

**RICE PRICE VOLATILITY AND TRANSMISSION: IMPLICATIONS FOR
FOOD SECURITY IN GHANA**

BY

ADDEY OWUSU PRINCE

(10449484)

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON, IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER
OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS**

**DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
SCHOOL OF AGRICULTURE, COLLEGE OF BASIC AND APPLIED SCIENCES
UNIVERSITY OF GHANA, LEGON**

October, 2020

DECLARATION

I, **Prince Addey Owusu**, the author of this thesis, "**RICE PRICE VOLATILITY AND TRANSMISSION: IMPLICATIONS FOR FOOD SECURITY IN GHANA**" do hereby declare that but for the references which have been duly cited, the work presented in this thesis was done entirely by me. This work has never been presented either in whole or in part for any other degree of this University or elsewhere.



.....

Addey Owusu Prince
(Student)

09/11/2021
.....

Date

This thesis has been presented for examination with our approval as supervisors:



.....

Rev. Dr. Edward Ebo Onumah
(Major Supervisor)

09/11/21
.....

Date



.....

Professor Akwasi Mensah-Bonsu
(Co-Supervisor)

09-11-2021
.....

Date

DEDICATION

I dedicate this thesis to my parents, Rev. Douglas Owusu-Addey and Mrs. Anna Owusu-Addey who supported me in various ways throughout my studies.

ACKNOWLEDGEMENT

I am truly indebted to the Almighty God for having given me the strength, courage and determination to complete this master program in general and this thesis work in particular.

My heart felt gratitude goes to Rev. Dr. Edward Ebo Onumah whose able encouragement, technical support, direction, assistance, supervision, cooperation and a great sense of judgment has led to the successful completion of this work. Rev. Dr. Onumah among his eventful schedule, always made time to attend and guided me through the thick and thin of this work. My special thanks do go to Dr. Akwasi Mensah-Bonsu for his constructive criticism, corrections, continuous support, advice, encouragement and suggestions during the course of this thesis. I also want to express my gratitude to Prof. Bruce Daniel Sarpong for his support, corrections and suggestion during the course of my work.

Further, I want to thank all senior members in the Department of Agricultural Economics and Agribusiness for their constructive criticisms during seminars and also members of the entire Department for their diverse support. I am also thankful to the Agricultural Trade and Market Access for Food Security (ATMA4FS) project for their support during data collection, and the Statistics, Research and Information Directorate of the Ministry of Food and Agriculture (SRID-MOFA) where the data was sourced.

Finally, I am thankful to my family especially my Dad, Rev. D.K. Owusu-Addey for his financial support and encouragement. May God richly bless you.

ABSTRACT

This thesis presents analysis of price volatility and transmission in rice markets and their implications for availability, accessibility and stability of imported rice in Ghana. Using monthly imported rice price data over the period of 2013 – 2018, the study examines the relationship between World and domestic markets to ensure availability of imported rice, the extent of price transmission and symmetry in ensuring accessibility of rice and the effect of rice price fluctuation on the stability of imported rice in Ghana. The study deploys Johansen cointegration test, Granger causality test and Error Correction Model (ECM) to examine the price transmission in the various markets to ensure availability of imported rice. The asymmetric vector error correction model is used to compute the long-run adjustment in price to ascertain whether there is symmetry in the various markets to ensure accessibility of imported rice. Again, the study employs the ARCH/GARCH model to capture the conditional volatility in the various market to help understand their impact on the stability of imported rice in Ghana. By testing for Unit-Root, the study finds the data to exhibit non-stationarity at levels but stationary after first difference at 1% significant levels. Cointegration is established between the World market and Accra (Local) market, where inter-market prices adjust to achieve long-run market equilibrium which enhance trade thereby ensuring availability of imported in Ghana. The speed of adjustment and half-live from the vector error correction model shows that monthly, 15.05% of the disequilibrium between the short-run and long-run estimates are corrected back to equilibrium in 4.25 months. In the long-run, an increase in the world price for rice is likely to increase the price of imported rice in Accra by 27.38% thereby reducing its access. Again, all the local market pairs under consideration are cointegrated. The evidence of price causation and leadership by Granger causality test shows Accra as price leaders. The findings emanating from the studies also indicate that imported rice markets in Ghana are well integrated to ensure accessibility of rice. The asymmetric vector error correction model (AVECM) indicates that positive shocks in market pairs are corrected faster than negative shocks. The speed of adjustment in the Accra – Techiman market is the fastest when compared to the other market pairs. Likewise, the adjustment mechanism for these markets after a shock was characterized by symmetry thereby removing arbitrage in the markets and ensure accessibility of imported rice. Results from the estimates (ARCH-GARCH) shows that at the world level, volatility is highly influenced by the fluctuations of the last month (17%) and also by the errors squared of last month at (46.3%). In the domestic market, results for Accra, Tamale, Bolgatanga and Kumasi shows that volatility is influenced by the fluctuations of last month (0.171%, 0.55%, 0.11% and 0.05%) and error squared of previous month (0.77, 0.11, 0.44 and 0.94). Thus, in most cases, the price of imported rice depends on the condition prevailing in the market at that point in time. The result from Accra, Kumasi, Techiman, Tamale and Bolgatanga shows that volatilities in these markets are high, affecting the stability of imported rice. The study concludes that there is a well-integrated market with a stable long-run relationship which ensures availability of rice and market accessibility to imported rice. There is high fluctuation/volatility in prices, implying that prices of imported rice are not stable across all markets. The study, therefore, recommends that Government strengthens trade policies and other bilateral agreements with the countries where we import rice in order to maintain symmetry in market and other benefits that come with it. Also, Government and other stakeholders along the imported rice value chain should increase investment in building better infrastructure and increase rice production to reduce excessive volatility in the rice market to ensure consumer access and stability of rice. Likewise, to ensure timeliness and cost-effectiveness of intervention, policies should be directed to the Accra markets (leader) since most price changes will be transferred efficiently to follower markets.

