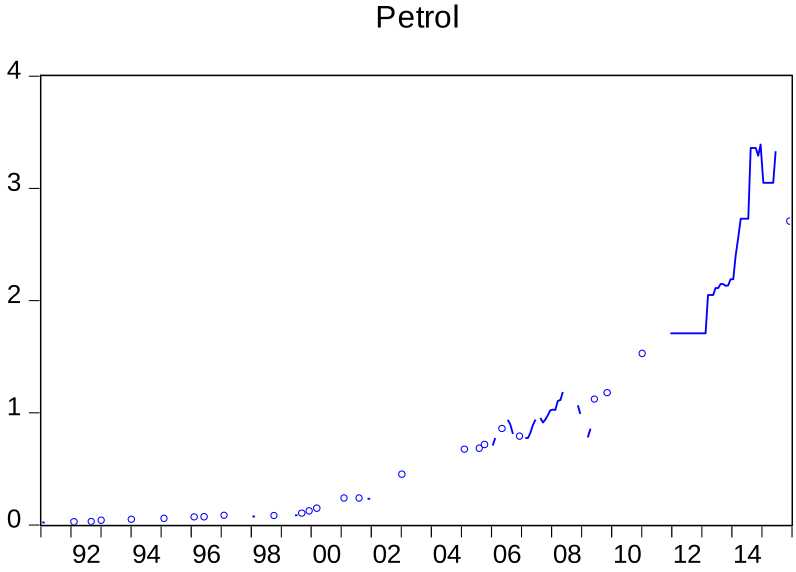


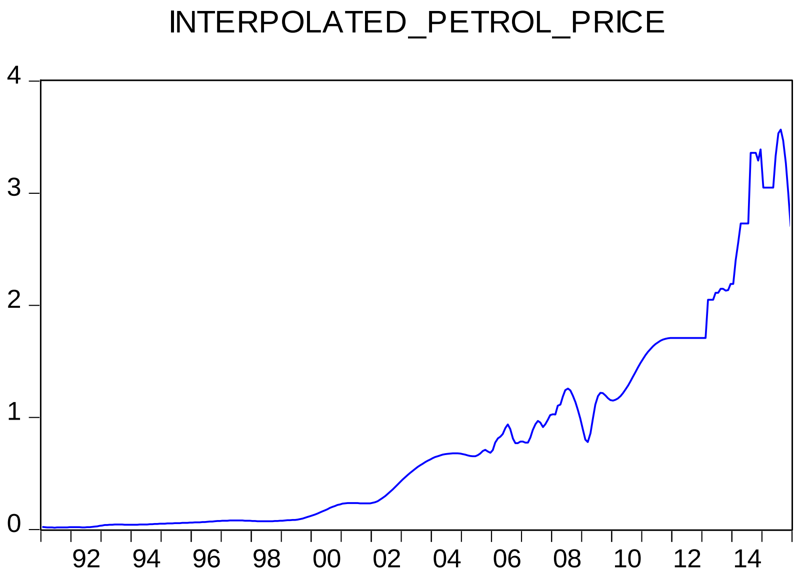
Appendix E3: Interpolated Kerosene price





Appendix E4: Interpolated petrol price





APPENDIX F: Lag order selection criteria for the mean equation of the GARCH BEKK models

Appendix F1: Lag order selection for the mean model of the four-variable crude oil price model

Model: Four-variable VAR for DLCOP DLSP500 DLGSECI DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	1848.096	NA	4.37e-11	-12.50235	-12.45235	-12.48233
1	1929.336	159.7252	2.81e-11*	-12.94465*	-12.69469*	-12.84456*
2	1943.992	28.41762*	2.83e-11	-12.93554	-12.48560	-12.75537
3	1955.757	22.49339	2.92e-11	-12.90683	-12.25692	-12.64659
4	1969.668	26.21860	2.96e-11	-12.89266	-12.04278	-12.55235

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

Appendix F2: Lag order selection for the mean model of the two-variable crude oil price model

