

**UNIVERSITY OF GHANA  
COLLEGE OF HUMANITIES**



**EFFECT OF WORLD OIL PRICES ON GHANA'S CEREAL PRICES**

**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,  
LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR  
THE AWARD OF MPhil ECONOMICS DEGREE**

**DEPARTMENT OF ECONOMICS**

**JULY, 2018**

## DECLARATION

This is to certify that this thesis is the outcome of research undertaken by Eugene Oku towards the award of a Master of Philosophy (MPhil) degree in Economics at the Department of Economics, University of Ghana under the guidance of the signed supervisors.

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## ABSTRACT

In Ghana, most of the oil needs of the country is largely dependent on imported crude oil which makes imported crude oil an essential part of the economy and as such changing world oil prices is a concern that needs to be examined. This thesis examines the effect of world oil prices on Ghana's cereal (maize and rice) prices using monthly data covering the period 1990 to 2015. Using the Vector Error Correction Models and generalized impulse response analysis, the study finds that among other variables, world oil prices is an important factor that influences cereal prices positively in Ghana in the long run. Also, world cereal prices and exchange rate were found to impact positively on domestic cereal prices in the long run. However, in the short run, the study finds that world oil prices only affected domestic maize price but not the other domestic prices. The impulse response analysis also supported the short run results obtained. The Granger causality test revealed a unidirectional causal link running from world oil prices to domestic maize prices but the same could not be found for the other food crops in the short run. However, the long run causality test showed a unidirectional causality from world oil prices to all the domestic prices. Overall, our results indicate that world oil prices significantly affects domestic cereal prices through the production costs and biofuel channels. The study thus recommends that considering the fiscal space of the economy, government and policy makers should adopt measures to subsidize oil related products particularly the ones used in agriculture such as inorganic fertilizers, as this will in turn reduce the impact of rising oil prices on the domestic front.

## **DEDICATION**

This thesis is dedicated to the Almighty God, my siblings; Thelma Oku, Ellis Oku and Abigail Crabbe, my parents; Mr. and Mrs. Jonathan Oku, the Armah-Attoh family and to everyone who through diverse ways have helped me reach this height.

## **ACKNOWLEDGEMENTS**

I first of all render my deep appreciation to God Almighty for the mercies, grace, wisdom and knowledge He bestowed on me to complete this thesis. Praise the Lord, for His mercies endures forever.

Much gratitude also goes to Prof. Robert D. Osei and Dr. Michael Danquah for their immense contribution, expert guidance and direction towards the success of this research. Also, to all the lecturers at Economics Department, University of Ghana, Legon, especially Dr. Kwadwo Adjei Tutu and Mr. G.K. Tsikata I say a big thank you.

I cannot end without extending a heartfelt gratitude to my friends; Thomas Twene-Sarpong, Manfred Kasapa, Emmanuel Quarshie, Stella Adjei-Laryea, Felicia Hammond, Derek Asuman, Elorm Blavo, my Mphil course mates and everyone who has aided in diverse ways towards the success of this research.

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## LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Augmented Dickey-Fuller
AR	Autoregression
ARCH	Autoregressive Conditional Heteroscedasticity
ARDL	Autoregressive Distributed Lag
BoG	Bank of Ghana
CPI	Consumer Price Index
DCP	Domestic Cereal Prices
DF	Dickey-Fuller
DMP	Domestic Maize Prices
DRP	Domestic Rice Prices
ECT	Error Correction Term
ECM	Error Correction Model
EIA	Energy Information Administration
ER	Exchange Rate
FAO	Food and Agricultural Organization
FOB	Free on Board
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Product
GIRF	Generalized Impulse Response Function
GLSS	Ghana Living Standard Survey
GNPC	Ghana National Petroleum Corporation
GSS	Ghana Statistical Service
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IRF	Impulse Response Function
J-J	Johansen-Juselius
KPSS	Kwiatkowski-Phillips-Scdmidt-Shin

L.H. S	Left Hand Side
LM	Lagrangian Multiplier
MoFA	Ministry of Food and Agriculture
MT	Metric tons
OK	Oklahoma
OLS	Ordinary Least Square
PP	Phillip and Perron
R.H. S	Right Hand Side
SRID	Statistics and Research Information Directorate
UN	United Nations
USA	United States of America
USAID	United States Agency for International Development
VAR	Vector Autoregression
VARMA	Vector Autoregressive Moving Average
VECM	Vector Error Correction Model
WCP	World Cereal Prices
WMP	World Maize Prices
WOP	World Oil Prices
WRP	World Rice Prices
WTI	West Texas Intermediate

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background**

The period between the 1960s and the 2000s experienced a considerable decline in the prices of food commodities in the international markets after which food commodity prices in world markets increased gradually from 2003 to 2006. Prices of food then soared from the year 2006 to the first half of 2008 before declining in the second half of that year (FAO, 2011). On average, over the last twenty years, cereal prices, particularly wheat, maize and rice have increased by about 13% annually in nominal terms. Also, the period between the years 2000 and 2007 showed an increment in rice, wheat and maize prices by 63%, 124% and 85% respectively (Elliot, 2008). This sequence of increasing food prices particularly during 2007 to 2008 and 2010 to 2011 period have worsened worries about whether there will be enough supply of food in the future (Elliot, 2008).

Many developing economies have experienced hunger crises due to price spikes which is a fore most threat to national food security (von Braun and Tadesse, 2012). Uncertainties concerning food and food prices still remain a key worry for governments and makers of policies in low income and developing economies even though undernourishment levels have been fruitfully reduced over the last decade (von Braun and Tadesse, 2012).

This phenomenon has stirred up many academic deliberations to make known to governments and policy makers the socio-economic consequences of rising food prices. Again, in order to draw good policies to contain rising prices of food, there have been various studies done to ascertain the factors responsible for food price changes (see Alexandratos, 2008; and Tadesse et al., 2014).

The contemporaneous increments in world oil prices does not come as a surprise as oil prices have been examined as a potential determinant of escalating food prices in recent discussions. The recent surge in global food prices in 2014-2015 transpired almost concurrently with an increase in the cost of crude oil buttressing the fact that food and prices may have a relationship (Abbott et al., 2008; Rosegrant et al., 2008; Tyner 2010; Mitchell 2008; Headey and Fan 2008; Baffes and Dennis 2013).

Between January and June 2008, food prices on the whole rose by 62%, whilst world rice prices doubled from US\$375 per metric ton to US\$757 per metric ton. Also, during the same period increments in oil prices reached a record high of US\$ 133 per barrel (IMF, 2008). A question which follows from this is whether the high unrefined petroleum costs caused the increase in price for all food crops, particularly for those that are utilized as a part of bio-fuel creation or vice versa.

The effect of oil prices on food prices can be traced through two key channels. Firstly, oil is an essential contributing factor to food production. For example, oil is employed in making inorganic manure and also utilized in producing other chemicals that are used in farming. Higher oil prices may therefore prompt inflationary pressures in the economy, through an increase in input and transportation costs and, consequently act as a disincentive to investment and thereby cause lower yields and hence higher food prices (Dillon and Barrett, 2015). Also, in periods of increasing oil prices, oil importing countries such as Ghana, who are reliant on food imports for consumption, will experience a surge in their food import bill which will additionally exert upward pressure on prices of domestic food crops given the rising cost of world production of food. This is through the wealth channel introduced by Golub (1983) and modified by Bodenstein et al. (2011). The wealth conduit shows the effects in the short run. Thus, an increase in prices of oil leads to the transfer of wealth to economies who export oil. This increase in wealth is shown as an enhancement in exports and the

balance on the current account of these countries. Consequently, there is an expected appreciation in the currencies of the exporting economies whereas that of the importing economies are expected to depreciate after the oil price increase (Beckmann and Czudaj, 2013). The depreciation in currency of the importing countries subsequently raises the food import bill and consequently the prices of domestic crops.

Secondly, the utilization of biofuel as an alternative to oil in producing energy may influence food costs. This is on the grounds that biofuels are produced using some food crops such as maize, soya beans, and other oilseeds. In this way, a growth in the need for these yields as a result of expanded interest in biofuel as an alternative energy source emanating from rising unrefined petroleum costs may influence the production, prices, and unpredictability of these yields accruing to the competition for the available arable land (Chen et al., 2010).

## **1.2 Problem Statement**

In recent years the abrupt hikes and spikes in prices of food has kindled concerns amongst producers, consumers and policymakers particularly, over the ability of the world food economy to adequately feed the ever-increasing world population. These fluctuations in food prices negatively impact on consumers and producers by increasing uncertainty about future market prices. The International Food Policy Research Institute (IFPRI) in 2008 affirmed before the United States (U.S.) Congress that growing costs of food products were bringing on revolts in many emerging nations, and that, as shown by the Food and Agriculture Organization (FAO) of the United Nations (UN), thirty-seven (37) nations were confronting food crises (Rosegrant et al., 2008). The World Bank anticipated that many countries would be crashed into impoverishment by rising food costs if strategy changes in the pricing of agricultural commodities were not implemented (Inman, 2011).

One of the crucial sectors that contribute significantly to the expansion of an economy is the agricultural sector. The national development agenda of Ghana spells out agriculture as the

tool to drive growth and structurally transform the economy in order to enjoy the full benefits of enhanced growth. While the cultivation of non-food crops such as cocoa and fibres are deemed very essential in some countries, in Ghana, food production is seen as the most important aspect of agriculture particularly in terms of area of cultivation and benefit obtained from the ensuing product (MoFA, 2013).

In Ghana, the crops sub-sector contributes about 64.7% to the gross domestic product (MoFA, 2015). Also, the agricultural sector employs majority (44.7%) of the economically active population with the rural dwellers (often poor) more involved in agriculture than urban dwellers (GSS, 2014). The prices of cereals, particularly maize, rice and sorghum increased by 45%, 40% and 185% respectively between 2000 and 2010 (Ganidekam, 2013). Hence rising cereal prices is a key concern to emerging economies such as Ghana as these cereals are the main diet of the populace. Also, continuous increases in cereal prices hurt the poor more than the rich as these crops constitute a larger share of the poor consumers' income than does the rich (GSS, 2014).

World oil supplies about 24.1% of the energy expended in the productive sectors of the Ghanaian economy (International Energy Agency, 2012). Relative to other sources of energy such as biofuels and hydro-electric energy, about 96.7% of energy utilized in Ghana's agricultural sector is obtained from oil (Armah, 2003). Oil is therefore a crucial component of agricultural production in Ghana and hence extensively determines the growth of the Ghanaian economy. Subsequently, fluctuations in oil prices have a significant influence on the economy. The effect of these fluctuations on the economy is transmitted through both demand and supply conduits.

World oil prices over the past years have been rising. The concurrent surges in prices of agricultural products and world oil prices between the periods 2006 through to 2008 and 2010 to 2014 have opened the debate on food versus oil (Ibrahim, 2015).

The seemingly high correlation (see Dillion and Barret 2015) as seen in recent times between cereals and oil prices therefore begs the question as to the nature of this nexus. Although many empirical studies (Zhang and Reed, 2008; Nazlioglu and Soytas; 2010, Asghar and Naveed, 2015) on the link between oil prices and food prices have been examined, very few (Dillion and Barret, 2015, Nwoko et al., 2016) have focused on Africa. There is also limited literature on the possible transmission channels. Thus, this study tries to empirically assess the link between world prices of oil and Ghana's cereal (maize and rice) prices looking at the likely transmission channels. The study focuses on cereal prices because cereals are the most consumed food item in Ghana (Mensah-Bonsu et al., 2011).

### **1.3 Research Questions**

1. What is the effect of world oil prices on domestic cereal, domestic maize and domestic rice prices?
2. What is the direction of causation between world oil prices and domestic cereal prices?

### **1.4 Research Objectives**

The general objective of this study is to investigate the effect of world oil prices on Ghana's cereal (maize and rice) prices from 1990 to 2015.

More specifically, the study seeks to:

1. Examine both the short-run and long-run effects of world oil price changes on domestic cereal, domestic maize and domestic rice prices.
2. Examine the direction of causation between these variables.

### **1.5 Study Hypothesis**

$H_0$ : Change in world oil prices does not influence domestic cereal prices.

$H_a$ : Change in the world oil prices influences domestic cereal prices.

### **1.6 Significance of Study**

Higher food prices significantly impact the welfare of food importing countries such as Ghana by either increasing the amount spent on food purchases or reducing the quantity or quality demanded. Also, food price hikes can raise inflationary risk which could influence the expectations of prices, higher wage demands and consequently increase headline inflation.

In light of the above discussion, this study is considered significant because knowing the response of cereal prices to shocks in world oil prices will help inform decisions of farmers, traders, consumers and other key players in the value chain process so as to make informed choices that will enhance food security and increase welfare.

Also, this study focuses on the individual cereal prices as well as a composite of the cereal prices. This makes this thesis different from other studies done which focuses on food price inflation and not the individual prices of these crops.

### **1.7 Structure of the study**

The study is structured into five chapters. The first chapter is the introduction. This is made up of the background of the study, problem statement, research questions, research objectives, study hypothesis, significance of the study and structure of the study. Chapter two presents the theoretical and empirical literature related to the effect of oil prices on food prices. The third chapter concentrates on the methodology and data employed in the study. The fourth chapter presents the findings and discussions while conclusions, policy recommendations and limitations of the study are presented in the fifth chapter of this study.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter is divided into three sections. The first section is the introduction. The second section discusses some of the theoretical explanations of rising agricultural commodity prices while the third section sheds light on some of the empirical literature on oil price and food price changes.

#### **2.2 Theoretical Literature Review**

##### **2.2.1 Drivers of Food Prices**

Food price changes in recent times have become a topical issue both locally and internationally because of its impact on welfare. As such there is the need to identify the factors influencing food prices. The FAO discusses these factors in its report dubbed “The State of Agricultural Commodity markets-2009” and classifies them into categories. These are the supply and demand mechanisms. These mechanisms are elaborated in the next subsection.

##### **2.2.1.1 Supply Channel**

In explaining the supply dynamics, the FAO identifies that stocks are very important in determining the prices of food commodities. Thus, the formation of the price of the crop all through the year has an inverse relationship with the initial stocks of that crop at the beginning of the year (FAO, 2009). This inverse relationship implies that, less stocks at the beginning of the year will lead to higher food prices. The amount of food stock declined about 3.4% on average yearly between 1995 and 2009 (FAO, 2009). This is suggestive that stocks were a major factor responsible for the 2008 food price hikes.

Climate and weather are also under the supply umbrella since to a large extent climate and weather determine supply. Thus, rising temperatures affect yield and consequently prices of

these yields. The World Bank points out that the anticipation of major climatic events can strongly influence the prices of food. For example, the anticipation of 2009-2010 El Nino further caused high food prices (FAO, 2011).

The two supply factors discussed however, do not show how oil prices can influence food prices. Another supply factor that shows to some extent the channel through which oil prices affect food prices is the production inputs and transport cost channel.

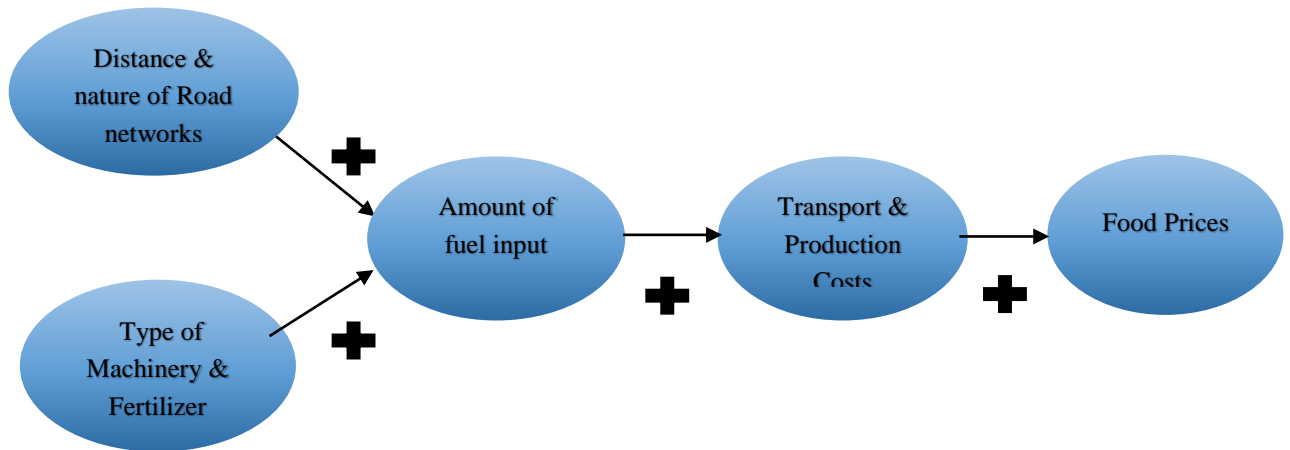
As expected, transport and production input costs of food commodities impact their prices (Dillion and Barrett, 2015). The influence of oil prices on the food sector is quite significant. A number of these effects are evident. The cost of transporting food items from the farm to final buyers increases when rising oil prices lead to higher costs of diesel and gas. Regardless of whether crops are transported by ship or vehicles, the cost of oil will influence transport costs and consequently raise the prices of food.

Agriculturists utilize oil to power machines and other farm equipment used in the production of food. The production of some inputs such as inorganic fertilizer, used in food production is manufactured using fossil fuel. The processing of food also involves the use of relatively higher volumes of oil. Hence, rising oil prices may decrease the returns of retailers and farmers. This could also lead to an increase in end user food prices.

Dillon and Barrett (2015) observed 17 different cities in a number of countries in East Africa. The authors examined the difference in the elasticities of local maize prices and world oil prices. The study revealed that, cities that were far from major market and trading centres had higher elasticities. Dillon and Barrett (2015) thus concluded that, it is the costs of transporting food from the city to a major market centre that affect the prices of these food crops. Oil acts as fuel for the transportation these food crops. Thus, the further one has to transport the food and the quality (bad) of road network from the farm to the major market centre, the more oil

has to be used and this is mirrored in the price of the food crop. This relationship is depicted in Figure 2.1.