Table of Contents

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ACRONYMS	x
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background	1
1.2 Problem statement	6
1.4 Objectives of the study	9
1.5 Relevance of the study	10
1.6 Organization of the thesis.....	11
CHAPTER TWO	12
REVIEW OF LITERATURE	12
2.1 Introduction	12
2.2 Economic importance of rice in Ghana.....	12
2.2.1 Contribution of rice to employment	14
2.2.2 Contribution of rice to poverty reduction and food security	15
2.3 The concept of market.....	17
2.3.1 Rice marketing system in Ghana	18
2.3.2 Price transmission and market integration.....	20
2.3.3 Spatial arbitrage and market efficiency	22
2.3.4 Spatial arbitrage	22
2.3.5 The law of one price	23
2.3.6 Spatial market efficiency	23
2.5 Review of theories underling price volatility and transmission analysis	26
2.5.1 The Cobweb model.....	27
2.5.2 The storage model	30
2.5.3 Agricultural price fluctuation model	32
2.6 Empirical studies on price volatility.....	33

2.7 Empirical estimates of volatility and food security.....	36
CHAPTER THREE	39
METHODOLOGY	39
3.1 Introduction	39
3.2 Theoretical framework	39
3.3 Conceptual framework	40
3.4 Method of analysis	43
3.5 Model diagnostics	43
3.6 Examine the relationship between the various markets for rice.....	49
3.6.1 Cointegration between markets to ensure availability and accessibility of rice.....	49
3.6.2 Testing for cointegration	50
3.6.3 Johansen test for cointegration	51
3.6.4 Test for Granger causality	53
3.7 Adjustment to long-run equilibrium and symmetry in ensuring accessibility of rice.....	54
3.8 Analyze of the degree of price volatility/stability in rice market.....	56
3.8.1 ARCH model specification.....	57
3.8.2 GARCH model specification.....	59
3.8.3 Distributions of error terms in volatility models	60
3.9 Source and type of data	61
CHAPTER FOUR.....	64
RESULTS AND DISCUSSION	64
4.1 Introduction	64
4.2 Analysis of imported rice market	64
4.2.1 Annual rice import volumes	64
4.2.2 Descriptive analysis of real price in rice markets.....	66
4.2.3 Annual drifts in retail prices of imported rice in Ghanaian markets	68
4.3 The relationship between world and domestic markets for rice.....	70
4.3.1 The extent of price transmission between world and local (Accra) market	73
4.3.2 Test for long-run relationship between world and local (Accra) market	74
4.4 Price transmission in the domestic market to ensuring accessibility of imported rice.	76
4.5 Adjustment to long-run equilibrium and symmetry in ensuring accessibility of rice.	80
4.6 Examine the effect of rice price changes on the stability of rice in Ghana.....	83

CHAPTER FIVE	89
SUMMARY, CONCLUSION AND RECOMMENDATIONS.....	89
5.1 Introduction	89
5.2 Summary and major findings	89
5.3 Conclusion.....	92
5.4 Recommendations	93
References.....	94
Appendix.....	113