Model: Two-Variable VAR for DLCOP DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	956.3078	NA	5.43e-06	-6.448026	-6.423091	-6.438043
1	989.5832	65.87631	4.45e-06	-6.645833	6.571028*	-6.615882
2	998.5098	17.55161	4.31e-06*	6.679121*	-6.554446	6.629203*
3	999.4450	1.826162	4.40e-06	-6.658412	-6.483868	-6.588528
4	1005.406	11.5586*	4.34e-06	-6.671659	-6.447246	-6.581809

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

Appendix F3: Lag order selection for the mean model of the four-variable diesel price model

VAR Lag Order Selection Criteria						
Model: Four-variable VAR for DLDIESEL DLSP500 DLGSECI DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	2104.925	NA	7.66e-12	-14.24356	-14.19357	-14.22354
1	2239.566	264.7172	3.43e-12*	-15.04790*	14.79794*	-14.94781*
2	2254.631	29.21188	3.45e-12	-15.04157	-14.59163	-14.86140
3	2270.208	29.78150*	3.46e-12	-15.03870	-14.38879	-14.77846
4	2279.376	17.27886	3.62e-12	-14.99238	-14.14250	-14.65207

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

Appendix F4: Lag order selection for the mean model of the two-variable diesel price model

Model: Two-variable VAR for DLDIESEL DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	1210.768	NA	9.73e-07	-8.167355	-8.142420	-8.157371
1	1302.148	180.9068	5.39e-07	-8.757757	-8.682952*	-8.727807
2	1310.943	17.2928*	5.22e-07*	8.790156*	-8.665481	8.740238*
3	1314.872	7.672369	5.22e-07	-8.789677	-8.615133	-8.719793
4	1317.626	5.341180	5.27e-07	-8.781260	-8.556846	-8.691409

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

Appendix F5: Lag order selection for the mean model of the four-variable petrol price model

Model: Four-variable DLPETROL DLSP500 DLGSECI DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	2098.176	NA	8.02e-12	-14.19780	-14.14781	-14.17778
1	2238.353	275.6027	3.46e-12*	-15.03968*	-14.78972*	-14.93959*
2	2253.274	28.93112	3.48e-12	-15.03236	-14.58243	-14.85220
3	2268.881	29.83900*	3.49e-12	-15.02970	-14.37979	-14.76946
4	2277.391	16.03987	3.67e-12	-14.97892	-14.12904	-14.63861

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

Appendix F6: Lag order selection for the mean model of the two-variable petrol price model

Model: Two-variable VAR for DLPETROL DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	1205.003	NA	1.01e-06	-8.128401	-8.103467	-8.118418
1	1300.838	189.7263	5.44e-07	-8.748904	8.674100*	-8.718954
2	1309.774	17.5698*	5.26e-07*	8.782255*	-8.657580	8.732338*
3	1313.345	6.972748	5.28e-07	-8.779355	-8.604811	-8.709471
4	1314.915	3.045680	5.36e-07	-8.762940	-8.538526	-8.673089

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

Appendix F7: Lag order selection for the mean model of the four-variable kerosene price model

Model: Four-variable VAR for DLKEROSENE DLSP500 DLGSECI DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	2030.883	NA	1.27e-11	-13.74158	-13.69159	-13.72156
1	2160.653	255.1409	5.85e-12*	-14.51290*	-14.26294*	-14.41281*
2	2174.387	26.63006	5.94e-12	-14.49754	-14.04760	-14.31737
3	2190.213	30.25743*	5.95e-12	-14.49636	-13.84645	-14.23612
4	2201.104	20.52643	6.16e-12	-14.46172	-13.61184	-14.12141

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

Appendix F8: Lag order selection for the mean model of the two-variable kerosene price model

Model: Two-variable VAR for DLKEROSENE DLEXR						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	1137.011	NA	1.60e-06	-7.668990	-7.644055	-7.659007
1	1222.411	169.0697	9.24e-07	-8.218993	8.144188*	-8.189043
2	1231.503	17.8771*	8.93e-07*	8.253399*	-8.128725	8.203482*
3	1235.188	7.196050	8.94e-07	-8.251272	-8.076728	-8.181388
4	1238.638	6.688695	8.98e-07	-8.247551	-8.023137	-8.157700

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