Figure 2.1: Transport & Production Input Costs Transmission Channel



Source: Author's inference from the theoretical and empirical literature

The positive relationship running from distance, and nature of road networks through to food prices as shown in Figure 2.1 imply that, the further the distance the farm is to major market centres the more fuel is required which increases the transport costs and consequently the prices of the food crops.

Also, the quantity of and fertilizer type (organic or inorganic) and machines employed in agriculture mostly shows the amount of money spent on oil which then affects the food prices. Thus, as more inorganic fertilizer is used, it increases the amount of oil being used since inorganic fertilizers are made with oil. Increase in the amount of fuel input leads to increased production costs and consequently increased food prices.

### **2.2.1.2 Demand Channels**

The rapid rise in incomes and population in South Asian countries, particularly India and China have been identified as a key factor that led to the food (mainly cereals) price spikes in 2007-2008 (von Braun and Tadesse, 2012). Thus, increased population and incomes leads to increased demand for food. Given that India and China are both net cereal exporters, increased demand for food in their respective economies imply a decrease in the level of their exports. Consequently, leading to an increase in world cereal prices. Also, the ban imposed by the Indian government on export of rice because of increased demand for rice contributed to the spike in world rice prices in 2007-2008 (FAO, 2009).

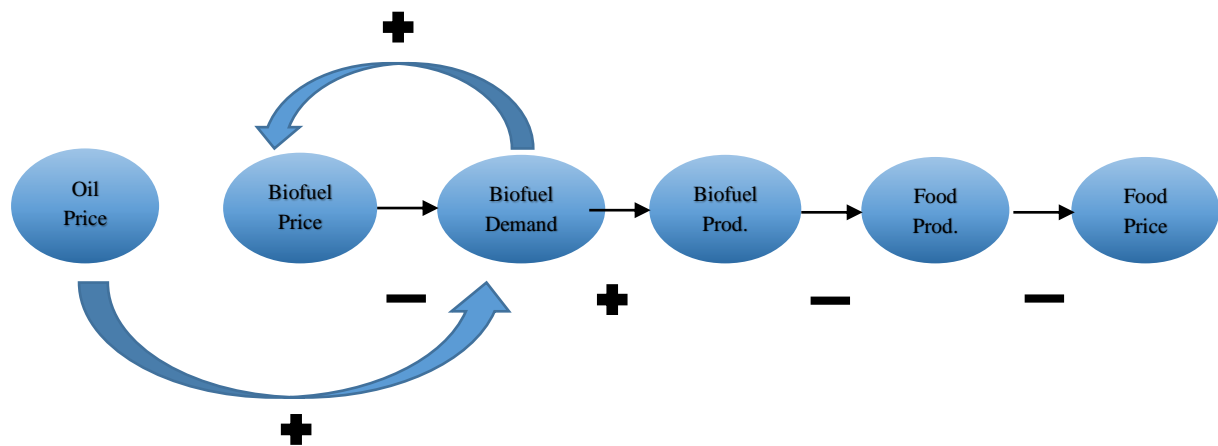
Another demand side channel through which food prices change is the biofuel transmission channel. This channel has received much attention in recent times. Oil price hikes increase the potential of diverting food crops as biofuel (which will be more profitable) other than food. This channel has been modelled by Chen et al., (2010) as the Global Cropland Allocation Model. This model posits that, through the diversion of food crops and more generally agricultural land into the production of biofuel, there is the creation of scarcity of both food and land putting an upward pressure on food prices, thus linking changes in food prices to changes in crude oil price.

Cereals are increasingly being used to produce energy in the form of biofuels in recent years mainly due to considerations of energy independence and environmental preoccupations (Bakhat and Würzburg, 2013). For these reasons, there is a new substitution relationship between oil and food commodities making conversions of food products into fossil fuel more attractive especially in the phase of fuel price hikes. This substitution effect was coined by Rosegrant et al. (2008) as the “food-vs-fuel” trade-off.

Although maize is but one example of the vast majority of food commodities the price of which is directly linked to the price of crude oil, other cereals have been identified in the

literature to have a link with the price of crude oil. Other agricultural commodities such as soybeans, oil seeds and other grains could be used in the production of biodiesel or food for consumption. Again, maize and sugarcane as well as soya beans provide highly competitive fuel alternative for ethanol and diesel products respectively. These emerging events provide financial incentives for farmers and food processors to convert their agricultural products into fuels which could yield higher returns other than raw food products thereby providing a much stronger link between food and energy commodities than before (Bakhat and Würzburg, 2013). The biofuel transmission channel is shown in Figure 2.2.

Figure 2.2: Biofuel transmission channel



Source: Author's inference from the theoretical and empirical literature

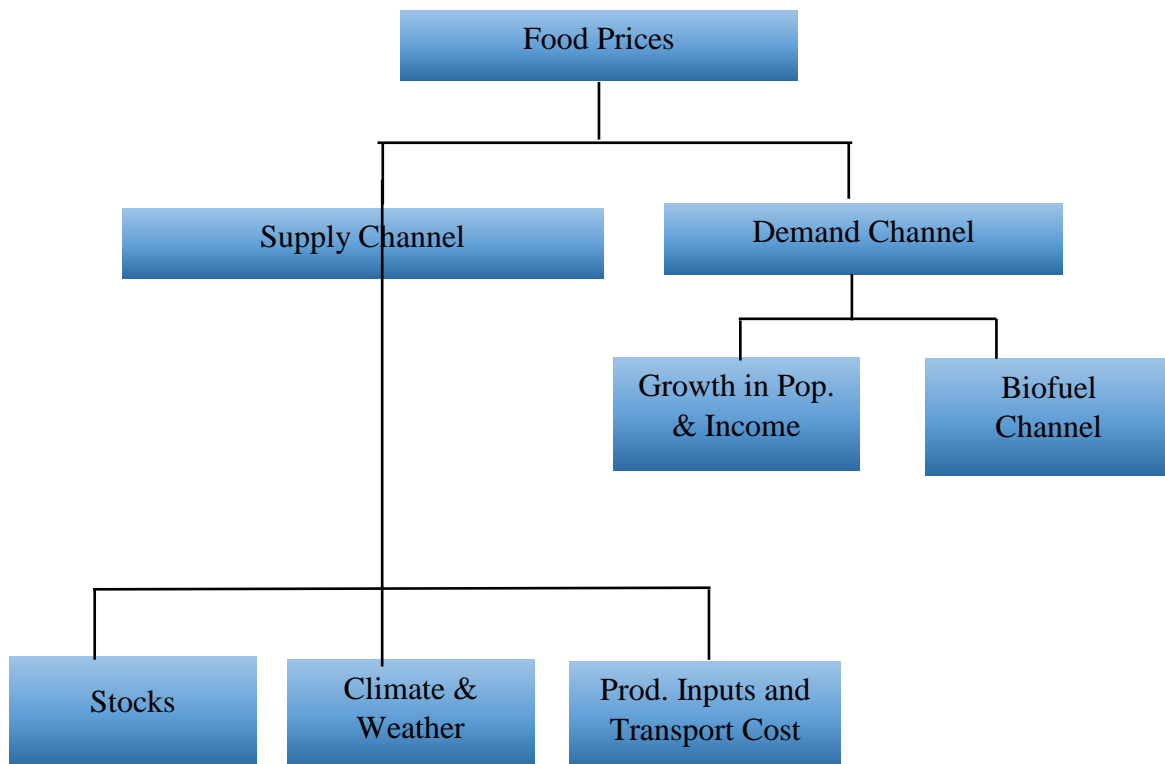
From Figure 2.2, there is a positive relationship between oil price and biofuel demand implying that increases in oil prices will lead to an increase in the demand for biofuel. There is also a positive relationship between biofuel demand and biofuel production which means that as more of biofuel is demanded the production of biofuel will increase. This implies that there will be a reduction in the production of that crop for food purposes since it will be channelled to biofuel production instead. This explains the inverse relationship between biofuel production and food production. Consequently, less production of that crop for food

purposes will lead to increases in the price of that food crop explaining the inverse relationship between food production and food prices.

This channel is an indirect process but it submits great effects. For instance, it implies that this link is made stronger and its likely effects great, when more food crops that are also energy crops are used to produce biofuel because of high demand for biofuel (Chen et al., 2010).

To conclude, the discussions made so far through the supply and demand conduits are some of the drivers and not all the drivers that drive food prices. Nonetheless, it should be noted that no single factor explains the determination of food prices but a combination of these drivers (FAO, 2009). Figure 2.3 gives a pictorial representation of the deliberations in this sub-section.

Figure 2.3: Drivers of Food Prices



Source: Author’s inference from the theoretical and empirical literature

### **2.3 Empirical Literature Review**

The understanding of global commodity price variations by economists and researchers became paramount in the advent of 2007 to 2008 commodity and oil price hikes. This caused researchers to focus more particularly on two areas. These are the understanding of the causal link between world oil prices and global food markets, and the impact of rising biofuel production on food (e.g. maize) commodity prices. The latter strand of literature (the impact of rising biofuel production on food commodity prices) focused on knowing how local subsidies given to biofuel industries affected oil (energy) prices in major grain and food markets such as the U.S and Brazil. The literature on the former (the understanding of the causal link between world oil prices and global food markets) which is the is vast. There have been a significant number of studies within the past decade on the impact of world oil prices on food prices. Yet despite the huge body of research on this topic, findings on this topic are far from being in agreement as the findings vary from positive long run relationships to no long run relationships at all. The empirical review of this study follows a chronological order.

Campiche et al., (2007) investigated the relationship between world crude oil prices and world corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices for the duration 2003 to 2007 using weekly data. Using the Johansen cointegration test, the study found no long run relationship between world oil prices and the selected products from 2003 to 2005. However, the study found a long run relationship between corn, and soybean prices and world crude oil prices in the period 2006-2007.

Baffes (2007) also examined the effect of crude oil prices on 35 internationally traded primary commodities prices between 1960 and 2005. Baffes discovered that the pass-through of crude oil variations to the overall non-energy commodity index was 0.16. This pass-through was highest for the fertilizer index which stood at 0.33, followed by agriculture at 0.17 then metals at 0.11. The study hence concluded that as expected by analysts, if crude oil

prices remain high for some time then the recent food price booms is likely to last longer than the earlier booms.

An examination of the impact of world crude oil prices on corn, pork and soybean prices by Zhang and Reed (2008) in China covering January 2000 to October 2007. The study concluded that world crude oil prices is not a main determinant of the current surge in China's corn, pork and soybean prices. The study used co-integration, VARMA model, impulse response function and variance decomposition to determine this relationship.

Kaltalioglu and Soytas (2009) concluded in their investigation of the inter-temporal link between world food, crude oil and agricultural raw material prices for the period January 1980 to April 2008 that changes in world oil prices have no substantial influence on world food and agricultural raw material spot prices. The study employed impulse response functions in its estimations.

Employing the bivariate co-integration approach using the Engle-Granger two-stage estimation procedure spanning January 1980 to March 2008, Arshad and Hameed (2009) investigated the long-run relationship between world petroleum prices and cereal prices in Thailand and the United States of America. The study showed that there exists a long-term relationship between world petroleum prices and cereal prices in both Thailand and the USA. The study also confirmed a unidirectional causality running from petroleum to cereal prices.

Nazlioglu and Soytas (2010) also investigated the direct and indirect effects of world oil prices on cereal prices in Turkey. The study used the Toda–Yamamoto causality approach and generalized impulse-response analysis for the identification of the long-run and short-run interrelationships using monthly data spanning from January 1994 to March 2010. The generalized impulse response analysis revealed that cereal prices are nonaligned to world oil prices and exchange rate in the short run. The study revealed that the neutrality of Turkey's

cereal prices to variations in world prices of oil is attributed to the less demanding energy production process. Hence, the study recommended that policies to stabilize agricultural prices in Turkey should emphasize on supply and demand dynamics since these prices do not respond to external shocks.

In addition to the literature, Mutuc et al., (2010) estimated a vector error correction model using monthly data spanning January 1975 to February 2008 in the US to ascertain the response of cotton prices to fluctuations in world oil prices. Their findings indicate that, in the long run world oil prices only explain 3% of the variance in US cotton prices. Hence, rise in cotton prices in the US cannot be ascribed to oil price shocks.

Also, Esmaeili and Shokoohi (2010) used the principal component analysis to investigate the co-movement of food prices and world oil prices and also to comprehend the effect of the oil price on food prices. They found no direct long- term relationship between world oil prices and food prices.

Chen et al., (2010) additionally probed the connections existing between unrefined petroleum prices and the worldwide grain prices for three cereals namely corn, soybean, and wheat. The study spans from the 12th week of 1983 to the 5th week of 2010. This period was separated into three sub-periods as the information on price of oil fluctuates amid various periods. The study utilized an Autoregressive distributed lag (ARDL) model. The results of the study showed that the changes in one grain price was impressively impacted by the changes in other grain prices. This result is predictable with the possibility that grains are rivalling the derived demand for biofuel by utilizing soybeans or corn to create ethanol or bio-diesel. They additionally found in their results that variations in oil prices prompt changes in grain prices. The study hence concludes that oil price is a basic element of production cost for grains and this deepens the struggle for the available arable land between the alternative grains.

Serra et al., (2010) employed a smooth transition vector error correction model to evaluate price interactions in the US ethanol market. The study utilized daily maize, oil futures and ethanol prices from the mid-year of 2005 to the mid-year of 2007. The outcome of the paper showed there exist an equilibrium relationship among the variables. Nonetheless, only prices of ethanol change in a nonlinear manner to deviations from the long run equilibrium. The GIRF also reveals that a shock to both maize and oil prices cause changes in prices of ethanol in the same direction. Also, prices of ethanol reach its maximum after about 10 days of the initial shock and fade away in about 35 days.

Ciaian and Kancs (2011) also studied the relationship between world oil prices, biofuel prices and prices of food by looking at a direct biofuel transmission and an indirect input transmission. Using a weighted average price of world oil and prices of nine major tradable agricultural commodities, Ciaian and Kancs employed time series techniques to assess this relationship from the period 1994 to 2004. The study period was sub divided into three to account for structural breaks. The results of the empirical study concurred with the hypothesis that oil prices do influence agricultural prices and this relationship increases overtime. The findings of the study also revealed no cointegrating relationship in the first period, i.e., 1994 to 1998. However, maize and soya beans prices were found to have a long run relationship with world oil prices in the 1999 to 2003 period which marked the second period although this relationship was found to be weaker than what is predicted in theory. In the third period thus 2004 to 2008, the prices of all nine commodities were found to have a long run relationship with world oil prices and this was attributed to the incidence of direct biofuel transmission. The study also showed that the long run pass through of world oil price change to these commodities vary between 0.05 and 0.30 implying that a 1\$/barrel change in world oil price will trigger between 0.10\$/ton and 1.80\$/ton change in agricultural commodity prices.

Elmarzougui and Larue (2011) examined the evolving relationship between world oil prices and world maize prices. Their results assert that this relationship is not a stable one. This relationship was found to be stronger in periods of high oil price volatility and when policies in the agricultural sector generate less distortion. The impulse response functions (IRF) also indicate systematic response of maize prices to oil price shocks but the reverse is not confirmed. Their results are in line with Balcombe and Raspomanikis (2008) who investigated the oil-sugar-ethanol relationship in Brazil.

Contrary to the study of Nazlioglu and Soytas (2010), Nazlioglu and Soytas (2011) found a significant effect of global oil price variations on prices of agricultural commodities using monthly data from January 1980 to February 2010. The study employed panel cointegration and Granger causality techniques. The study examined the dynamic relationship between global prices of oil and twenty-four global prices of agricultural commodities giving recognition to the relative strength of the US dollar. The study also confirmed a positive weak dollar effect on these commodity prices. The different results obtained in the two studies could be due to the methods used and also the type of economy. Thus, the earlier study in 2010 showed that Turkey's production process was less energy intensive which could be a reason for finding no relationship between world oil prices and domestic food prices. However, it could be that the study of the relationship between world oil prices and world agricultural commodities in 2011 by Nazlioglu and Soytas found a significant effect because world agricultural production might be more energy intensive.

Ghaith and Awad (2011) also studied the potential long run relationship between world oil prices and US maize, palm oil, wheat, sorghum, soybean, barley, linseed oil, and soybean oil. By applying time series techniques on monthly data covering the period 1980 to 2009, the study results revealed that there is a solid confirmation of long-term relationship between

prices of these crops and world oil prices. The study also revealed a unidirectional causality between the prices of world oil and some of the crops.

The analysis by Natanelov et al., (2011) focuses on the movement of price between world crude oil and some world cereal prices. They apply several cointegration techniques and causality to compare changes in relationships through time. The findings of the study indicate that the observed cointegration among the variables is a dynamic idea which is influenced by several factors such as economic and policy improvement. This study also highlighted that policy on biofuel cushions the co-movement of maize and world oil till the prices of world oil exceed a certain threshold.

Ackah et al., (2012) also examined the transmission of world commodity prices to local markets in Ghana focusing on household welfare effects. The study covered the period 1990-2008 using monthly data on world and domestic prices of maize, rice and groundnut and also exchange rates and tariffs. The findings of the study indicated a long run relationship between the variables of interest. The study revealed that the long-run pass through of the international prices of maize and rice is almost unitary, implying a complete pass through. The same could not be said about groundnut where the long-run pass through was found to be 0.7 and 0.8 for the two models estimated.

Nazlioglu et al., (2012) again examined the volatility transmission between world oil and selected agricultural food prices. They employed the causality in variance test and impulse response functions to daily data from 1st January 1986 to 1st March 2011. The study further divided the periods into the pre-crisis and post-crises period. The causality in variance test findings showed no risk transmission between oil and agricultural markets in the pre-crises period. The impulse response functions also showed that oil price volatility is passed on to agricultural markets in the post-crisis periods only.

Hassouneh et al., (2012) also modelled a multivariate local linear regression and parametric ECM to examine the price nexus and transmission trend between prices of food and energy in Spain using weekly prices of crude oil, sunflower and biodiesel spanning November 2006 to October 2010. The study showed that, the only variable that adjusts to aberrations from its long run equilibrium is biodiesel. This finding is also attuned with previous studies (Balcombe and Rapsomanikis, 2008; Serra et al., 2011). Also, the study showed that the speed of adjustment is higher when biodiesel is cheap than when it is expensive. The short term price variations also posit an influence of energy (oil) prices on prices of sunflower oil.