LIST OF TABLES

Table	Page
Table 2. 1: A linear Cobweb Model.....	27
Table 2. 2: A non-linear cobweb model.....	29
Table 2. 3: A storage model.....	31
Table 4. 1 Descriptive analysis of world price of rice (2013-2018).....	66
Table 4. 2 Descriptive statistics of retail prices (GH/kg) of imported rice (2013-2018).....	67
Table 4. 3 Results of ADF test on monthly imported rice prices (real).....	70
Table 4. 4: Test for co-movement between the world market and local market (Accra).....	74
Table 4. 5: Vector Error Correction Results (VECM).....	75
Table 4. 6: VECM model diagnostics.....	76
Table 4. 7: Johansen tests for cointegration between local markets.....	77
Table 4. 8: Result of Granger-causality Test.....	78
Table 4. 9: Results of the AECM Model.....	82
Table 4. 10: Autoregressive Conditional Heteroscedasticity Lagrange Multiplier Test.....	83
Table 4. 11: Estimates of the ARCH-GARCH (1,1) model.....	84
Table 4. 12: Results of Conditional Volatility.....	88

LIST OF FIGURES

Figure	Page
Figure 2. 1: Percentage of households saved from poverty due to adoption of improved rice . . .	16
Figure 2. 2: Distribution network of both local and imported rice in Ghana.....	19
Figure 3. 1: Stylized framework of the causes of food price volatility and transmission.....	41
Figure 3. 2: Map of study area	63
Figure 4. 1: Volume of rice import in Ghana.....	65
Figure 4. 2: Trend in retail price of imported rice	69
Figure 4. 3: Trend in return retail price of imported rice.....	72
Figure 4. 4: Conditional volatility in various markets	86

LIST OF ACRONYMS

ADF	Augmented Dickey Fuller
APT	Asymmetric Price Transmission
ARCH	Auto Regressive Conditional Heteroscedasticity
ARDL	Auto Regressive Distributed Lag
ARIMA	Auto Regressive Integrated Moving Average
AVECM	Asymmetry Vector Error Correction Model
CPI	Consumer Price Index
ECM	Error Correction Model
ECT	Error Correction Term
EGARCH	Exponential Generalized Auto Regressive Conditional Heteroscedasticity
FAO	Food and Agriculture Organization
FASDEP	Food and Agricultural Sector Development Plan
GARCH	Generalized Auto Regressive Conditional Heteroscedasticity
GOG	Government of Ghana
GSS	Ghana Statistical Service
IC	Information Criterion
IFPRI	International Food Policy Research Institute
KPSS	Kwiatkowski, Phillips Schmidt and Shin
LOP	Law of One Price
MoFA-SRID	Ministry of Food and Agriculture–Statistical Research Information Directorate
MT	Metric Tones
PFJ	Planting for Food and Jobs
SDGs	Sustainable Development Goals
VAR	Vector Autoregressive Model
VECM	Vector Error Correction Model

CHAPTER ONE

INTRODUCTION

1.1 Background

Ghana is both a producer and importer of rice. The domestic rice production in 2017 / 2018 production season was estimated at approximately 450,000 MT, which is less than half the country's rice requirement (USDA, 2018). On the other hand, the amount of rice imported during the same period amounted to approximately 680,000 MT (Archibald & Taylor, 2019). After corn as a major staple food in Ghana, rice has become the second most important cereal (Ashitey & Archibald, 2018; MoFA, 2009). The annual per capita consumption of rice in Ghana grew from 17.5 kg (1999-2001) to 24 kg (2010 – 2011) (Ragasa, Takeshima, Chapoto, & Kolavalli, 2014). This per capita rice consumption further increased to 35kg in 2016 – 2017 with a total consumption of about 1.0 million MT in 2017 / 2018. As indicated by the Government of Ghana (GOG), the annual per capita rice consumption in Ghana is expected to reach 40kg by 2020.

As noted from the above statistics, rice consumption in Ghana has increased over the years. Ashitey & Archibald (2018) attributed the increase in rice consumption in Ghana to a growing expatriate community, increasing urbanization, a rapid sectoral growth, a growing middle-class home and its relative convenience in preparation and recipes. Rice in the 1990s was once a grain eaten only during festive seasons in Ghana but has now become a daily staple food for many homes (Ayeduvor, 2018).

For several years now, Government interventions in the agricultural sector has laid more emphasis on improvement in rice market performance and rice marketing efficiency. Recently, the Government of Ghana introduced a 50% rice seed subsidy, fertilizer and other agricultural inputs

to increase their affordability. In order to increase Ghana's food security and reduce import costs, this also aims to significantly increase domestic agricultural production, particularly in maize, rice, soybeans, sorghum and plants (USDA, 2018).

Agricultural prices and agricultural markets significantly affect the speed and path of developments of an economy, and given the significance of the agricultural sector to the Ghanaian economy, an increase in the level of efficiency of Ghanaian agricultural markets will help to improve upon the growth rate of the rice market. Over the years, FASDEP II has concentrated on modernizing agricultural markets, to create connections in the use of resources with sustainability in mind and commercializing agricultural activities to promote the expansion of markets (FASDEP II, 2008).

In developing countries like Ghana, the degree to which markets are integrated and the price transmission of shocks to food markets is a key determinant of stability in prices and overall food security (Kalkuhl *et al.*, 2016). In markets that are not well integrated, signals from price shocks may not be passed on from food deficit areas to food surplus areas, hence resulting in prices becoming increasingly volatile which might affect consumers' purchasing power and economic accessibility to food (Bekkers *et al.*, 2017; FAO, 2011).

The existence of poor market integration for rice may result in decrease in the information on prices accessible to economic agents; this may limit the allocative efficiency and long-run growth which in turn affects the accessibility of rice. According to Olila *et al.* (2016), most agricultural markets in African countries are poorly integrated.

The price of products and services is usually seen to be the key determinant for consumers to choose from. In determining market segmentation and profit, prices are also an important factor.

Prices are seen in many respects not only as the prime consumer's focus, but also as a critical factor for the manufacturer (Kotler & Keller, 2009; Keller, 2009). Price policy is therefore a central focus in efforts to increase marketing efficiency, and it is therefore always the interest of the participants in both markets to maximize profit from marketing transactions.

The price of rice for consumption (purchased price) and for supplier prices (selling prices) affect the trading of rice (HLPE, 2011). In theory, times of high harvest is characterized with high supply and low prices (Moseley, 2017). That is in periods when the commodity in question is scarce, the price of the product increases, which induces a decline in consumption and signals greater investment in the production of that commodity. The regular price fluctuations (normal daily volatility) combine to make a competitive market work correctly (Sarris *et al.*, 2011). It is therefore very important to understand the reason why prices have gone up so as to adequately counter the lack (Bekkers *et al.*, 2017). However, the efficiency of the price system begins to break down when price movements become increasingly uncertain and precipitous, and ultimately reaches the point of redundancy when prices undergo "extreme volatility" or "crisis".

Volatility is a clear concept, nonetheless an accurate definition is unclear, and its measurement is susceptible to considerable subjectivity. However, in the mainstream economic theory, volatility refers to two major concepts: variability and uncertainty, while the former refers to unpredictable movement, the later describes overall motion. As households and planning agencies can better manage foreseeable variations, the primary concern is erratic variations or shocks. Shocks that exceed certain perilous threshold and continue to exceed that threshold will likely fail with the traditional policies and coping mechanisms (Prakash 2011).

Besides the difference between regular and extreme volatility, prices can surpass what is predictionally expected by successful market theories and is referred to as "excessively volatile" when compared with the changes in "fundamentals" (e.g. demand and supply shock).

As commonly defined, Food security is a state whereby "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (HLPE, 2020). The post-2015 development agenda gives high priority to food and nutrition in line with the Sustainable Development Goals (SDGs). Food security is designed in six dimensions on an operational level: availability, accessibility, utilization, stabilization (short-term), agency and sustainability (long-range) level (HLPE, 2020).

The availability component of food security measures the quantity of food stock, while access component of food security measures whether or not individuals have food, for example, this is measured by real household income (relative to food prices). Utilization is another crucial aspect of food security; it measures the degree to which a consumer meets his or her dietetic needs, as well as macronutrients and micronutrients requirement subjective to their food preferences.

Stability component of food security measures individual temporal dimensional circumstances that helps them achieve their food demand (Kalkuhl *et al.* 2016). Agency is more concern about the individuals or communities who may function on their own to determine what they consume, what they harvest, how they harvest and how they store and distribute food and to engage in food systems-related policy process. Agency security requires socio-political processes that maintain governance mechanisms that allow everyone to meet the requirements of food security. With sustainability, focus is on practices in the food system that help the natural, social and economic systems regenerate long term, and ensure that the food needs of present generations are met without jeopardizing the future generations' food requirements (HLPE, 2020).

Kalkuhl (2016) identified diverse ways of affecting the food security stability aspect: variation in crops (often controlled by trade and storage), actual variations in incomes that affect food and nutrient access, or frequent occurrence of natural disaster (floods or pandemics). In all these situations, variations in food price indicate changes in the conditions of food availability, accessibility and stability for the consumer (Von Braun, 2014).

Having high prices is an indication low food supply (availability of rice) expectation (Webber 2018), which could pose a serious threat to food safety, as short-term policy intervention is limited (at least when global scarcity is present). But high prices may likewise signal increasing food demand, to which governments can more effectively respond with a broad range of measures from trade policies, rich consumer taxes to poor consumer transfers. As poor people spend greater proportion (around 2/3) of earnings to access food, an increase in price of food means a shift in actual incomes; the tendency with which real revenue changes hinges on the position of a household 's business.