The link between prices of crude oil, ethanol and grains (maize, wheat and rice) again has been examined by Merkusheva and Rapsomanikis (2014) with the working hypothesis: “profit maximization, the US biofuel policies and automotive engine technology give rise to a nonlinear relationship between oil and ethanol prices and by extension between oil and grains”. Using both discrete and smooth threshold error correction models, they explored the price relationships in the food-ethanol-oil link. The study revealed that oil prices are the long-run drivers of ethanol and grain prices.

Kyei et al. (2014) investigated the causality between oil prices and agricultural commodity prices in South Africa using daily data for prices of oil, soya beans, wheat, sunflower and corn spanning the period April 2005 to July 2014. Their study employed Granger causality in conditional quantiles proposed by Jeong et al. (2012). Their findings show that oil price effects vary across the different quantiles of the conditional distribution. The effect is lesser on the tails compared to the rest of the distribution. The study also revealed that the conventional Granger causality test provides misrepresentative results due to the nonlinear dependence between prices of agricultural prices and oil prices and the conventional Granger causality fails to illustrate the relationship over the full conditional joint distribution of the variables.

Gilbert and Mugeru (2014) using daily prices of crude oil and grains spanning 2000 to 2011 investigated the role of biofuels in explaining increased unpredictability in food crops. The study used multivariate GARCH models and volatility decompositions. The study found correlations and co-movements between prices of grains and crude oil after 2006 and in particular 2008 when crude oil prices were high. The study also revealed that increased unpredictability in grains throughout the 2008-2009 spike was chiefly owed to shocks conveyed from crude oil to grains mainly soybean, corn and wheat price.

Dillon and Barrett (2015) explored the relationship between world oil prices and domestic food prices in East Africa using maize and world oil price data. World oil prices was found to be a significant driver of domestic food prices but mainly through cost of transportation rather than through biofuel and production cost channels. The study further showed that world oil prices transmits more rapidly than prices of global maize indicating that programmes to assist food insecure households during associated commodity price spikes should reflect transport cost effects.

Nwoko et al., (2016) examined the long-run, short-run, and causal connection between oil price and the instability of cereal prices in Nigeria. The study uncovered no long run connection among the factors. Notwithstanding, utilizing the Vector Autoregressive (VAR) on yearly information on oil and individual prices of maize, rice, sorghum, soya beans, and wheat covering the period 2000 to 2013, the study affirmed a critical short-run connection between oil cost and each of the chosen cereal price volatility excluding that of rice and wheat price volatility. The study likewise revealed that oil price Granger causes maize, soya bean, and sorghum price volatilities and this relationship is unidirectional.

In summary, the literature on this topic is flooded with works that simplify the complex relationship between oil and food prices and are therefore unable to provide clear economic

explanation for the transmission channel between these variables. Thus, most studies reviewed estimate bivariate models and also used relatively shorter time frames which make it difficult to establish long run relationships. Besides, it could be that the very forces driving world oil prices are the same affecting food price cycles. Hence, estimating bivariate models to establish long run causal links between these variables (oil and food prices) may lead to deceptive and inadequate understanding of the relationship. This might be a possible explanation to why studies on this topic have revealed different conclusions even when similar time frames have been used since the fundamental forces driving this link may be strengthened or weakened independently of the changes between these variables.

To conclude, a major disadvantage of the current strand of literature on the causal link between world oil prices and food prices is the inadequate understanding of the transmission channel between agricultural commodities and oil. Accordingly, there is the need to move away from using bivariate models and include basic economic factors in the estimation in order to capture possible changing forces, if any, in this link. Also, little work on this topic has been done on Sub-Saharan Africa. This study adds to the existing literature by looking at the effects of world oil prices on Ghana's food prices particularly on cereals which is the first to be done in Ghana to the best of my knowledge. Again, this study includes exchange rate as a macroeconomic variable and world cereal prices in addition to world oil prices in an attempt to explain both the transport, and production input costs channels.

## CHAPTER THREE

### METHODOLOGY AND DATA

#### 3.1 Introduction

The research methodology and the data sources for the estimation of the empirical model are presented in this chapter. The method selected is driven by the objectives of the study and is centred on the best approach for answering the research questions.

#### 3.2 Theoretical Framework

Following from the theoretical review, it can be seen that the transmission of world oil prices to domestic cereal prices can be traced through two main channels (i.e. biofuel, and transport and production input costs channels). This study adopts the McConnell (1989) cropland allocation model which has been extended to a Global Cropland Allocation Model by Chen et al. (2010) to study the link between domestic cereal prices and world oil prices.

In this model, the assumption is made that total land endowment ( $L$ ) is allocated either to producing food crops ( $L_F$ ) and or energy (e.g. biofuel) crops ( $L_E$ ). The model further assumes that some of the food crops can also be used in the production of energy. Hence, there is competition between the crops for the fixed available land. The acreage for food crop production is then denoted as ( $X^F$ ) and the acreage for energy purpose is denoted as ( $X^E$ ). The inverse demand function of the  $i$ th food crop is  $P_i^d(Q_i^d)$  where  $P_i^d$  and  $Q_i^d$  are the price and quantity demanded respectively. Consequently, the inverse demand function for the  $j$ th biofuel is given as  $P_j^d(Q_j^d)$ , where  $P_j^d$  and  $Q_j^d$  are the price and quantity demanded for the  $j$ th biofuel product. The cost per hectare for the production of the  $i$ th food crop planted is denoted as  $TC_i^F$  whereas the production cost per hectare of the  $i$ th energy crop used to produce biofuel is denoted as  $TC_i^E$ . The total cost of producing the  $j$ th biofuel is  $C_j(Q_j^d)$ .

The Global Cropland Allocation Model is stated as:

$$\begin{aligned}
 \text{MAX: } & \sum_{i=1}^n P_i^d Q_i^d - TC_i^F X_i^F + \sum_{j=1}^m P_j^d Q_j^d - TC_j^F X_j^F \\
 & - \sum_{i=1}^n TC_i^E X_i^E \tag{1}
 \end{aligned}$$

Subject to the constraints below

$$-Y_i X_i^F + Q_i^d \leq 0, \quad \forall i \tag{2}$$

$$- \sum_{i=1}^n BY_{ij} X_i^E + Q_j^d \leq 0, \quad \forall j \tag{3}$$

$$\sum_{i=1}^n X_i^F + X_i^E \leq L \tag{4}$$

$Y_i$  is the  $i$ th food crop yield and the transformation rate from the  $i$ th crop to the  $j$ th biofuel is denoted by  $BY_{ij}$ . Equation (1) is the global social welfare function. The social welfare for food crops is the first term. Likewise, the social welfare function of biofuel production is shown in the second and third terms. The demand and supply balance constraints for the food crops and biofuel products are given in equations (2) and (3) respectively, while equation (4) denotes the global land constraint.

The optimization problem can therefore be written as follows:

$$\begin{aligned}
 L = & \sum_{i=1}^n P_i^d Q_i^d - TC_i^F X_i^F + \sum_{j=1}^m P_j^d Q_j^d - TC_j^F X_j^F - \sum_{i=1}^n TC_i^E X_i^E \\
 & + \mu_i Y_i X_i^F - Q_i^d + \lambda_j \sum_{i=1}^n BY_{ij} X_i^E - Q_j^d + \gamma L \\
 & - \sum_{i=1}^n X_i^F + X_i^E \quad (5)
 \end{aligned}$$

$\mu_i, \lambda_j, \gamma$  represent shadow prices

Assuming positive solutions assumptions, the first-order conditions result in:

$$\begin{aligned}
 \frac{\partial L}{\partial Q_i^d} = P_i^d - \mu_i = 0, & \quad \frac{\partial L}{\partial Q_j^d} = P_j^d - MC_j - \lambda_j = 0 \\
 \frac{\partial L}{\partial X_i^F} = -TC_i^F + \mu_i Y_i - \gamma = 0 & \quad \frac{\partial L}{\partial X_i^E} = -TC_i^E + \lambda_j BY_{ij} - \gamma = 0
 \end{aligned}$$

The equilibrium conditions can be written as

$$P_i^d = TC_i^F + \gamma \quad (6)$$

$$P_j^d BY_{ij} = TC_i^E + MC_j BY_{ij} + \gamma \quad (7)$$

Equation (6) equates the additional revenue from producing the *i*th food crop to the additional cost that includes the production cost per hectare plus the rent on land per hectare. Correspondingly the marginal revenue for producing the *j*th biofuel is on the L.H.S of equation (7) and the R.H.S of equation (7) shows the marginal cost.

Equations (6) and (7) imply that food crops and biofuel quantity demanded is dependent on the food crops prices, energy crop prices, the production technology of the energy as well as costs of production.

Also, from the first order conditions,  $\frac{\partial L}{\partial Q_i^d}$  and  $\frac{\partial L}{\partial Q_j^d} > 0$ . This implies that an increase in demand for food crops will lead to increase in its production. Likewise, an increase in demand for biofuel products will lead to an increase in the production of energy crops. Given that the total land endowment ( $L$ ) is allocated either to producing food crops ( $L_F$ ) and or energy (e.g. biofuel) crops ( $L_E$ ), an increase in oil prices all other things being equal makes biofuel products relatively cheaper hence an increase in the demand for energy crops. The increase in demand for biofuel products will then cause a shift in the production of food crops to energy crops and consequently affect the prices of both food and energy crops. These conditions show the possibility of a relationship between energy (oil) prices and cereal prices.

From the theoretical model it can be inferred that

$$FP = f(OP, OFP, PC)$$

Where FP is the price of food, PC is the production costs, OP is oil prices and OFP is the price of other food crops that compete with the particular food commodity in question for a fixed land endowment.

### 3.3 Specification of Empirical model

In order to arrive at an appropriate estimation model for the purpose of this study, the Global Cropland Allocation model is modified to include other variables of interest.

One of the variables of interest included in this study is the exchange rate. Exchange rate is the value of one currency for the purpose of conversion to another. Shocks to the exchange rate influence prices of domestic products through two channels. These are the direct and the

indirect effects. The direct effect is through the marginal cost channel, as exchange rate changes influence imported input prices. For instance, an appreciation of the Ghana Cedi makes imported inputs such as tractors and inorganic fertilizers cheaper and this makes per unit cost of production lower. This channel impacts more when most of the inputs used in production are imported. The indirect effect is through the markup. Again, an appreciation of the Ghana cedi makes imported food cheaper. Consequently, domestic producers will also reduce prices domestic food so as to maintain market share. Thus, even without any change in marginal costs, domestic prices may fall mainly due to change in prices of competitors (foreign prices). The inclusion of exchange rate is guided by the empirical works of Nazlioglu and Soytas, (2011), and Bakucs and Ferto, (2013). The exchange rate variable is to capture the effect of changing production input costs on domestic cereal prices since most of the inputs (especially inorganic fertilizers) are imported (MoFA, 2013).

This study also includes world prices of selected cereals in the estimation of the empirical model. In Ghana, the influence of world oil prices on domestic cereal prices through the biofuel channel is not direct. This is because, Ghana's dependence on biofuel as an alternative source of energy when prices of oil increase are to a large extent negligible. However, world biofuel demand is expected to expand at a 3.6% annual pace, reaching 115million metric tons by the end of 2018 (Ciaian and Kancs, 2011). This therefore implies that demand for cereals such as maize (i.e. an energy crop), on the world market will increase. And holding supply of world maize constant, world prices of maize will therefore rise. As shown in the study by Ackah et al., (2012), international prices of maize and rice have an almost unitary pass through on domestic prices. Thus, the selected world cereal prices are added in this study to explain the indirect influence of oil price transmission to domestic prices through the biofuel channel.

The Cobweb theory put forward by Kaldor (1934) explains why prices of products are subject to periodic oscillations. The model illustrates that price expectations of producers are built on previous prices observed. This is due to the nature of supply and demand decisions made. Thus, the model postulates that planting decisions by farmers in the current year are based on the previous year's prices and the next year's planting decision will be based on this year's prices. Hence, the lag of domestic cereal prices is added to the empirical model to capture the effect of previous month's prices on current cereal prices (Chen et al., 2010). Also, the lags of world oil prices, world cereal (maize and rice) prices and exchange rates are included in the empirical estimation.

Following from the discussions, the empirical model to be estimated can be stated as:

$$\Delta CP_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta WOP_{t-i} + \sum_{i=0}^n \tau_i \Delta CP_{t-i} + \sum_{i=0}^n \alpha_i \Delta OFP_{t-i} + \sum_{i=0}^n \delta_i \Delta WCP_{t-i} + \sum_{i=0}^n \gamma_i ER_{t-i} + \pi Z_{t-1} + \mu_{t-1} \dots \dots \dots (8)$$

Equation (8) is a vector error correction model (VECM) which estimates both the long run and short run effects of the series in the model. The variables included in the model are transformed into logarithms. Logarithmic transformation of variables helps to show influential points in very sharp manner and also corrects skewed variables into the right distribution and toward normality (Green, 2003). Hence the coefficients will be interpreted as elasticities.

From equation (8), three Models will be estimated for the three dependent variables in this study. Model 1, will have domestic cereal prices as its dependent variable. The second (Model 2), will have domestic maize prices as its dependent variable while domestic rice prices will be the dependent variable in Model 3.

From equation (8), **Model 1** can be stated as:

$$\begin{aligned} \Delta LNDMP_t = & \beta_0 + \sum_{i=1}^n \beta_i \Delta LNWOP_{t-i} + \sum_{i=0}^n \tau_i \Delta LNDMP_{t-i} + \sum_{i=0}^n \alpha_i \Delta LNDMP_{t-i} \\ & + \sum_{i=0}^n \delta_i \Delta LNWCP_{t-i} + \sum_{i=0}^n \gamma_i LNER_{t-i} + \pi Z_{t-1} \\ & + \mu_{t-1} \dots \dots \dots (9) \end{aligned}$$

- ❖  $\beta_i, \tau_i, \alpha_i, \delta_i, \gamma_i$  : show the short run effects LNWOP, LNDMP, LNDMP, LNWCP and LNER on domestic cereal prices (LNDMP) respectively.
- ❖ LNDMP is the log of domestic cereal prices.
- ❖ LNWOP is the log of world oil prices.
- ❖ LNDMP is the log of domestic maize prices.
- ❖ LNWCP is the log of world cereal prices.
- ❖ LNER is the log of exchange rate.

**Model 2** can be stated as:

$$\begin{aligned} \Delta LNDMP_t = & \beta_0 + \sum_{i=1}^n \beta_i \Delta LNWOP_{t-i} + \sum_{i=0}^n \tau_i \Delta LNDMP_{t-i} + \sum_{i=0}^n \alpha_i \Delta LNDMP_{t-i} \\ & + \sum_{i=0}^n \delta_i \Delta LNWMP_{t-i} + \sum_{i=0}^n \gamma_i LNER_{t-i} + \pi Z_{t-1} + \mu_{t-1} \dots \dots \dots (10) \end{aligned}$$

- ❖  $\beta_i, \tau_i, \alpha_i, \delta_i, \gamma_i$  : show the short run effects LNWOP, LNDMP, LNDMP, LNWMP and LNER on domestic maize prices (LNDMP) respectively.
- ❖ LNWMP is the log of world maize prices.

Similarly, **Model 3** can be stated as:

$$\Delta LNDRP_t = \beta_0 + \sum_{i=1}^n \beta_i \Delta LNWOP_{t-i} + \sum_{i=0}^n \tau_i \Delta LNDCP_{t-i} + \sum_{i=0}^n \alpha_i \Delta LNDP_{t-i} + \sum_{i=0}^n \delta_i \Delta LNWRP_{t-i} + \sum_{i=0}^n \gamma_i LNER_{t-i} + \pi Z_{t-1} + \mu_{t-1} \dots \dots \dots (11)$$

- ❖  $\beta_i, \tau_i, \alpha_i, \delta_i, \gamma_i$  : show the short run effects LNWOP, LNDCP, LNDP, LNWRP and LNER on domestic rice prices (LNDP) respectively.
- ❖ LNDP is the log of domestic rice prices.
- ❖ LNWRP is the log of world rice prices.
- ❖  $Z_{t-1}$  is the error correction term (ECT<sub>t-1</sub>) which gives the long run equation in all three Models.
- ❖  $\pi$  is the coefficient of the ECT<sub>t-1</sub> in all three Models.
- ❖  $\mu_{t-1}$  is the stochastic error term that captures all the other unobserved variables that influence cereal prices in Ghana.

### 3.4.1 Unit Root Test

The stationarity characteristic of any series is ascertained using the Unit root test. The series is said to be non-stationary if the test reveals that the series has a unit root. A series that exhibits this unit root property therefore has its mean, variance and auto covariance changing overtime. On the other hand, a stationary series has a constant mean, constant variance and a constant auto covariance; (Hatanaka M, 2003). Time series dataset is usually characterized by non-stationarity or unit root hence the need to test for its presence in order to avoid estimating spurious regressions. Time series datasets mostly break up the conditions of stationarity hence using Ordinary Least Square (OLS) approach in estimating non-stationary series may lead to misleading results and false conclusion of the existence of a relationship between

economic variables. Granger and Newbold (1974) termed the estimation of non-stationary series using OLS as spurious regression.

Many ways of testing the presence of unit root or non-stationarity of a series have been proposed. Examples include the Dickey-Fuller (DF) test, Phillip and Perron (PP) test, Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Scdmidt-Shin (KPSS) test. The most generally used test is the ADF. The ADF test can be formally written as:

$$\Delta x_t = m_1 + m_2t + m_3x_{t-1} + \sum_{i=1}^n \alpha_i \Delta x_{t-i} + \varepsilon_t \tag{12}$$

where  $x_t$  is the series being tested for the presence of unit root. The constant in this equation is  $m_1$  while  $m_2$  is the time trend's coefficient. The error term is denoted by  $\varepsilon_t$  and  $n$  is the lag order of the autoregressive (AR) process,  $\Delta x_t = x_t - x_{t-1}$  and are lagged values of order of  $x_t$  (Green, 2003).

There are three ways by which the ADF test can be applied:

- a) A stochastic walk with a drift. This model is gotten by imposing  $m_2 = 0, m_3 = 0$  in the general ADF equation to get:

$$\Delta x_t = m_1 + \Delta x_{t-1} + \varepsilon_t \dots \dots \dots (12a)$$

- b) A deterministic trend with a drift. This is obtained when  $m_2 \neq 0$ . The general ADF equation is therefore reduced to:

$$\Delta x_t = m_1 + m_2t + \Delta x_{t-1} + \varepsilon_t \dots \dots \dots (12b)$$

- c) A pure stochastic walk without a drift. In this model  $m_1 = 0, m_2 = 0, m_3 = 0$  and hence the general ADF equation becomes:

$$\Delta x_t = \Delta x_{t-1} + \varepsilon_t \dots \dots \dots (12c)$$

The sign of  $m_1$  determines how the series moves. If  $m_1$  is positive, then the series wanders upwards and downwards when  $m_1$  is negative.

The null hypothesis for the ADF test is  $m_3 = 0$  against the alternative hypothesis that  $m_3 \neq 0$ . When the alternative hypothesis is rejected;  $m_3 \neq 0$ , it implies that the series  $x_t$  is non-stationary or has a unit root. In order to be able to reject or accept the null hypothesis, the significance of  $m_3$  must be checked. This can be done by comparing the  $t$  ratio of the coefficient of  $\Delta x_{t-1}$  known as the ADF statistic to the ADF critical values.

The results obtained from the stationarity test are crucial in determining the next step to be carried out. If the series are non-stationary I(1) then a cointegration test must be performed to ascertain the number of cointegrating equations and consequently an error correction model (ECM) will be carried out. On the other hand, if the series exhibits stationarity, I(0), then a vector autoregression (VAR) will be estimated instead of an error correction model (ECM).

### **3.4.2 Cointegration Test**

The Engle-Granger two-step and the Johansen and Juselius approach to cointegration are the most common techniques employed in assessing the existence of a long-run relationship between variables in most economic and financial literature. The Engle-Granger two-step approach developed in 1987 by Engle and Granger is a bivariate approach to cointegration hence can only be used to determine the existence of cointegration between two variables. Also the Engle-Granger approach could lead to simultaneous equation bias if the causality between the two variables of interest runs in both directions. Again employing this approach could give misleading results since it is only able to predict one cointegrating relationship. Hence in the case where there may be more than one cointegrating relationship, this approach is inappropriate. The Johansen approach advanced by Johansen and Juselius (1990) is based on maximum likelihood estimation. This technique is superior to the Engle-Granger two-step approach since it is capable of establishing more than one cointegrating relationship. There

are more than two variables in this study, hence the study adopts the Johansen approach to cointegration in establishing the existence of a long run relationship. Again the Johansen and Juselius (1990) approach performs better than other estimation approaches by including additional lags, even when the errors are not normally distributed or when the dynamics are unknown, and the model is over-parameterized (Gonzalo, 1994).

Formally a  $q$ -dimensional vector autoregressive model, with an error correction model (ECM) is given by:

$$\Delta x_t = \prod x_{t-q} + \sum_{i=1}^{q-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t \quad (13)$$

where  $\Delta$  is the difference operator.

$\Delta x_t = (k * 1)$  vector of  $I(0)$  variables.

$\prod = \sum_{i=1}^q A_i - I$   $I$  = a  $(k*k)$  identity matrix

$\Gamma_i = \sum_{j=1}^i A_j - I$   $I$  = a  $(k*k)$  matrix of parameters.

$S_t$  = constant trend and time trend

$\xi$  = vector of Gaussian zero mean disturbances

The long run matrix  $\prod$  can be disintegrated into the product of  $\alpha$  and  $\beta$ , two  $(k*r)$  matrices each of rank  $r$ , such that  $\prod = \alpha\beta'$ , where  $\beta'$  contains  $r$  cointegrating vectors and  $\alpha$  denotes the speed of adjustment back to equilibrium. The ECM can therefore be written as:

$$\Delta x_t = (\alpha\beta)x_{t-q} + \sum_{i=1}^{q-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t \quad (14)$$

The null hypothesis of testing for  $r$  cointegrating relationships among the variables is stated as:

$$H_0: \Pi = \alpha\beta$$

The null of no cointegration ( $r = 0$ ) indicates  $\Pi = 0$ . If  $\Pi$  is of a rank  $k$ , there is stationarity in the vector process.  $\Pi = 1$  implies one cointegrating relationship and for several cointegrating vectors  $1 < \Pi < k$  (Engle and Granger, 1987).

### 3.5.1 Error Correction Model (ECM)

In order to achieve the first objective of the study, an error correction model (if series are  $I(1)$ ) or a vector autoregression (if series are  $I(0)$ ) will be estimated to assess the long run and short run effects.

The results of the cointegration test to a larger extent influences the choice of model used in the estimation. Following from the outcome of the cointegration test, if the variables are found to be cointegrated then an error correction model (ECM) will be estimated. On the other hand, if the Johansen cointegration test reveal no long run relationship among the variables then a vector autoregression (VAR) will be estimated instead.

The establishment of cointegration between series just reflects the long-run characteristics of the model and often ignores the short-run changing aspects completely. For a model to be deemed an appropriate time series model then that model should be able to explain both the long and short run impacts of the different factors. To this effect an ECM is estimated. The ECM is a group of time-series representations that directly assess the rate at which a regressand:  $X$  comes back to stability after a variation in a regressor:  $Z$ . An ECM can be explained as a representation in which developments of a variable in any time period is associated with the preceding period's gap from long-run stability.

The Granger representation theorem shows that variables must be integrated of order (1,1) if there exists a dynamic linear model with stationary disturbances and the data are I(1). The ECM is used to correct aberrations from the long-run equilibrium that still occur even when the existence of cointegration is established.

A simple short-run adjustment model can be written as:

$$x_t = m_0 + \beta_0 z_t + \beta_1 z_{t-1} + m_1 x_{t-1} + \varepsilon_t \quad (15)$$

where  $x_t$  is the regressand,  $z_t$  is the regressor,  $x_{t-1}$  and  $z_{t-1}$  are the lagged values of  $x_t$  and  $z_t$  respectively.  $m_0, m_1, \beta_0, \beta_1$  are the model parameters and  $\varepsilon_t$  is the stochastic error term assumed to be  $\varepsilon_t \sim i N 0, \delta^2$ .

The problem of spurious regression is most often than not evident in short-run adjustment models and as a result creates an illusion of causal relationship which in actual sense does not exist. A way to arrest this problem is to de-trend the data. This de-trending is done by estimating the first difference of the short-run adjustment model. However, de-trending also eliminates relevant information about the long-run performance of the variables. Therefore, in order to avoid spurious regression and not eliminate relevant information about the performance of the variables an ECM is estimated instead. The ECM can be obtained through the process below:

$$x_t = m_0 + \beta_0 z_t + \beta_1 z_{t-1} + m_1 x_{t-1} + \varepsilon_t$$

Subtracting  $x_{t-1}$  from both side the LHS and RHS of the equation and simplifying it gives

$$\Delta x_t = m_0 + \beta_0 z_t + \beta_1 z_{t-1} - (1 - m_1)x_{t-1} + \varepsilon_t$$

Subtracting again  $\beta_0 z_{t-1}$  from both sides gives:

$$\Delta x_t - \beta_0 z_{t-1} = m_0 + \beta_0 z_t - \beta_0 z_{t-1} + \beta_1 z_{t-1} - (1 - m_1)x_{t-1} + \varepsilon_t$$

$$\Delta x_t = m_0 + \beta_0 \Delta z_t + (\beta_0 + \beta_1)z_{t-1} - (1 - m_1)x_{t-1} + \varepsilon_t$$

Simplifying the equation gives:

$$\Delta x_t = \beta_0 \Delta z_t - (1 - m_1)x_{t-1} - \varphi_0 - \varphi_1 z_{t-1} + \varepsilon_t \quad (16a)$$

$$\Delta x_t = \beta_0 \Delta z_t + \mu_0 x_{t-1} - \varphi_0 - \varphi_1 z_{t-1} + \varepsilon_t \quad (16b)$$

where  $\varphi_0 = \frac{m_0}{(1-m_1)}$ ,  $\varphi_1 = \frac{(\beta_0+\beta_1)}{(1-\beta_1)}$  and  $\mu_0 = -(1 - m_1)$

Equation (16b) depicts the Error Correction Model (ECM).  $\beta_0$  is the short-run impact of  $z_t$  on  $x_t$ . The speed of adjustment back to equilibrium is denoted by  $\mu_0 = -(1 - m_1)$  and  $\varphi_1$  shows long run impact. The value of  $\mu_0$  should be negative to ensure that the system converges to the long run equilibrium path. A positive sign of  $\mu_0$  implies divergence of the system from the long run equilibrium path. The closer the value of  $\mu_0$  is to -1, the faster and larger the percentage of the deviation is corrected and if the value of  $\mu_0$  is approaching 0 then the slower the adjustment process (Engle and Granger, 1987).

### 3.5.2 Generalized Impulse Response Functions (GIRF)

The generalized impulse response function (GIRF) will also be estimated to complement the short run effects. Structural vector autoregression (VAR) engrafts economic theory into models of time series thereby providing expedient and strong structure for policy advancements. Impulse response function (IRF) is used to assess how innovations to a variable influence other endogenous variable and the duration it takes for the effect to die out.

IRF is an important tool in empirical and efficient policy analysis. IRF is sensitive to the ordering of the variables and also omission of relevant variables could lead to significant misrepresentations in IRF and render results insignificant. The generalized impulse response function (GIRF) developed by Koop et al. (1996) and Pesaran and Shin (1998) is superior to the IRF since it is not sensitive to the ordering of the variables hence not subject to Lutkepohl's orthogonality critique.

An innovation to a variable affect both that variable and other endogenous variables in the model. Thus, when a unit innovation is applied to a variable, generalized impulse response functions (GIRF) can be used to assess the response of the dependent variable to that innovation in the VAR. To throw more lights, GIRF considers the shock to one of the disturbances on present and expected values of the endogenous variables. IRF should die out in time for stationary vector autoregressions (VARs).

### **3.6 Causality Test**

To address the second objective of this thesis the Granger Causality test and alternative VECMs will be estimated to assess the causal relationships between these variables.

A variable is said to Granger-cause another variable if the former helps in predicting the later or if the coefficients of the lagged values of the former are statistically significant. The Granger causality test by Granger (1969) is used to assess the extent to which the current variable say X can be explained by a past value of say Z and also to check whether including past values can improve the explanation.

The Granger causality test should be run on only stationary variables (I(0)) series and to test the assertion of whether  $\Delta Z$  aids in predicting  $\Delta X$ , the F-test can be used. The test can be formally written as:

$$\Delta Z_t = \sum_{i=1}^n \beta_{1i} \Delta Z_{t-i} + \sum_{i=1}^n \gamma_{1i} \Delta X_{t-i} + \varepsilon_{1t} \quad (17a)$$

$$\Delta X_t = \sum_{i=1}^n \beta_{2i} \Delta Z_{t-i} + \sum_{i=1}^n \gamma_{2i} \Delta X_{t-i} + \varepsilon_{2t} \quad (17b)$$

The null hypothesis that is tested is that Z does not Granger-cause X, and X does not Granger-cause Z i.e.  $H_0: \gamma_{1i} = 0$ , and  $H_0: \beta_{2i} = 0$ ,  $i = 1, 2, \dots, m$ .

The two variables are said to be independent of each other if the null hypothesis is not rejected implying no causal relationship between them. When the two null hypotheses are rejected it implies causality in both direction and if only one is reject it indicates a unidirectional causality between the variables. The Pairwise Granger Causality test was chosen because the study seeks to find causality between oil prices and cereal prices only.

### **3.7 Description and Sources of Data**

#### **3.7.1 Data**

To estimate the effect of world oil prices on cereal prices in Ghana, monthly time series data for world prices of oil is obtained from the US Energy Information Administration (EIA). Prices of domestic individual cereal prices are obtained from the Statistics Research and Information Directorate (SRID) of the Ministry of Food & Agriculture (MoFA), Ghana and that of world cereal prices is sourced from Food and Agriculture Organization (FAO). Data on exchange rates for the period under consideration is obtained from the Central Bank of Ghana (BoG). The time period for the study spans from January 1990 to December 2015 due to data availability constraints. The period of study captures two oil price shocks; the 2007-2008 world oil price shock and that of the 2014-2015 world oil price shock.

#### **3.7.2 Description and Measurement of Variables**

The measurements and descriptions of the regressand and the regressors contained within in the empirical model of this study are as follows:

##### **❖ Domestic Cereal prices**

The domestic cereals included in the estimation of the empirical model are maize and rice. Prices of these domestic cereals were sourced from the Statistical and Research Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA), Ghana. The prices of maize used represent the national wholesale average Ghana Cedi per metric ton (MT). That of rice is also the national wholesale average of local rice in Ghana Cedi per metric ton (MT).

##### **❖ World Cereal prices**

The world cereals added to the model to be estimated are the same as the basket of domestic cereals included. These are maize and rice. Prices of these world cereals were obtained from the Food and Agriculture Organization (FAOSTATS) database. The maize price used is the U.S. No.2 Yellow, FOB Gulf of Mexico, U.S. price. The rice price used is the 5% broken

milled white rice. The unit of measurement for all these cereals are in US dollar per metric ton. World cereal prices are added to assess the indirect effects of world oil prices on Ghana's cereal prices as shown by Chen et al., (2010) and Ackah et al., (2012).

#### ❖ **World Oil Price**

The monthly world oil price series was obtained from the US Energy Information Administration (EIA) and denote an average of the Europe Brent Spot Price FOB, Cushing, and OK West Texas Intermediate (WTI) Spot Price FOB. The inclusion of world oil prices in the empirical model is because to the inflationary effect oil prices impart. Oil is one of the relevant elements in the cost structure of the production, transportation and services subdivisions. Also, general price levels could be affected when consistent increases in world oil prices lead to rise in CPI expectations and as a result, workers demand higher wages to compensate for the increased cost of living. Additionally, oil price increase provides a reason for the production of biofuel; an alternative energy source which further forces food commodity prices to further increase.

#### ❖ **Exchange Rate**

The nominal exchange rate used in this study is the monthly average bilateral nominal exchange rate of Ghana Cedi in relation to the US dollar. Most of the empirical literature regularly use an exchange rate index relative to the basket of other currencies, known as the nominal effective exchange rate. Nonetheless, in this study the exchange rate employed is the nominal bilateral exchange rate owing to the fact that most of Ghana's imports and exports are valued in US dollars and the US dollar makes up most of the multi-currency basket. The amount of domestic currency per a unit of US dollar; the direct quotation is used which means that an increase in the exchange rate implies a depreciation of the Ghana Cedi, whereas a decrease in the exchange rate denotes an appreciation of the Ghana Cedi. The exchange rate data was sourced from the database of the Bank of Ghana (BoG).

A summary of the description and measurement of the dependent and independent variables included in the empirical estimation is shown in Table 3.1.

Table 3.1: Summary of description and measurement of variables.

VARIABLE	DESCRIPTION OF VARIABLE	MEASUREMENT
<b>DEPENDENT VARIABLE</b>		
Domestic Maize prices	National wholesale average	This measured by Ghana cedi per metric ton
Domestic Rice Prices	National wholesale average local rice	This measured by Ghana cedi per metric ton
Domestic Cereal Prices	Represents a basket of domestic cereal prices	This measured by Ghana cedi per metric ton
<b>INDEPENDENT VARIABLE</b>		
World Oil Price	An average of the Cushing, OK West Texas Intermediate (WTI) Spot Price FOB, and Europe Brent Spot Price FOB	This measured as US dollar per barrel.
Exchange rate	Nominal exchange rate	It measured as monthly average bilateral nominal exchange rate of Ghana cedi in relation to the US dollar.
World Maize Prices	U.S. No.2 Yellow, FOB Gulf of Mexico, U.S. price	This is measured as US dollar per metric ton
World Rice Prices	5% broken milled white rice, Thailand price	This is measured as US dollar per metric ton
World Cereal Prices	Represents a basket of world cereal prices	This is measured as US dollar per metric ton

Source: Author's inference from the theoretical and empirical literature

### 3.7.3 Descriptive Statistics

Table 3.2: Summary Statistics of Variables from 1990-2015.

Series	Observation	Mean	Standard Deviation	Minimum	Maximum
Domestic Maize Prices	312	313.93	377.48	5.24	1728.67
Domestic Rice Prices	312	571.61	624.43	15.35	2762.30
World Oil Prices	312	47.26	32.85	10.59	133.10
Exchange Rate	312	0.91	0.90	0.03	4.19
World Maize Prices	312	145.84	63.96	75.06	332.95
World Rice Prices	312	348.43	146.74	162.10	1015.21
Domestic Cereal Prices	312	424.84	479.48	10.87	1834.32
World Cereal Prices	312	212.02	85.38	113.05	500.72

Source: Author's computations using E-views 9

The total number of observations used in this thesis sums up to three hundred and twelve (312). This consist of monthly data of seven series each having twenty-six (26) observational years. Domestic maize prices vary from Gh5.24 Cedis per metric ton to Gh1728.67 Cedis per metric ton with an average price of Gh314 Cedis per metric ton. Domestic rice prices also reported an average price of about Gh572 Cedis per metric ton with its prices ranging from about Gh15 Cedis per metric ton to about Gh2762 Cedis per metric ton. Domestic maize prices have the lowest average price compared to the other domestic price series in the study. Domestic cereal prices also recorded a mean price of about Gh424.8 Cedis per metric ton with a minimum price of Gh10.9 Cedis per metric ton and a maximum price of Gh1834 Cedis per metric ton.

The average prices for world maize and rice are also approximately \$146 and \$348 per metric ton respectively. The prices of world maize fall between \$75.1 and \$ 332.9 per metric ton. That of world rice is between \$162.1 and \$1015.2 per metric ton.

The mean value of world oil prices stands at \$47.3 per barrel with its prices lying between \$10.6 per barrel and \$133 per barrel. Exchange rates also had an average of about Gh0.91 Cedis to the dollar (\$). The exchange rate ranges from 0.03 to 4.19 Ghana Cedis to the dollar. Within the study period, world cereal prices had a minimum value of \$113.05 per metric ton and a maximum value of \$500.72 per metric ton with an average price of \$212.02.