In spite of the heterogeneity associated with price links to changes in underlying determinants of food security, Kalkuhl *et al.* (2016) noted three important reasons that price understanding and evaluation are the perfect proxy for food security:

1. Prices are thoroughly linked to a number of factors causing food security (provision, real income, cross-market connections).
2. Prices are observed more often than most other food security indicators and are less costly to collect.
3. Prices provide a broad range of market participants with expectations for future changes and risks to allow researchers to leverage large market capabilities for information processing.

The above characteristics make price dynamics an essential element for food security understanding.

1.2 Problem statement

World food prices have increased over the years with various explanations formulated for the price rise; from extremes of weather to an increase in food reserves as biofuel supply, higher oil prices, higher demand for meat and cereals in the developing countries, exchange rate changes and low stock expectations (see Asseng *et al.*, 2015; Ray *et al.*, 2015; Abbott & Battisti, 2011; Timmer, 2008; Diouf, 2008). Currently, the quick rise in the cost of food has triggered questions mainly between stakeholders about the global food economy's ability to feed the ever-increasing global population adequately, since fluctuations in food prices poses a direct negative impact (ie. increasing uncertainty regarding future market prices). Before the US Congress, Von Braun *et al.* (2008) declared that the increasing price of food products had led to revolt in many emerging countries. In the absence of strategic changes in the agricultural commodities price, the World Bank anticipated many countries would crash into diminution by rising food prices (Inman, 2011).

Food security is influenced by the fluctuations of food prices, and the latter has long been a recurring problem in many African country, of which Ghana is no exception (Olila *et al.*, 2016; HLPE, 2011; Onyuma *et al.*, 2006). This can be seen in Morrison & Sarris (2016) in which price spikes raised undernourished household number from about 850 million to around 1023 million. According to Minot (2011) as cited by Tanaka & Guo (2020) in their study noted that the transmission of high world prices to the domestic markets, caused an erosion of the purchasing power of consumers in developing counties and urban households since they are principal importers (purchasers) of food, hence forcing consumers to buy (spending) cheaper foods. In Ghana, poor households spend a greater share of their income on food (Zereyesus *et al.*, 2017),

whiles at the national level, the country is faced with balance-of-payments pressure due to higher cost of food importation.

Rice remains Ghana's second largest consumed staple food, a source of household income and livelihood along the rice value chain (Amanor-Boadu, 2012; Amikuzuno, Issahaku, & Daadi, 2013; Ashitey & Archibald, 2018; Ayeduvor, 2018). As a result of population growth and subsequent increase in the demand for rice combined with the increasing deficit in the supply of rice (about 66% is from imports), the country may plumb into food insecurity (Amikuzuno *et al.*, 2013; Ashitey & Archibald, 2018).

Rakotoarisoa (2006) observed the rice market to be characterized by a high level of policy distortion. Various interventions made by the Government of Ghana in an attempt to achieve self-sufficiency can be said to be a contributing factor towards rice being a residual market (Ghoshray, 2008). Also, factors such as specific types and qualities of rice affects the rice market. This is further seen in the substitution of the various local rice for high quality imported rice as limited by the taste preferences of the people (Ayeduvor, 2018). For instance, high-quality imported rice (which would imply a lower percentage of broken kernels) commands a premium and is strongly preferred in developed countries and the higher income groups of developing countries.

In particular, the movement of prices for imported rice in the country could provide insights into how the variations in the price of imported rice in one market can influence the price, output, consumption and social welfare of the same commodity in a different market. Therefore, spikes in global prices for imported rice in the future will directly be felt as an outward shock, which will aggravate the availability, accessibility and stability of imported rice in the country.

Although the global social implications of local price transmission have been particularly significant for rice importing countries like Ghana, government interventions are both likely to lead to asymmetric price transmission, via price management programs and huge trade cost in rice commercialization in Ghana on the one hand and market power for imported rice marketing on the other.

The stabilization of the price of imported rice through either trade or buffer stock has been sought to reduce price fluctuation. However, whichever approach is adopted, the cost of stabilization will be high. Unless the internal markets of the said commodity (imported rice) is well integrated in the sense that price movements are transmitted across all spatially dispersed markets (Abunyuwah, 2020; Rashid, 2011; Dawe & Opazo, 2009). Nonetheless, what is of great concern is the cost-effectiveness of the approach adopted and for social welfare implications, a minimum cost approach would be ideal. Imported rice markets in Ghana, like many other developing economies, are likely to be segmented due to several reasons such as poor transportation infrastructure (Amikuzuno *et al.*, 2013; Abdulai, 2000).