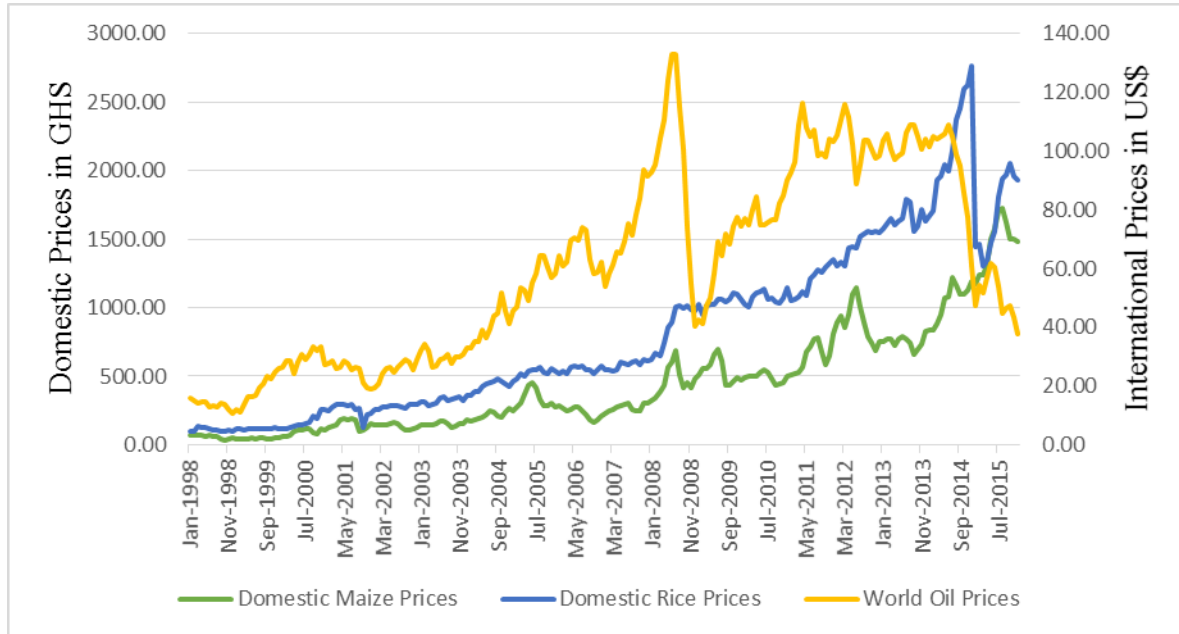
#### **3.7.4 Trend of Variables**

Maize is important in Ghana because it is found in most of the indigenous foods and also, it is the primary feed for most livestock. Again, 64% of families having farms in Ghana cultivate maize (FASDEP, 2002). Maize is commonly grown in every part of Ghana but about 70% of production is concentrated in the Central, Eastern, Northern, Brong-Ahafo and Ashanti regions (Amanor-Boadu, 2012).

Rice is also an important food crop in Ghana although its consumption per capita (24kg/annum) is lower than the consumption per capita (43.8kg/annum) of maize (MofA, 2013). The output of rice per hectare in Ghana oscillated between 1.7 and 2.7 metric tons per hectare between the years 2000 and 2010. However, the production level burgeoned to an estimated 294,962 metric tons in 2011 (MoFA, 2013). This increase can be largely attributable to programs initiated by the MoFA such as the Block Farm programme of 2009. In spite of the appreciable increase in rice production in Ghana, it was unable to meet demand which was 581, 352 metric tons as at 2011 and is due to the fact that Ghana's sustainability level for rice production is 30% which is invariably low. According to USAID (2011), production in the Volta, Northern and Upper East regions accounted for about 80% of the

total national output in Ghana and 73% of total production area in 2010. About half of the rice consumed in Ghana is however imported.

Figure 3.4: Trend of Variables



Source: Author's computation.

Figure 3.4 shows the plot of domestic maize prices, domestic rice prices and world oil prices. Evidence from the graph shows domestic maize prices was stable between the years 1998 to 2000. Nevertheless, after that period, prices began to increase slowly till 2005. Domestic maize prices then began to decrease up to 2006. However, over the entire time period domestic maize prices have showed an increasing trend. The sharp increments in domestic maize prices recorded in the 2005 and 2008 periods could be attributed to the high demand for maize in the poultry industry due to the aid the poultry industry received from government and also the increase in tariffs on imported chicken which served as a disincentive to import chicken from the international market (Codjoe, 2007). Thus, this policy led to local farmers producing more chicken; hence demand for maize increased leading to increases in domestic maize prices. Figure 3.4 also indicates that, domestic rice prices showed fairly steady prices from 1998 to 2000. The increase turned out to be more

evident from the last three months of 2007 to the first six months of 2008. In the local market, the acute increase can be ascribed to the international oil and food crises that hit Ghana during that period. Even though rice is a staple crop, importation is very high since local production does not match domestic demand (MoFA, 2013). Codjoe, (2007) showed that the production of rice in Ghana in 2007, was 20% less than the total rice imported. This therefore implies that world rice prices will affect domestic rice prices.

The graph of world oil prices in Figure 3.4 shows a similar trend to that of domestic maize and rice prices. The graph shows steady increments in world oil prices to 2006. However, world oil prices reached a record high of about \$130 per barrel in 2008. On main explanation to the record high reached in 2008 is the shortfall in supply from major oil producing and exporting countries (Rosegrant et al., 2008).

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Introduction

This chapter sheds light on the empirical evidence on the link between world prices of oil and Ghana's cereal (maize and rice) prices. Test for stationarity (unit root), cointegration analysis and the discussions of the observed outcomes of the models are presented. Again the discussions on both the long and short run causal relationships are shown in this section.

#### 4.2 Test Results for Unit Root

The examination of the characteristics of the all the variables used in estimating the empirical model in this study is of primary importance. In this light, the stationarity properties of the variables in this study were examined using the Phillips and Perron (PP) and Augmented Dickey-Fuller (ADF) tests for unit roots. The series were first tested at levels with the null hypothesis; existence of unit root (non-stationarity) as against the alternative hypothesis; no unit root in the series (stationarity). The results of the test for stationarity of the series at levels are reported in Table 4.2.1.

Table 4.2.1: Unit Root test at levels

Series	ADF Test		PP Test	
	t-stats	prob-value	t-stats	prob-value
In domestic maize prices	-0.569260	0.8739	-1.169276	0.6885
In domestic rice prices	-0.991066	0.7572	-0.970102	0.7645
In world oil prices	-1.621097	0.4706	-1.456179	0.5546
In exchange rate	-1.363044	0.5272	-4.247379	0.0006***
In world maize prices	-1.644408	0.3657	-1.652884	0.4543
In world rice prices	-1.800412	0.3800	-1.761710	0.3992
In domestic cereal prices	-1.082729	0.7234	-1.027038	0.7444
In world cereal prices	-1.751777	0.4042	-1.472094	0.5466

Source: Author's computations using E-views 9 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

The results presented in Table 4.2.1 are the test for stationarity for all the variables in levels. The Phillips and Perron (PP) test revealed that all the series are non-stationary at 1%, 5%, and 10% significance levels with the exception of the exchange rate variable which is integrated of order zero. Thus, the exchange rate variable is  $I(0)$  with all the other variables  $I(1)$ .

However, the null hypotheses of non-stationarity of all the series in the model were not rejected at all three levels of significance (1%, 5%, and 10%) when the Augmented Dickey-Fuller (ADF) test is employed. Therefore, all the variables in the model exhibit the unit root property. Thus, all the variables (ln domestic maize prices, ln domestic rice prices, ln world oil prices, ln world maize prices, ln world rice prices, ln exchange rate, ln domestic cereal prices and ln world cereal prices) are non-stationary therefore statistical inferences drawn from estimating these series with the conventional OLS method will give misleading conclusions.

Table 4.2.3: Unit Root test at first difference

Series	ADF Test		PP Test	
	t-stats	prob-value	t-stats	prob-value
ln domestic maize prices	-4.438665	0.0035***	-13.08623	0.0000***
ln domestic rice prices	-22.32012	0.0000***	-22.82480	0.0000***
ln world oil prices	-12.81087	0.0000***	-12.35989	0.0000***
ln exchange rate	-9.699795	0.0000***	-173.1172	0.0001***
ln world maize prices	-6.740836	0.0000***	-13.26294	0.0000***
ln world rice prices	-11.64006	0.0000***	-11.21437	0.0000***
ln domestic cereal prices	-21.38289	0.0000***	-21.29033	0.0000***
ln world cereal prices	-11.16860	0.0000***	-10.90298	0.0000***

Source: Author's computations using E-views 9. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

As stated earlier, the test of stationarity (unit root) is a necessity for the specification of an appropriate econometric model. The use of non-stationary variables in econometric models leads to spurious regressions. One way of arresting this problem is by differencing these variables in order to get rid of the non-stationarity property. The number of times a variable is differenced to eliminate the non-stationarity feature gives the order of integration of that variable. Thus, if a variable is differenced twice before the variable becomes stationary then that variable is integrated of order two (I(2)). At all three significant levels (1%, 5% and 10%), both the Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) test show that all the series in the model are stationary in their first difference. Thus, the null hypothesis of non-stationarity is rejected. This therefore implies that all the series have an integrated order of one (i.e. I(1) processes). The determination of this order of integration is very crucial since the specification of the cointegrating relationship between the variables, its ensuing Vector Error Correction Model (VECM) and long run causality test depend on it as the variables need to be in the first difference before included in the models. The results for the test for stationarity in the first difference is reported in Table 4.2.2

### **4.3 Cointegration Tests**

As explained in the third chapter, the Johansen-Juselius (J-J) test for cointegration is needed to estimate the changing aspects of the model when the series are integrated of order one (I(1) process). The check demands that all the series that are contained within the model are of the same order of integration. Although the PP test revealed that the exchange rate variable was I(0) at levels, this study chose the results obtained from the ADF test given that it is more problematic if a series is I(1) and it is treated as I(0). This is because if a series is truly I(1) and used as I(0), then it can dominate other I(0) variables and lead to spurious regression. The reverse (i.e. I(0) treated as I(1)) however, will mean over differencing and results in losing some of the long run information (Green, 2003). Nonetheless, standard test performed using

this series will be correct. Also, the exchange rate variable included in the literature consider it as an  $I(1)$  variable (Nazlioglu and Soytas, 2011; Ackah et al., 2012; Loloh, 2014; Wong and Shamsudin, 2017). The study hence proceeds to test for cointegration relationship employing the J-J multivariate test for cointegration among the series.

From the stationarity assessment already discussed in the preceding section, it is evident that all the series are of the same integration order (i.e. all the series are an  $I(1)$  process) and as such the J-J test for co-integration can be used to know the number of cointegrating relationships among the series. The existence of cointegration therefore means there is a long run relationship. The total number of long run associations is established using both the trace and Maximum-Eigen test values. The outcome of the co-integration test is discussed in this sub-section.

The results of the J-J cointegration for Models 1 and 2 indicate that, the null hypothesis of no long run link between the series is rejected by the two test (trace and maximum eigenvalue) statistics. However, the null hypothesis of at most 1 is not rejected for both at 5% level of significance. Model 1 tests for cointegration when domestic cereal prices is the dependent variable while model 2 tests for cointegration when domestic maize prices is the dependent variable. However, in Model 3, where domestic rice prices is the dependent variable, both the trace and maximum eigenvalue statistics of the J-J cointegration test show that there are two (2) cointegrating relationships between the variables at 5% significance level. The results of the J-J cointegration test for Models 1, 2 and 3 are shown in Tables 4.3.1, 4.3.2 and 4.3.3 respectively.

Table 4.3.1: Johansen- Juselius (J-J) Cointegration test Results (Model 1)

<b>Null Hypothesis</b>	<b>Trace-Stats</b>	<b>0.05 Critical Value</b>	<b>Max- Eigen Stats</b>	<b>0.05 Critical Value</b>
<b>None *</b>	124.35	69.82	77.20	33.88
<b>At most 1</b>	47.15	47.86	26.92	27.58
<b>At most 2</b>	20.23	29.80	13.64	21.13
<b>At most 3</b>	6.59	15.49	4.38	14.26
<b>At most 4</b>	2.21	3.84	2.21	3.84

Source: Author's computation using E-views 9. \* shows non-acceptance of null hypothesis at 0.05 significance level.

Table 4.3.2: Johansen- Juselius (J-J) Cointegration test Results (Model 2)

<b>Null Hypothesis</b>	<b>Trace-Stats</b>	<b>0.05 Critical Value</b>	<b>Max- Eigen Stats</b>	<b>0.05 Critical Value</b>
<b>None *</b>	116.56	69.82	70.82	33.88
<b>At most 1</b>	45.75	47.86	25.38	27.58
<b>At most 2</b>	20.37	29.80	13.91	21.13
<b>At most 3</b>	6.47	15.49	4.07	14.26
<b>At most 4</b>	2.39	3.84	2.39	3.84

Source: Author's computation using E-views 9. \* shows non-acceptance of null hypothesis at 0.05 significance level.

Table 4.3.3: Johansen- Juselius (J-J) Cointegration test Results (Model 3)

<b>Null Hypothesis</b>	<b>Trace-Stats</b>	<b>0.05 Critical Value</b>	<b>Max- Eigen Stats</b>	<b>0.05 Critical Value</b>
<b>None *</b>	104.71	69.82	56.57	33.88
<b>At most 1*</b>	48.14	47.86	28.57	27.58
<b>At most 2</b>	19.57	29.80	13.42	21.13
<b>At most 3</b>	6.15	15.49	4.05	14.26
<b>At most 4</b>	2.10	3.84	2.10	3.84

Source: Author's computation using E-views 9. \* shows non-acceptance of null hypothesis at 0.05 significance level.

**Objective 1**

Examine both the short-run and long-run effects of world oil price changes on domestic cereal, domestic maize and domestic rice prices.

**4.4 Vector Error Correction Model (VECM)**

The establishment of co-integration signifies that domestic cereal prices (maize and rice) and the other independent variables in the model namely world oil prices, exchange rate and world cereal prices (maize and rice) have a mutual connection in the long run. The long run estimates of this study are gotten from the estimation of a VECM. Also, the coefficients from the system results of the VECMs are used to examine the short run elasticities of the Models. The results of the various short run and long run results are shown in the Tables 4.5.1 and 4.6.1 respectively under this sub-section. The lags included were based on lag selection tests shown in APPENDIX E.

**4.5 Short run Elasticities**

Table 4.5.1: Parsimonious Results for Short Run Estimates

**Dependent Variables:  $\Delta$  Domestic Cereal,  $\Delta$  Domestic Maize &  $\Delta$  Domestic Rice Prices Respectively.**

Variable	Model 1	Model 2	Model 3
ECT(-1)	-0.243*** (0.044)	-0.137*** (0.050)	-0.287*** (0.063)
$\Delta$ world oil prices(-1)		-0.153* (0.081)	
$\Delta$ world oil prices (-2)		0.184** (0.085)	
$\Delta$ domestic cereal prices (-1)	0.327*** (0.065)		
$\Delta$ domestic cereal prices (-2)			0.256*** (0.090)
$\Delta$ exchange rate(-1)			0.196** (0.077)
$\Delta$ exchange rate (-2)		0.378*** (0.109)	0.205** (0.085)
$\Delta$ exchange rate (-3)		0.282***	0.158**

		(0.097)	(0.071)
$\Delta$ domestic maize prices (-1)	0.209***	0.405***	
	(0.038)	(0.070)	
$\Delta$ domestic maize prices (-2)	0.128***	0.017**	
	(0.039)	(0.071)	
$\Delta$ domestic maize prices (-3)	0.105***		
	(0.038)		
$\Delta$ world maize prices(-1)		0.430***	
		(0.116)	
$\Delta$ world maize prices (-2)		0.285**	
		(0.123)	
$\Delta$ world maize prices (-3)		0.221*	
		(0.119)	
R-squared	0.3443	0.2525	0.2435
<b>Adjusted R-squared</b>	0.3083	0.2114	0.1991

Source: Author's computations using E-views 9 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Robust standard errors in parentheses.

Table 4.5.1 presents the short run dynamics of the three Models (1, 2 and 3) estimated. In Model 1, domestic cereal prices is the dependent variable while domestic maize prices and domestic rice prices are dependent variables for Models 2 and 3 respectively. The vector error correction models estimated reveal that the coefficient of the error correction term (speed of adjustment) which shows how fast the disequilibrium that occurs in model is corrected as they move towards long run stability in all three models was significant at 1%. The coefficients of the ECT for Models 1, 2 and 3 are -0.243, -0.137 and -0.287 respectively. This implies that about 24%, 14% and 28% of the disequilibrium in Models 1, 2 and 3 due to shocks in the short run are corrected as they move towards the long run. The coefficients also carry the expected negative sign which imply convergence.

In Model 1, there is a positive significant relationship between the lags of domestic cereal prices, and domestic cereal prices. The lags of domestic cereal prices also influence domestic rice prices (Model 3) positively. Again, the lags of domestic maize prices significantly affect domestic cereal prices. This supports the findings of Chen et al., (2010) who had similar

results. The lags of exchange rates also positively influenced domestic maize and domestic rice prices. The effects of the lags of the variables on the dependent variables goes to confirm the Cobweb model (1934) that shows that lags of prices of variables aid in the explanation of their price in the current period.

In Model 2, world oil prices is found to significantly influence domestic maize prices in the short run at 5% all other things being equal. This is shown by the effects of the first and second lags of world oil prices effect on domestic maize prices. However, world oil prices do not affect domestic cereal prices, (Model 1) and domestic rice prices (Model 2) in the short run. This result is not dissimilar to the findings of Nwonko et al., (2016) who found that world oil prices only affected domestic maize price but not the other cereals. The reason could be maize being an energy crop and hence an increase in world oil price triggers an increase the demand for maize because of its use in biofuel production and consequently higher prices. Also, in the short run, world maize prices is found to significantly influence domestic maize prices positively.