While the increasing global food prices is a substantial risk in developing countries to needy people, inflation and volatility in the domestic price of food are determinants of the impact of food crises on poverty and food security. International food rise may be transferred to domestic price in Ghana, as in many developing countries, but not equal and with substantial delays in certain cases. The irregular flow of global price spikes to local price of rice and periods does, however, require the transmission to be carefully characterized in every case to properly develop price stabilization and food safety policies.

Study on price volatility and transmission which greatly impact food security on hand and helps in policy formulation by providing the right information on how to reduce fluctuations or to increase the measure to cope with fluctuations and or implement policies to measure marketing efficiency on the other hand, is limited in our part of the world, especially Ghana. Although a plethora of studies have examined the cereal market of Ghana, integration and transmission of shocks to price in Ghana, most of them were focused on maize and neglecting rice which doubles up as the second most important commodities for the Ghanaian people which is also important for food security and development of the nation.

Against the background information, the study proceeds by asking the following questions.

1. Does the world market have any relationship with the domestic markets for imported rice, to what degree are these changes transmitted to ensure availability of imported rice?
2. What is the extent of price transmission and the speed of adjustment to long-run equilibrium in ensuring accessibility of imported rice in the domestic markets?
3. How does market information and price exchange improve the accessibility of imported rice in the domestic rice markets in Ghana?
4. What is the effect of rice price changes on the stability of imported rice in Ghana?

1.4 Objectives of the study

The main objective of the study is to examine price volatility, how it is transmitted in rice markets and its implications for food security in terms of availability, accessibility and stability of imported rice in Ghana.

The specific objectives are to:

1. To examine the relationship between world and domestic markets for imported rice in ensuring availability of the commodity.
2. To examine the extent of price transmission in the domestic market to ensure accessibility of imported rice.
3. To determine whether transmission in the domestic market is symmetric or asymmetric to ensure accessibility of imported rice.
4. To examine the effect of rice price changes on the stability of imported rice in Ghana.

1.5 Relevance of the study

Studies on price variations (fluctuations), market integration and price transmission have received increasing attention since the recent so-called 'food crisis,' particularly in less-developed countries. Studies of this kind help understand the impact of food security on the livelihoods in food-insecure countries in an interconnected world of price relationships in different markets.

In developing food importing countries, there are serious welfare implications of global to local price transmission arising from the fact that government interference through price control policies as well as high transaction costs in the marketing of rice in Ghana and the presence of market power in the marketing system of rice are both likely to contribute to asymmetric price transmission. Despite the resulting huge welfare loss, no study has either investigated asymmetric price transmission nor determined the extent to which rice price shocks on the global market are transmitted to domestic markets of rice in Ghana. It is imperative to examine the effect of asymmetric price transmission on the imported rice market in Ghana. This is important because results from the analysis will be useful in evaluating whether or not the imported rice market is efficient in addressing welfare (availability, accessibility and stability) needs of poor households in Ghana.

Results from the study will also provide information, policies and measures aimed at improving price transmission between markets, which will enhance market efficiency and increase the accessibility of rice in Ghana. Information relating to the short-run and long-run dynamic movement of price between the wholesaler and the retailer and across time will provide information on the stability of price adjustment policies.

Again, the majority of the works done on price effect and market studies have focused on maize neglecting rice which is the second most important staple food commodity for Ghanaians. Hence the study will add to the growing literature on price volatility and market efficiency of rice in Ghana.

1.6 Organization of the thesis

This research has been organized into five main chapters. Chapter one is the introductory chapter. Relevant literature which significantly contributes to the current study is reviewed in chapter two of the study. Chapter three focuses on the methodology and describes the various analytical tools and methods used to answer the research questions raised for the study. These include the method of data collection, method of data analysis, a brief description of the study area as well as the sample size. The results obtained are presented and discussed in chapter four. Finally, chapter five presents the summary and major findings, conclusions and recommendations.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

This chapter reviews literature available on rice and commodity price volatility in general. The chapter begins with the economic importance of rice. Thereafter, it discusses some concepts of the market and asymmetry in price transmission. The final parts of the chapter review empirical evidence relating to agricultural price volatility studies.

2.2 Economic importance of rice in Ghana

The World Bank (2010) and Foster *et al.* (2010) noted the agricultural sector to be predominant in most Sub-Saharan Africa economies, thereby contributing more than one-third of the regional gross national product and employing more than two-thirds of the labour force. Further, agriculture is one of the major sources of foreign exchange earnings. However, the sector remains largely underdeveloped, in respect of production both for the domestic market and for export (FAO, 2001).