#### 4.6. Long run Elasticities

Table 4.6.1: Parsimonious Results for Long Run Models

**Dependent Variables: Domestic Cereal, Domestic Maize & Domestic Rice Prices respectively.**

Variable	Model 1	Model 2	Model 3
world oil prices	0.1096* (0.0315)	0.1560* (0.0576)	0.2466** (0.0495)
exchange rate	0.3353* (0.0438)	0.3934* (0.0893)	0.9169** (0.0197)
world cereal prices	0.2222* (0.0455)		
domestic cereal prices		1.4720* (0.0952)	
domestic maize prices	0.6134* (0.0438)		
domestic rice prices			
world maize prices		0.2471* (0.0716)	
world rice prices			0.5232** (0.0612)
CONSTANT	0.8970*	1.3163*	2.2881**

Source: Author's computations using E-views 9 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Robust standard errors in parentheses.

Again, in Model 1, domestic cereal prices is the dependent variable while domestic maize prices and domestic rice prices are dependent variables for Models 2 and 3 respectively.

The long run estimates for Model 1 indicate that world oil prices, exchange rate, world cereal prices and domestic maize prices all have positive influences on domestic cereal prices. Also, the coefficients of these variables are all significant at 10%. The coefficient of world cereal prices is 0.2222. This therefore means that, all other things being equal, a percentage increase in world cereal prices will lead to a 0.2222 percentage points increase in domestic cereal

prices. Also, a percentage increase in exchange rates holding all other variables constant imply a 0.3353 percentage points increase in domestic food prices. These findings are in line with results obtained by Ackah et al., (2010) and Bakucs and Ferto (2013) that world food prices and exchange rate have positive effects on domestic food prices. This is not unexpected as Ghana is a net importer of food hence world food prices and exchange rates can easily affect domestic prices. Also, world oil prices has a an elasticity of 0.1096 which is also in agreement with studies by Chen et al., (2010), Merkusheva and Rapsomanikis (2014), and Gilbert and Mugeru (2014) that world oil prices are the long run drivers of food prices.

Model 2's long run estimates presented in Table 4.6.1 reveal that all the variables, i.e., world oil prices, exchange rates, world maize prices and domestic cereal prices all have positive effects on domestic maize prices. The coefficients of the all the variables in Model 2A are significant at 10%. The elasticities for exchange rate, world maize prices, domestic cereal prices and world oil prices are 0.3934, 0.2471, 1.4720 and 0.1560 respectively. The positive effect exchange rate, world maize prices, domestic cereal prices and world oil prices have on domestic maize prices is expected. Also, the results show that the effect of domestic cereal prices on domestic maize prices is elastic. The other variables however, had inelastic effects on domestic maize prices.

The long run estimates of Model 3 presented in Table 4.6.1 show that the coefficients of world rice prices (0.5232), exchange rate (0.9169) and world oil prices (0.2466) are all positive and significant at 5% which is not surprising as it is supported by Ackah et al., (2010) and Nazlioglu and Soytas (2011) who found a positive effect of world oil prices, exchange rate and world food prices on domestic food prices. In Model 3A, exchange rates had the highest effect on domestic rice prices. This is to be expected as most of the rice consumed in Ghana is imported (MoFA, 2013).

In sum, it is evident in all the three long run Models that, there is a positive and significant long run relationship between domestic cereal, domestic maize and domestic rice prices and exchange rate. Thus, an increase in the exchange rate (depreciation of the Ghana cedi relative to the US dollar) leads to an increase in domestic cereal prices. The exchange rate variable was included to capture the effect of world oil prices through transport and production inputs cost channel as discussed in chapter three. Thus, as exchange rate increases (i.e. depreciates), it leads to increase in input costs such as inorganic fertilizer. In Ghana, majority of the fertilizer used is imported (MoFA, 2015). Therefore, higher input costs will increase the production costs of these cereals and consequently translate to higher domestic prices. Again, Ghana is not able to meet the domestic demand of food particularly the cereals in this study, the appreciation of the exchange rate therefore creates a deficit in supply of these crops leading to excess demand of these crops and consequently increments in their prices. This result is supported by the empirical works of Ackah et al., (2010) and Nazlioglu and Soytas (2011).

Again, world maize and rice and prices have a positive significant influence on domestic cereal maize and rice prices in the long run. Thus, as Ghana is a net importer of food, it implies that higher international food prices will be translated into domestic food prices as shown by Ackah et al., (2010). Also, the dependence on biofuel as an alternative source of energy when world oil prices increase could explain why world maize and rice prices positively influence domestic prices. Although the dependence on biofuel in Ghana is low, world dependence on biofuel indirectly affects domestic cereal prices. Thus, increased world demand for biofuel because of increased world oil prices creates a rivalry between the cultivation of food crops and energy crops. The increased world oil prices make biofuel production more attractive thereby leading to an increase in the demand for energy crops. This consequently increases world energy crop prices. And since Ghana is a net importer of

food, the higher world prices are then translated to domestic prices (Chen et al., 2010; Ibrahim, 2015).

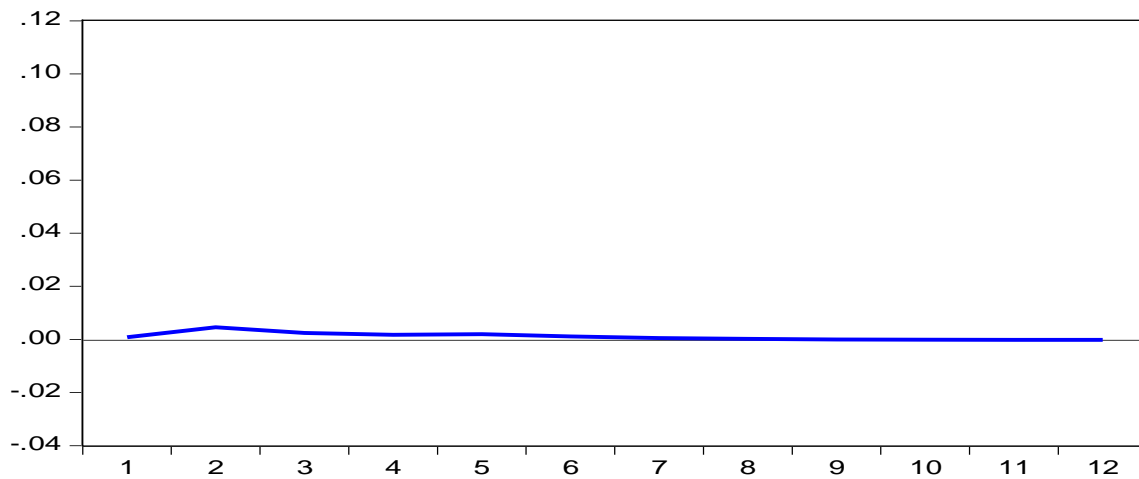
And finally, world oil prices are also found to significantly impact domestic food prices (maize and rice) positively. This is a plausible result since modern agriculture relies greatly on crude oil in each phase of food production and marketing. The worldwide implementation of seed fertilizer technology is energy intensive. Hence, production of food has become more dependent on chemical fertilizers, which uses crude oil as its primary input. Increases in oil prices therefore raise the costs of producing cereal crops. For instance, the prices of some fertilizers (e.g. triple super phosphate) in US dollar increased by more than 160 percent in the first two months of 2008, compared to the same period in 2007 (Arshad and Hameed, 2009). Thus, increments in world oil prices lead to relatively higher prices of inputs (i.e. oil) of production. Higher production costs inhibit supply and thus translate to increases in domestic cereal prices. This is consistent with the findings of Dillon and Barrett (2015).

The efficiency of the Models is determined by performing residual diagnostic tests. The Breusch-Godfrey Serial Correlation test and the Breusch-Pagan-Godfrey test for heteroscedasticity are used to check for serial correlation and heteroscedasticity correspondingly. The outcomes of the residual diagnostic checks are shown in Appendix B. The null hypothesis of no serial correlation is not rejected at all levels of significance for Models 1, 2 and 3. Likewise the null hypotheses of the residuals being homoscedastic are not rejected for all three Models. The CUSUM test was carried out for all three Models to assess the stability of the Models. All three Models were found to be dynamically stable at 5%. The CUSUM tests are shown in APPENDIX D.

#### 4.7 Generalized Impulse Response Functions

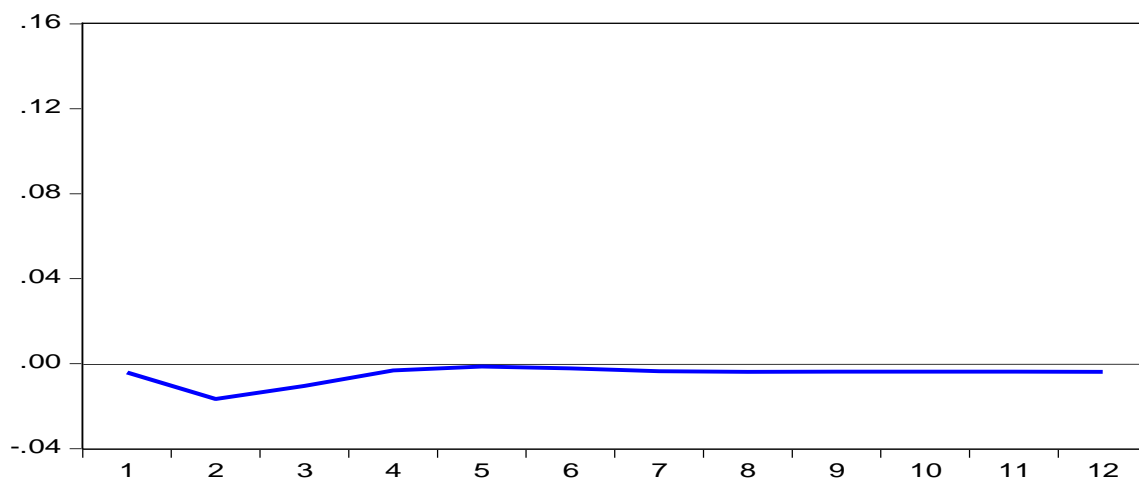
The impulse response shows how the variables in the model react to a positive one standard deviation shock to the VAR system and how long it takes for shocks to die out. The impulse response functions are estimated in this study to complement the short run analysis of the relationship between domestic cereal (maize and rice) prices and world oil prices.

Figure 4.7.1: Response of domestic cereal prices to world oil prices (Model 1)



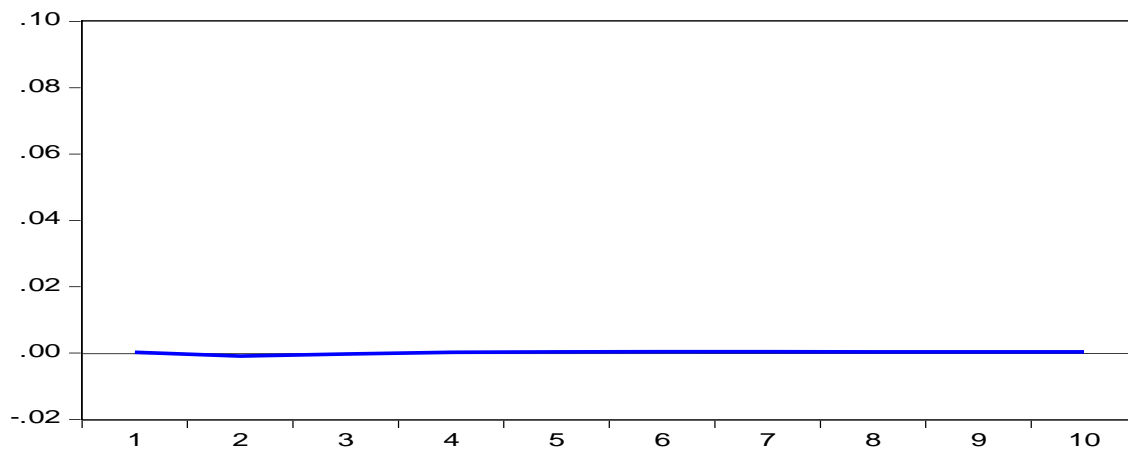
Source: Author's computation using E-views 9

Figure 4.7.2: Response of domestic maize prices to world oil prices (Model 2)



Source: Author's computation using E-views

Figure 4.7.3: Response of domestic rice prices to world oil prices (Model 3)



Source: Author's computation using E-views 9

The impulse responses for Models 1 and 3 depicted in Figures 4.7.1 and 4.7.3 show that domestic cereal prices (LNDCP), and domestic rice prices (LNDRP) do not respond to positive shocks in world oil prices (LNCRO) as confirmed by the short run estimates presented in sub-section 4.5.1. However, from the first to the second month, domestic maize prices (LNDMP) responded negatively to positive shocks in world oil prices. After the second month positive shocks to world oil prices induced a positive response from domestic maize prices to the third month. The responses were then negative which remain steady throughout the remaining 10 months. This confirms the results from the short run analysis. The response of domestic maize prices to positive shocks in world oil prices is shown in Figure 4.7.2.

**Objective 2:** Examine the direction of causation between these variables

To address the second objective, the short run and long run causality test results are presented in this sub-section. The Pairwise Granger Causality test is conducted to identify the direction of causality in the short run, while the long run causality results is obtained from the estimation of alternative VECMs.

## 4.8 Causality tests

### 4.8.1 Short Run Causality

As already highlighted in Chapter 3, the variables to be used in the Granger Causality test needs to be stationary and as such the first difference of the variables will be used in this test.

The result of the Short run causality is presented in Table 4.8.1

Table 4.8.1: Pairwise Granger Causality Test

Null Hypothesis	Observations	F-Statistics	Prob. Value
D(Ln World Oil Prices) does not Granger Cause D(Ln Domestic Maize Prices)	308	3.4085	0.0180**
D(Ln Domestic Maize Prices) does not Granger Cause D(Ln World Oil Prices)		1.4964	0.2156
D(Ln Domestic Cereal Prices) does not Granger Cause D(Ln World Oil Prices)	308	1.6021	0.1889
D(Ln World Oil Prices) does not Granger Cause D(Ln Domestic Cereal Prices)		0.9846	0.4003
D(Ln World Oil Prices) does not Granger Cause D(Ln Domestic Rice Prices)	308	0.5268	0.5910
D(Ln Domestic Rice Prices) does not Granger Cause D(Ln World Oil Prices)		1.9528	0.1437

Source: Author's computation using E-views 9. \*\* denotes 5% significance level.

The Pairwise Granger Causality test shown in Table 4.8.1 reveals that the null hypotheses of no causality from world oil prices (LNWOP) to domestic cereal prices (LNDPC) and

domestic rice prices (LNDRP) are accepted. Again, the null hypotheses of no causality from domestic maize prices, domestic cereal prices and domestic rice prices to world oil prices are also accepted at all significance levels. However, the null hypothesis of no causality running from world oil prices to domestic maize prices is rejected at 5% level of significance. This implies that world oil prices can be used to predict domestic maize prices in the short run and this causality is unidirectional. The causality running from world oil prices to domestic maize prices could be due to the relative importance of maize in Ghana. Thus, the consumption of maize in Ghana is very high and as such production is more than the other domestic cereals in the study. Hence, the short run causal relationship between world oil prices and maize prices in Ghana. These findings are consistent with the results of Nazlioglu and Soytas (2010) and Nwonko et al., (2016) who found unidirectional short run causality from world oil prices to maize prices but not for rice prices. The Wald test in Appendix C for Model 2 also confirms the results from the Pairwise Granger Causality test. Thus, the Wald test also shows that, there exists causality from world oil prices to domestic maize prices in the short run and this relationship is unidirectional.

#### **4.8.2 Long run Causality**

The existence of a long run relationship between the variables implies an error correction model is estimated instead of a vector autoregression. The coefficient of the error correction term shows the speed of adjustment back to long run equilibrium after short run aberrations. The  $ECT_{t-1}$  also points out the long run causality based on the statistical significance and the sign of the coefficient. Tables 4.8.2, 4.8.3, 4.8.4, 4.8.5, 4.8.6 and 4.8.7 show the result for the long run causality. These Tables are extracts from the estimation of alternative VECMs shown in Appendix A.

Table 4.8.2: Long Run Causality Model 1

<b>DEPENDENT VARIABLE: <math>\Delta \ln</math> Domestic Cereal Prices</b>				
<b>Variable</b>	<b>Coefficient</b>	<b>Std. Error</b>	<b>t-Statistic</b>	<b>P-value</b>
$ECT_{t-1}$	-0.2435	0.0434	-5.5780	0.0000***
R-squared	0.3443	F-statistic	9.5519	
Adjusted R-squared	0.3083	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Table 4.8.3: Long Run Causality Model 2

<b>DEPENDENT VARIABLE: <math>\Delta \ln</math> Domestic Maize Prices</b>				
<b>Variable</b>	<b>Coefficient</b>	<b>Std. Error</b>	<b>t-Statistic</b>	<b>P-value</b>
$ECT_{t-1}$	-0.1371	0.0503	-2.724	0.0068***
R-squared	0.2525	F-statistic	6.1444	
Adjusted R-squared	0.2114	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Table 4.8.4: Long Run Causality Model 3

<b>DEPENDENT VARIABLE: <math>\Delta \ln</math> Domestic Rice Prices</b>				
<b>Variable</b>	<b>Coefficient</b>	<b>Std. Error</b>	<b>t-Statistic</b>	<b>P-value</b>
$ECT_{t-1}$	-0.2865	0.0623	-4.5710	0.0000***
R-squared	0.2435	F-statistic	5.4901	
Adjusted R-squared	0.1991	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Table 4.8.5: Long Run Causality Model 4

DEPENDENT VARIABLE: $\Delta \text{Ln World Oil Prices}$				
Variable	Coefficient	Std. Error	t-Statistic	P-value
$ECT_{t-1}$	-0.0064	0.0063	-1.0247	0.3063
R-squared	0.1702	F-statistic	3.7317	
Adjusted R-squared	0.1246	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Table 4.8.6: Long Run Causality Model 5

DEPENDENT VARIABLE: $\Delta \text{Ln World Oil Prices}$				
Variable	Coefficient	Std. Error	t-Statistic	P-value
$ECT_{t-1}$	-0.0048	0.0057	-0.8385	0.4024
R-squared	0.1568	F-statistic	3.3817	
Adjusted R-squared	0.1104	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Table 4.8.7: Long Run Causality Model 6

DEPENDENT VARIABLE: $\Delta \text{Ln World Oil Prices}$				
Variable	Coefficient	Std. Error	t-Statistic	P-value
$ECT_{t-1}$	-0.0091	0.0101	-0.9000	0.3691
R-squared	0.1681	F-statistic	3.4473	
Adjusted R-squared	0.1193	P-value	0.0000	

Source: Author's computation using E-views 9. \*\*\*, \*\*, \* denote 1%, 5% and 10% significance levels respectively.

Models 4, 5 and 6 show the long run causality running from domestic cereals, domestic maize and domestic rice prices to world oil prices respectively. The coefficient of the error correction term in Models 4, 5 and 6 were found to be statistically insignificant although all they had the appropriate sign (-). This implies there is no long run causality from the domestic cereal, domestic maize and domestic rice prices to world oil prices.

However, the coefficient of the error correction term in all Models 1, 2 and 3 which show the long run causality from world oil prices to domestic cereal, domestic maize and domestic rice prices were found to be significant at 1%. Also, the coefficients carried the expected sign (-). This implies that, there is a long run causal relationship from world oil prices to domestic cereal, domestic maize and domestic rice prices. The  $ECT_{t-1}$  for Model 1, Model 2 and Model 3 are -0.2435, -0.1371 and -0.2865 respectively. This implies that about 24%, 13% and 28% of the disequilibrium in Models 1, 2 and 3 are corrected as the move toward long run equilibrium respectively and there is convergence. The results indicate unidirectional long run causality from world oil prices to cereal prices in Ghana. These findings are consistent with the results of Arshad and Hameed (2009), Merkusheva and Rapsomanikis (2014), Gilbert and Mugeru (2014), and Dillion and Barrett (2015) who found oil prices to be a long run driver of food prices.

#### **4.9 Conclusion**

This chapter investigated empirically how world oil prices influence cereal prices in Ghana. The ADF and PP test for stationarity indicated the variables are I(1). Hence the J-J cointegration test was then performed. The results from the J-J test revealed the existence of cointegration in all the three Models. The results indicate that there is a long run relationship between the dependent and independent variables. The short run estimates showed that world oil prices only influence domestic maize prices (Model 2) and not domestic cereal and domestic rice prices (Models 1 and 3). Exchange rate is also found to positively influence domestic maize and domestic rice prices. The results also show a positive effect of lags of domestic cereal prices on domestic rice and domestic cereal prices. The impulse response analysis also confirmed the results obtained in the short run estimates.

However, in the long run the study revealed that world cereal prices, world maize prices, world rice prices, exchange rate and world prices of oil significantly affected domestic cereal,

domestic maize and domestic rice prices positively. The Granger causality test also showed a unidirectional causality running from world oil prices to domestic maize prices in the short run. Nonetheless, the study found unidirectional long run causality from world oil prices to all the domestic cereal, domestic maize and domestic rice prices.

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSION AND RECOMMENDATION**

#### **5.1 Introduction**

This chapter of the thesis by presents the summary, conclusions and policy recommendations of the study based on the results obtained. The chapter also, identifies some limitations to the study and suggests areas for further research.

#### **5.2 Summary and Conclusion**

The main aim of this study was to assess the effect of oil prices on Ghana's cereal (maize and rice) prices from 1990-2015. The study sought to achieve this main aim through two objectives. These objectives were to (i) examine the long run and short run effects of oil prices changes on Ghana's Cereals (maize and rice) prices and (ii) examine the direction of causation between these variables.

To accomplish the purpose of the study, various tests and estimations were performed. The test for stationarity (unit root test) was performed to ascertain the order of integration of the series that were used in the study. The Augmented Dickey-Fuller and the Phillips and Perron tests were used in that regard. The outcomes of the two methods were not dissimilar. The ADF test showed that all the series were stationary at first difference but not at levels (I(1)). However, one variable (exchange rate), was stationary at level (I(0)) while all the others were stationary after first difference when the PP test was employed. Nonetheless, this study chose the results obtained from the ADF test given that it is more problematic if a series is I(1) and it is treated as I(0). This is because if a series is truly I(1) and used as I(0), then it can dominate other I(0) variables and lead to spurious regression. The reverse (i.e. I(0) treated as I(1)) however will mean over differencing and results in losing some of the long run information. Even so, standard test performed using this series will be correct.

Also, the Johansen-Juselius cointegration test was used to establish whether or not there exists a long run relationship between the variables. The variables included in the test are domestic cereal prices, world oil prices, exchange rate, world cereal prices, domestic maize prices, domestic rice prices, world maize prices and world rice prices. Three cointegration tests were performed. The first test was for domestic cereal prices being the dependent variable (Model 1). The other two tests were for domestic maize prices (Model 2) and domestic rice prices (Model 3) being the dependent variables. The results from the J-J cointegration test showed that there was one cointegrating relationship for Models 1 and 2. However, the test results revealed two long run relations for Model 3. Based on this information, three vector error correction models were estimated.

The results revealed that, in all the three long run models there is a significant positive relationship between world oil prices and domestic cereal prices. The positive relationship between oil and prices is also confirmed by Gohin and Chantret (2010) and Chen et al., (2010). The long run elasticities of Model 1, 2 and 3 are 0.1096, 0.1560 and 0.2466 respectively.

Again, in the long run, exchange rate is found to be statistically significant in influencing the prices of domestic cereals. The work by Nazlioglu and Soytas (2011) supports this relationship. Thus, holding all other things constant, a percentage change (appreciation or depreciation) in exchange rate leads to 0.3934 percentage points change (increase or decrease) in domestic maize prices. The long run elasticities for Model 1 and 3 are 0.3353 and 0.9169 correspondingly. The effect of exchange rate in all three Models is positive.

The outcome of the study also revealed that world cereal prices had a significant positive effect on domestic cereal prices. This relationship has also been established in the work of Ackah et al. (2010). For Model 1, a percentage point increase in world cereal prices translates

to a 0.2222 percentage point increase in domestic cereal prices holding all other factors constant. Also, *ceteris paribus*, a percentage point increase in world maize prices leads to a 0.2471 percentage point increase in domestic maize prices (Model 2). The elasticities for domestic rice prices (Model 3) is 0.5232.

Thus, in the long run changes in world oil prices, exchange rates and world cereal prices influence domestic cereal (maize and rice) prices positively. However, the study showed that the effect of exchange rate on domestic maize and domestic rice prices is the highest compared to the impacts exerted by the world oil prices and world cereal prices.

The short run dynamics of the study was also examined and the results indicated that the error correction term (ECT) for all the three Models were significant and also had the expected negative sign. This therefore means that, in all the three Models, any disequilibrium that occurred in the short run were corrected as they moved to long run stability.

However, in the short run, world oil prices was seen to significantly influence domestic maize prices (Model 2) but not on domestic cereal and domestic rice prices (Model 1 and 3). Again, the short run results showed a positive effect of exchange rate on domestic maize and domestic rice prices.

The outcome of the impulse response analysis was in concord with the findings posited by the short run dynamics of the study. Thus world oil prices only affected domestic maize prices in the short run.

The Pairwise Granger Causality test revealed that there is a significant unidirectional causal effect running from world oil prices to domestic maize prices in the short run. In the long run however, the study found unidirectional causality from world oil prices to all the domestic cereal (maize and rice) prices.

### **5.3 Recommendations**

Evidence from the study show that one important factor that affects cereal prices in Ghana is world oil prices. The study thus recommends that considering the fiscal space of the economy, government and policy makers should adopt measures to subsidize oil related products particularly the ones used in agriculture as this will in turn reduce the impact of rising oil prices on the domestic front.

Again, exchange rate is found to influence domestic food prices positively. Thus, government and policy makers in Ghana should advance policies aimed at achieving stable exchange rates to mitigate the effects of exchange rates on cereal price fluctuations in the domestic food market. This is accruing to the positive impact of exchange rate exert on domestic cereal prices.

Finally, it is evident that there is a positive relationship between domestic cereal prices and world cereal prices. This link implies that higher world cereal prices are translated to domestic cereal prices as Ghana is a net importer of food. In the longer term, policy makers, stakeholders and government can stimulate resilience to variations in world cereal prices by varying the staple food diets of consumers. During the global food crisis, prices of cassava, sweet potatoes and other non-tradable staple foods rose less than that of cereals on the domestic market (Minot, 2011). Hence, varying diets will enable family units substitute one food diet for another when the price of one of them increases.

As with most studies, there are always areas in which further research can be conducted. Future works can broaden the scope to look at a more general picture of all food prices (cereals, starchy, industrial, and fruits and vegetables) in the crop sub-sector of Ghana. Also, GDP could be included in further studies to capture the effect of changing economic activities on domestic food prices. This will allow for a more detailed statistical analysis.

#### **5.4 Limitations of the study**

The chief challenge faced in this study is the acquisition of data. This made other relevant variables such as GDP that could have further enriched the scope of this thesis to be omitted. Also, the unavailability of some of the data points of the variables used in this study for earlier time periods made it difficult for a pre and post Economic Reform Policy (ERP) analysis to be made hence limiting the depth the analysis.

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## APPENDICES

## APPENDIX A: VECTOR ERROR CORRECTION MODELS (VECM)

## Model 1

Dependent Variable: D(LNDCP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$\begin{aligned}
D(LNDCP) = & C(1)*(LNDCP(-1) - 0.109643827349*LNWOP(-1) - \\
& 0.613442856179*LNDCP(-1) - 0.222398444291*LNWCP(-1) - \\
& 0.335274380294*LNER(-1) - 0.897025272233) + C(2)*D(LNDCP(-1)) \\
& + C(3)*D(LNDCP(-2)) + C(4)*D(LNDCP(-3)) + C(5)*D(LNWOP(-1)) + \\
& C(6)*D(LNWOP(-2)) + C(7)*D(LNWOP(-3)) + C(8)*D(LNDCP(-1)) + C(9) \\
& *D(LNDCP(-2)) + C(10)*D(LNDCP(-3)) + C(11)*D(LNWCP(-1)) + C(12) \\
& *D(LNWCP(-2)) + C(13)*D(LNWCP(-3)) + C(14)*D(LNER(-1)) + C(15) \\
& *D(LNER(-2)) + C(16)*D(LNER(-3)) + C(17)
\end{aligned}$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.243494	0.043652	-5.578004	0.0000
C(2)	0.327019	0.065271	5.010174	0.0000
C(3)	0.026846	0.069177	0.388073	0.6982
C(4)	0.066465	0.062097	1.070340	0.2854
C(5)	0.011218	0.044359	0.252891	0.8005
C(6)	0.034338	0.046294	0.741751	0.4588
C(7)	0.005705	0.044547	0.128057	0.8982
C(8)	0.209310	0.037933	5.517869	0.0000
C(9)	0.127597	0.039245	3.251261	0.0013
C(10)	0.105302	0.038398	2.742388	0.0065
C(11)	0.063297	0.084777	0.746625	0.4559
C(12)	0.001210	0.092522	0.013078	0.9896
C(13)	0.053956	0.085515	0.630952	0.5286
C(14)	-0.035045	0.053671	-0.652961	0.5143
C(15)	-0.055435	0.060900	-0.910253	0.3634
C(16)	0.058330	0.054024	1.079721	0.2812
C(17)	0.020702	0.004381	4.725814	0.0000
R-squared	0.344345	Mean dependent var		0.016139
Adjusted R-squared	0.308295	S.D. dependent var		0.074660
S.E. of regression	0.062094	Akaike info criterion		-2.666733
Sum squared resid	1.121986	Schwarz criterion		-2.460851
Log likelihood	427.6769	Hannan-Quinn criter.		-2.584412
F-statistic	9.551934	Durbin-Watson stat		1.989905
Prob(F-statistic)	0.000000			

## MODEL 2

Dependent Variable: D(LNDMP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$D(LNDMP) = C(1)*(LNDMP(-1) - 0.156000844904*LNWOP(-1) - 1.47200446892*LNDCP(-1) - 0.393409567778*LNER(-1) - 0.247087556208*LNWMP(-1) - 1.31626693108) + C(2)*D(LNDMP(-1)) + C(3)*D(LNDMP(-2)) + C(4)*D(LNDMP(-3)) + C(5)*D(LNWOP(-1)) + C(6)*D(LNWOP(-2)) + C(7)*D(LNWOP(-3)) + C(8)*D(LNDCP(-1)) + C(9)*D(LNDCP(-2)) + C(10)*D(LNDCP(-3)) + C(11)*D(LNER(-1)) + C(12)*D(LNER(-2)) + C(13)*D(LNER(-3)) + C(14)*D(LNWMP(-1)) + C(15)*D(LNWMP(-2)) + C(16)*D(LNWMP(-3)) + C(17)$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.137119	0.050339	-2.723923	0.0068
C(2)	0.405355	0.070000	5.790819	0.0000
C(3)	0.174663	0.072876	2.396723	0.0172
C(4)	0.017265	0.070401	0.245241	0.8064
C(5)	-0.153152	0.080613	-1.899839	0.0584
C(6)	0.184447	0.085181	2.165342	0.0312
C(7)	-0.014545	0.082086	-0.177188	0.8595
C(8)	0.059752	0.117858	0.506980	0.6126
C(9)	-0.004376	0.125593	-0.034839	0.9722
C(10)	0.020298	0.112953	0.179704	0.8575
C(11)	0.125486	0.096357	1.302307	0.1938
C(12)	0.377671	0.109475	3.449842	0.0006
C(13)	0.282249	0.097498	2.894915	0.0041
C(14)	0.429952	0.116244	3.698720	0.0003
C(15)	0.284854	0.123436	2.307707	0.0217
C(16)	0.221157	0.118637	1.864152	0.0633
C(17)	-0.000654	0.007947	-0.082239	0.9345
R-squared	0.252525	Mean dependent var		0.017156
Adjusted R-squared	0.211426	S.D. dependent var		0.127590
S.E. of regression	0.113302	Akaike info criterion		-1.463906
Sum squared resid	3.735670	Schwarz criterion		-1.258024
Log likelihood	242.4415	Hannan-Quinn criter.		-1.381585
F-statistic	6.144404	Durbin-Watson stat		2.026409
Prob(F-statistic)	0.000000			

## MODEL 3

Dependent Variable: D(LNDRP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$D(LNDRP) = C(1)*(LNDRP(-1) - 0.246588249467*LNWOP(-1) - 0.523184858694*LNWRP(-1) - 0.916878129644*LNER(-1) - 2.28814108012) + C(2)*(LNDCP(-1) - 0.243280632126*LNWOP(-1) - 0.494802764286*LNWRP(-1) - 0.944189711806*LNER(-1) - 2.14251232263) + C(3)*D(LNDRP(-1)) + C(4)*D(LNDRP(-2)) + C(5)*D(LNDRP(-3)) + C(6)*D(LNDCP(-1)) + C(7)*D(LNDCP(-2)) + C(8)*D(LNDCP(-3)) + C(9)*D(LNWOP(-1)) + C(10)*D(LNWOP(-2)) + C(11)*D(LNWOP(-3)) + C(12)*D(LNWRP(-1)) + C(13)*D(LNWRP(-2)) + C(14)*D(LNWRP(-3)) + C(15)*D(LNER(-1)) + C(16)*D(LNER(-2)) + C(17)*D(LNER(-3)) + C(18)$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.286513	0.062681	-4.570991	0.0000
C(2)	0.032098	0.058362	0.549976	0.5828
C(3)	-0.121226	0.083272	-1.455789	0.1465
C(4)	-0.037572	0.080423	-0.467180	0.6407
C(5)	-0.048414	0.078092	-0.619970	0.5358
C(6)	-0.025944	0.091017	-0.285046	0.7758
C(7)	0.255578	0.090017	2.839235	0.0048
C(8)	0.110360	0.089849	1.228276	0.2203
C(9)	0.017322	0.056284	0.307760	0.7585
C(10)	-0.045660	0.058737	-0.777361	0.4376
C(11)	0.035350	0.056434	0.626386	0.5316
C(12)	-0.068686	0.080531	-0.852913	0.3944
C(13)	-0.000107	0.085482	-0.001250	0.9990
C(14)	-0.048720	0.080170	-0.607702	0.5439
C(15)	0.196575	0.076522	2.568852	0.0107
C(16)	0.205458	0.084885	2.420430	0.0161
C(17)	0.157965	0.071306	2.215311	0.0275
C(18)	0.021295	0.005498	3.873149	0.0001
R-squared	0.243475	Mean dependent var		0.014961
Adjusted R-squared	0.199127	S.D. dependent var		0.087341
S.E. of regression	0.078162	Akaike info criterion		-2.203390
Sum squared resid	1.771717	Schwarz criterion		-1.985398
Log likelihood	357.3221	Hannan-Quinn criter.		-2.116227
F-statistic	5.490108	Durbin-Watson stat		1.995099
Prob(F-statistic)	0.000000			

#### MODEL 4

Dependent Variable: D(LNWOP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$\begin{aligned}
 D(LNWOP) = & C(18)*(LNDMP(-1) - 0.109643827349*LNWOP(-1) - \\
 & 0.613442856179*LNDMP(-1) - 0.222398444291*LNWCP(-1) - \\
 & 0.335274380294*LNER(-1) - 0.897025272233) + C(19)*D(LNDMP( \\
 & -1)) + C(20)*D(LNDMP(-2)) + C(21)*D(LNDMP(-3)) + C(22)*D(LNWOP( \\
 & -1)) + C(23)*D(LNWOP(-2)) + C(24)*D(LNWOP(-3)) + C(25)*D(LNDMP( \\
 & -1)) + C(26)*D(LNDMP(-2)) + C(27)*D(LNDMP(-3)) + C(28)*D(LNWCP( \\
 & -1)) + C(29)*D(LNWCP(-2)) + C(30)*D(LNWCP(-3)) + C(31)*D(LNER( \\
 & -1)) + C(32)*D(LNER(-2)) + C(33)*D(LNER(-3)) + C(34)
 \end{aligned}$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(18)	0.058647	0.057231	1.024729	0.3063
C(19)	-0.116781	0.085575	-1.364667	0.1734
C(20)	-0.037323	0.090695	-0.411518	0.6810
C(21)	-0.135205	0.081414	-1.660718	0.0978
C(22)	0.289364	0.058158	4.975476	0.0000
C(23)	0.023320	0.060694	0.384220	0.7011
C(24)	-0.001581	0.058404	-0.027067	0.9784
C(25)	0.086804	0.049733	1.745406	0.0820
C(26)	0.082238	0.051453	1.598297	0.1111
C(27)	0.135408	0.050342	2.689748	0.0076
C(28)	-0.055370	0.111149	-0.498165	0.6187