Rice is a commodity of strategic importance to Africa and has become one of the fastest-growing food sources to both rich and poor households (Nwanze *et al.* 2006; Danquah & Egyir, 2014). It also contributes significantly to the economic growth of many nations in the world. Reidsma *et al.* (2011) described the crop (rice) as the foremost food of most developing countries. According to Vaughan *et al.* (2003), rice serves as a major source of nutrition for about two-thirds of mankind. Rice has increasingly become a popular food in Africa as it is tasty and quick to cook. It competes effectively with traditional coarse grains and roots and tuber crops.

In Ghana, the crop (rice) has been described as an important staple food for both rural and urban communities and an important cash crop in the communities in which it is produced (Assuming-Brempong & Osei-Asare, 2007). According to MoFA (2016), the crop is ranked as the second most important food staple after maize and its consumption keeps increasing as a result of population growth, urbanisation, and change in consumer habits. Rice crop became important in Ghana from 1960 (Kwadzo & Assuming-Brempong, 2008). Socio-economically, the trade in rice in Ghana contributes immensely in developmental goals. As an essential commercial food item, it is necessary to approach its production, management and marketing in more integrated manner in order to lessen poverty rate. An earlier report of the FAO (2005) identifies rice as vital in hunger eradication, poverty reduction, ensuring food stability, and promoting economic growth through productivity enhancement.

In Ghana, the per capita consumption of rice has grown from 17.5 kg to 35 kg in just two decades, with a current total rice consumption of about 1.17 million MT (MMT), (Archibald & Taylor, 2019). Conversely, domestic production accounts for about or a little over 30% of the total supply and is increasing at an average pace. Thus, roughly only 450,000 MT of rice consumed in this country constitute total yearly domestic production. Domestic production of rice has continued to lag behind other crops due to its low cereal yield and high reliance on grain imports, high cost of inputs and production constraints, difficulties in accessing credit, use of poor yielding seed varieties, inappropriate agronomic practices, limited mechanization, poor processing methods, and poor marketing strategies (Obirih-Opareh, 2008). Consequently, policy strategies over the years have sought to promote the production of rice. "Planting for Food and Jobs" is a recent agricultural program which aims to increase the yield of rice by 49% at the end of the fourth year of implementation, which is 2020 (MoFA, 2017). Domestic rice production serves as a means of

reducing dependency on imports, lowering the pressure on foreign currency reserves, ensuring stable and low-priced sources of food for people and generating employment and income for rice farmers (Ayeduvor, 2018). The significance of rice is seen in its inclusion in most of the agricultural policies in Ghana as a target crop.

Notwithstanding, the country's ability to increase domestic production is constrained by several factors such as high cost of inputs and production constraints, difficulties in accessing credit, use of poor yielding seed varieties, inappropriate agronomic practices, limited mechanization, poor processing methods, and poor marketing strategies (Obirih-Opareh, 2008). Besides, the economic importance of rice and its increasing demand worldwide, Africa, and Ghana, specifically, justifies the intense efforts to promote its productivity under various production systems through the development of improved rice varieties.

2.2.1 Contribution of rice to employment

The rice sector is an important provider of both direct and indirect jobs for many people in Ghana (Kranjac-Berisavljevic' *et al.*, 2003). Activities along with the value chain offer income opportunities for thousands of people in micro-enterprises, mostly women (DAI, 2015). The local value chain consists of several actors: input suppliers, producers, importers, millers, wholesalers and retailers or traders (Ampadu-Ameyaw *et al.*, 2017). Farmers procure inputs from private entities such as agrochemical dealers and seed producers at the local and urban market centres. Rice farmers constitute a large number of participants of the value chain actors (Addison *et al.*, 2015; Boansi, 2013). Many projects embarked on by government and development agencies have aimed to promote local rice production to improve the economic condition of small-scale rice farmers. Millers are those who either mill farmers' paddy at a fee or act as aggregators to purchase paddy from farmers, process them and sell to wholesalers or traders (Addison *et al.*, 2015).

Wholesalers are rice traders operating in large shops, selling mostly in large quantities of 25 or 50 kg bags/sacks. They function as intermediaries between millers/ importers and traders (Addison *et al.*, 2015). Retailers sell in small quantities to consumers. Example are those selling rice in bags of various sizes, as well as in bowls and tins. The import value chain is much simpler, the main wholesale rice importers distribute rice to wholesalers around the country, who in turn sell products to retail networks (DAI, 2015).

2.2.2 Contribution of rice to poverty reduction and food security

According to the World Bank (2016), the proportion of poor households in sub-Saharan Africa reduced by 7% from 2002 to 2012 as a result of the adoption of improved rice varieties with high yields. According to Figure 2.1, the adoption of NERICA rice variety led to increase in yield (quantity available) resulting in a 5% reduction in poor households in Ghana. A study done by Wiredu *et al.* (2014) showed that adoption of the variety had a significant impact on the incomes of rice-producing households in Northern Ghana. According to the study, the adoption significantly increased rice income, agricultural income, per-capita income and total annual income by \$196.52, \$446.37, \$0.44 and \$498.44, respectively.