C(29)	0.256510	0.121302	2.114642	0.0353
C(30)	0.038892	0.112116	0.346887	0.7289
C(31)	0.081747	0.070366	1.161746	0.2463
C(32)	-0.098929	0.079845	-1.239025	0.2163
C(33)	-0.087309	0.070828	-1.232688	0.2187
C(34)	0.002215	0.005743	0.385654	0.7000
<hr/>				
R-squared	0.170247	Mean dependent var	0.002479	
Adjusted R-squared	0.124625	S.D. dependent var	0.087011	
S.E. of regression	0.081409	Akaike info criterion	-2.125052	
Sum squared resid	1.928574	Schwarz criterion	-1.919170	
Log likelihood	344.2580	Hannan-Quinn criter.	-2.042731	
F-statistic	3.731672	Durbin-Watson stat	2.047881	
Prob(F-statistic)	0.000003			

## MODEL 5

Dependent Variable: D(LNWOP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$D(LNWOP) = C(18) * (LNDMP(-1) + 0.156000844904 * LNWOP(-1) - 1.47200446892 * LNDMP(-1) + 0.393409567778 * LNER(-1) + 0.247087556208 * LNWMP(-1) + 1.31626693108) + C(19) * D(LNDMP(-1)) + C(20) * D(LNDMP(-2)) + C(21) * D(LNDMP(-3)) + C(22) * D(LNWOP(-1)) + C(23) * D(LNWOP(-2)) + C(24) * D(LNWOP(-3)) + C(25) * D(LNDMP(-1)) + C(26) * D(LNDMP(-2)) + C(27) * D(LNDMP(-3)) + C(28) * D(LNER(-1)) + C(29) * D(LNER(-2)) + C(30) * D(LNER(-3)) + C(31) * D(LNWMP(-1)) + C(32) * D(LNWMP(-2)) + C(33) * D(LNWMP(-3)) + C(34)$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(18)	-0.030574	0.036461	-0.838530	0.4024
C(19)	0.080476	0.050702	1.587245	0.1135
C(20)	0.082707	0.052785	1.566866	0.1182
C(21)	0.139626	0.050992	2.738179	0.0066
C(22)	0.289890	0.058389	4.964768	0.0000
C(23)	0.023198	0.061698	0.375997	0.7072
C(24)	0.000527	0.059456	0.008872	0.9929
C(25)	-0.103209	0.085366	-1.209011	0.2276
C(26)	-0.044936	0.090969	-0.493966	0.6217
C(27)	-0.147720	0.081814	-1.805563	0.0720
C(28)	0.069533	0.069793	0.996276	0.3199
C(29)	-0.105150	0.079294	-1.326068	0.1859
C(30)	-0.085866	0.070620	-1.215889	0.2250
C(31)	0.044075	0.084197	0.523470	0.6010
C(32)	0.080695	0.089407	0.902559	0.3675
C(33)	0.008427	0.085930	0.098063	0.9220
C(34)	0.002685	0.005756	0.466448	0.6412
<hr/>				
R-squared	0.156786	Mean dependent var	0.002479	
Adjusted R-squared	0.110424	S.D. dependent var	0.087011	
S.E. of regression	0.082067	Akaike info criterion	-2.108960	
Sum squared resid	1.959861	Schwarz criterion	-1.903078	
Log likelihood	341.7798	Hannan-Quinn criter.	-2.026639	
F-statistic	3.381762	Durbin-Watson stat	2.049522	
Prob(F-statistic)	0.000017			

**MODEL 6**

Dependent Variable: D(LNWOP)

Method: Least Squares (Gauss-Newton / Marquardt steps)

Sample (adjusted): 1990M05 2015M12

Included observations: 308 after adjustments

$$D(LNWOP) = C(37)*(LND RP(-1) - 0.246588249467*LNWOP(-1) - 0.523184858694*LNWRP(-1) - 0.916878129644*LNER(-1) - 2.28814108012) + C(38)*(LND CP(-1) - 0.243280632126*LNWOP(-1) - 0.494802764286*LNWRP(-1) - 0.944189711806*LNER(-1) - 2.14251232263) + C(39)*D(LNDRP(-1)) + C(40)*D(LNDRP(-2)) + C(41)*D(LNDRP(-3)) + C(42)*D(LND CP(-1)) + C(43)*D(LND CP(-2)) + C(44)*D(LND CP(-3)) + C(45)*D(LNWOP(-1)) + C(46)*D(LNWOP(-2)) + C(47)*D(LNWOP(-3)) + C(48)*D(LNWRP(-1)) + C(49)*D(LNWRP(-2)) + C(50)*D(LNWRP(-3)) + C(51)*D(LNER(-1)) + C(52)*D(LNER(-2)) + C(53)*D(LNER(-3)) + C(54)$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(37)	-0.006430	0.006275	-1.024729	0.3063
C(38)	-0.079352	0.060969	-1.301513	0.1941
C(39)	-0.162515	0.086991	-1.868170	0.0627
C(40)	-0.096818	0.084015	-1.152389	0.2501
C(41)	-0.244795	0.081580	-3.000673	0.0029
C(42)	0.116109	0.095083	1.221136	0.2230
C(43)	0.215110	0.094038	2.287487	0.0229
C(44)	0.219530	0.093863	2.338828	0.0200
C(45)	0.311384	0.058798	5.295798	0.0000
C(46)	0.007018	0.061361	0.114371	0.9090
C(47)	-0.014597	0.058955	-0.247594	0.8046
C(48)	-0.091434	0.084128	-1.086846	0.2780
C(49)	0.193727	0.089300	2.169392	0.0309
C(50)	0.070315	0.083751	0.839564	0.4018
C(51)	0.079784	0.079941	0.998045	0.3191
C(52)	-0.070724	0.088677	-0.797545	0.4258
C(53)	-0.054841	0.074491	-0.736204	0.4622
C(54)	0.000791	0.005744	0.137691	0.8906
R-squared	0.168110	Mean dependent var		0.002479
Adjusted R-squared	0.119344	S.D. dependent var		0.087011
S.E. of regression	0.081654	Akaike info criterion		-2.115987
Sum squared resid	1.933540	Schwarz criterion		-1.897994
Log likelihood	343.8620	Hannan-Quinn criter.		-2.028824
F-statistic	3.447291	Durbin-Watson stat		2.006936
Prob(F-statistic)	0.000008			

**APPENDIX B: RESIDUAL DIAGNOSTIC TESTS**

- SERIAL CORRELATION TEST**

**MODEL 1**

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.543749	Prob. F(3,288)	0.6527
Obs*R-squared	1.734703	Prob. Chi-Square(3)	0.6292

**MODEL 2**

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.711983	Prob. F(3,288)	0.5455
Obs*R-squared	2.267461	Prob. Chi-Square(3)	0.5188

**MODEL 3**

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.719929	Prob. F(3,287)	0.5408
Obs*R-squared	2.300509	Prob. Chi-Square(3)	0.5124

- HETEROSCEDASTICITY**

**MODEL 1**

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.139179	Prob. F(20,287)	0.3087
Obs*R-squared	22.65240	Prob. Chi-Square(20)	0.3062
Scaled explained SS	96.35889	Prob. Chi-Square(20)	0.0000

**MODEL 2**

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.998297	Prob. F(20,287)	0.4505
Obs*R-squared	12.01926	Prob. Chi-Square(20)	0.4441
Scaled explained SS	27.51734	Prob. Chi-Square(20)	0.0000

**MODEL 3**

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.557432	Prob. F(20,287)	0.1033
Obs*R-squared	18.35131	Prob. Chi-Square(20)	0.1054
Scaled explained SS	291.9263	Prob. Chi-Square(20)	0.0000

## APPENDIX C: COEFFICIENT DIAGNOSTIC TESTS

- **WALD TESTS**

### MODEL 1

#### Wald Test: Short Run Causality from LNWOP to LNDCP

Test Statistic	Value	df	Probability
F-statistic	0.310817	(3, 291)	0.8176
Chi-square	0.932452	3	0.8176

Null Hypothesis:  $C(5)=C(6)=C(7)=0$

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(5)	0.011218	0.044359
C(6)	0.034338	0.046294
C(7)	0.005705	0.044547

Restrictions are linear in coefficients.

### MODEL 2

#### Wald Test: Short Run Causality from LNWOP to LNDMP

Test Statistic	Value	Df	Probability
F-statistic	2.208489	(3, 291)	0.0872
Chi-square	6.625468	3	0.0848

Null Hypothesis:  $C(5)=C(6)=C(7)=0$

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(5)	-0.153152	0.080613
C(6)	0.184447	0.085181
C(7)	-0.014545	0.082086

Restrictions are linear in coefficients.

### MODEL 3

#### Wald Test: Short Run Causality from LNWOP to LNDRP

Test Statistic	Value	df	Probability
F-statistic	0.268862	(3, 290)	0.8478
Chi-square	0.806587	3	0.8479

Null Hypothesis:  $C(9)=C(10)=C(11)=0$

Null Hypothesis Summary:

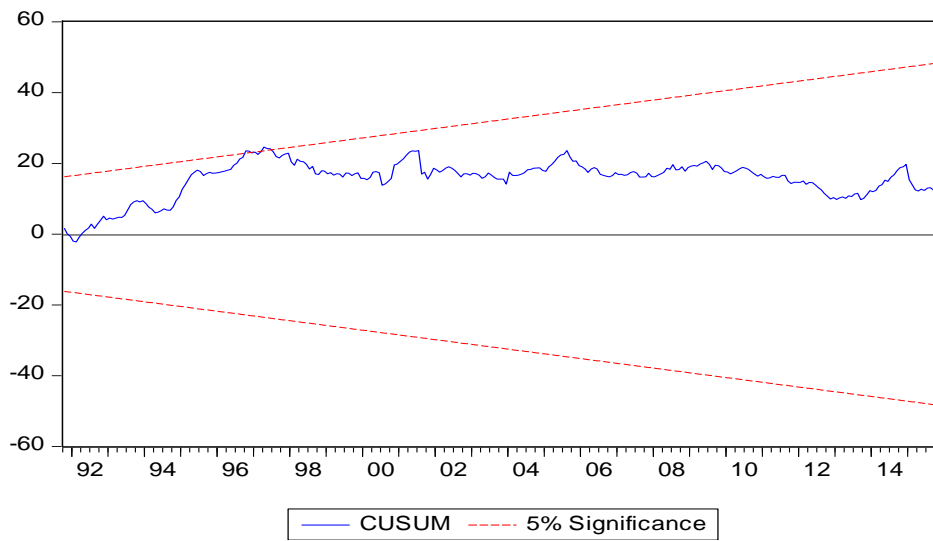
Normalized Restriction (= 0)	Value	Std. Err.
C(9)	0.017322	0.056284
C(10)	-0.045660	0.058737
C(11)	0.035350	0.056434

Restrictions are linear in coefficients.

## APPENDIX D: STABILITY DIAGNOSTIC TESTS

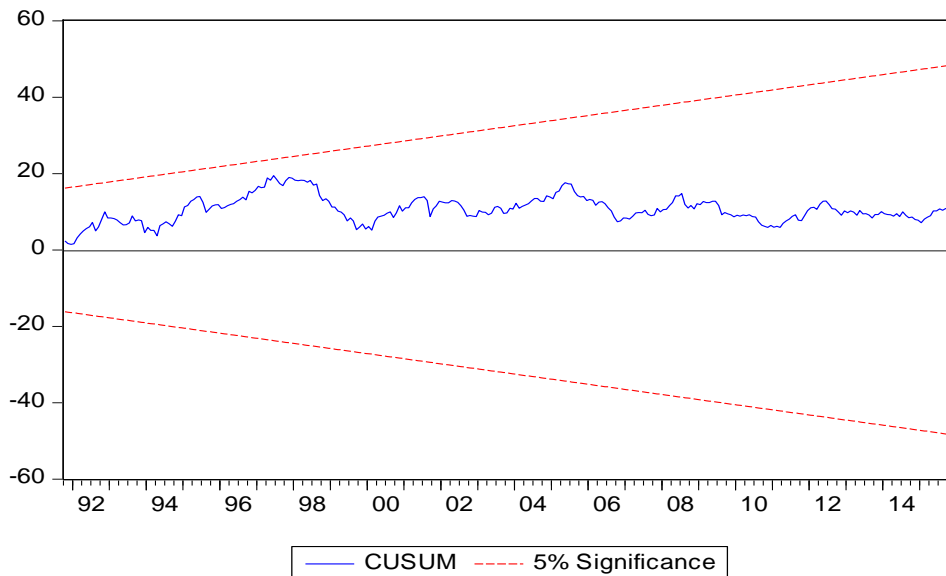
### MODEL 1

Domestic cereal prices as dependent variable



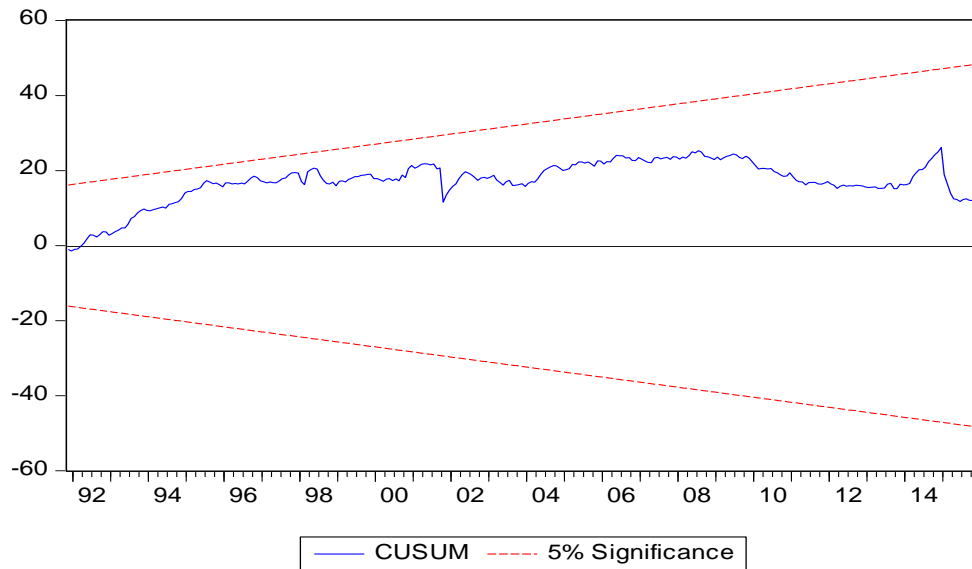
### MODEL 2

Domestic maize prices as dependent variable



### MODEL 3

#### Domestic rice prices as dependent variable



### APPENDIX E: LAG SELECTION

#### MODEL 1

VAR Lag Order Selection Criteria  
 Endogenous variables: LNDCP LNWOP LNDMP LNER  
 LNWCP  
 Exogenous variables: C  
 Sample: 1990M01 2015M12  
 Included observations: 304

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-453.3447	NA	1.40e-05	3.015426	3.076561	3.039881
1	1813.443	4444.097	5.52e-12	-11.73318	-11.36637	-11.58644
2	1979.268	319.6499	2.19e-12	-12.65966	-11.69237	-12.39065*
3	2005.922	50.50160	2.16e-12*	-12.67054*	-11.98717*	-12.27925
4	2028.474	41.98786	2.20e-12	-12.65443	-11.37059	-12.14086
5	2047.960	35.63892	2.28e-12	-12.61816	-11.02864	-11.98231
6	2059.267	20.30795	2.50e-12	-12.52807	-10.63287	-11.76995
7	2082.721	41.35391*	2.53e-12	-12.51790	-10.31703	-11.63750
8	2099.219	28.54520	2.69e-12	-12.46196	-9.955417	-11.45929

\* 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

**MODEL 2**

VAR Lag Order Selection Criteria

Endogenous variables: LNDMP LNWOP LNDPC LNER  
LNWMP

Exogenous variables: C

Date: 07/13/18 Time: 12:42

Sample: 1990M01 2015M12

Included observations: 304

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-498.6812	NA	1.89e-05	3.313692	3.374828	3.338148
1	1740.759	4390.482	8.91e-12	-11.25499	-10.88818	-11.10826
2	1891.801	291.1535	3.89e-12	-12.08422	-11.11697	-11.81521*
3	1918.461	50.51341*	3.85e-12*	-12.09514*	-11.41173*	-11.70385
4	1937.470	35.39068	4.00e-12	-12.05572	-10.77188	-11.54215
5	1952.189	26.92024	4.29e-12	-11.98808	-10.39856	-11.35224
6	1966.911	26.44258	4.59e-12	-11.92047	-10.02527	-11.16235
7	1981.470	25.67039	4.93e-12	-11.85178	-9.650908	-10.97138
8	1992.879	19.73957	5.41e-12	-11.76236	-9.255813	-10.75968

\* 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

**MODEL 3**

VAR Lag Order Selection Criteria

Endogenous variables: LNDMP LNWOP LNDPC LNWRP  
LNER

Exogenous variables: C

Sample: 1990M01 2015M12

Included observations: 302

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-280.0546	NA	4.54e-06	1.887779	1.949210	1.912358
1	1886.457	4246.937	3.15e-12	-12.29442	-11.92583	-12.14694
2	1990.934	201.3427	1.86e-12	-12.82076	-11.86331	-12.55038*
3	2019.776	54.62804	1.81e-12*	-12.84620*	-12.14502*	-12.45293
4	2041.546	40.51256*	1.86e-12	-12.82481	-11.53476	-12.30865
5	2051.780	18.70587	2.05e-12	-12.72702	-11.12982	-12.08796
6	2066.183	25.84830	2.20e-12	-12.65684	-10.75248	-11.89488
7	2086.578	35.92818	2.27e-12	-12.62635	-10.41483	-11.74149
8	2107.953	36.94673	2.33e-12	-12.60234	-10.08367	-11.59459
9	2124.316	27.74073	2.48e-12	-12.54514	-9.719318	-11.41449
10	2140.765	27.34182	2.64e-12	-12.48851	-9.355533	-11.23497

\* 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