Majority of value chain actors identified are smallholder male producers and processors dominated by women. Promoting the local rice industry will enhance the output and income of these actors, thus reducing the rate of poverty among households (MoFA, 2009).

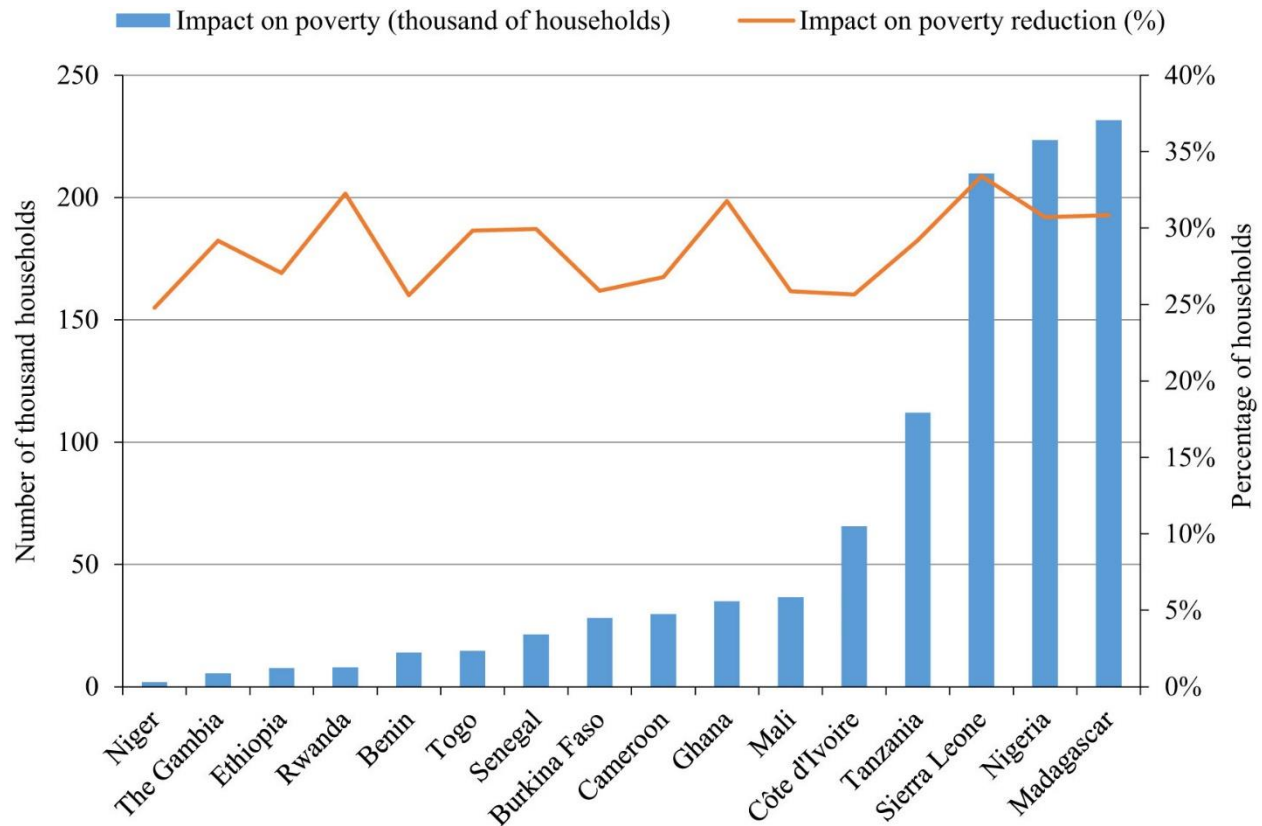


Figure 2. 1: Percentage and number of households saved from poverty due to adoption of improved rice varieties in SSA countries in 2014.

Source: World Bank (2016)

The country's production of rice satisfies between 30% and 40% of the demand, while the deficit is sourced through imports (Angelucci, 2013). Increase in rice production (availability) offers a sure way of addressing food security issues through stability of price of the commodity leading to access by the economic agent. For the past years, MoFA has embarked on various Food Security programs in collaboration with other institutions and NGOs in different regions of the country. Under the Multinational NERICA Rice Dissemination Project, the proportion of rice-producing households that shifted from food insecurity to food security due to the adoption of NERICA rice variety was found to be 44% and 26% in the abundance period and in the scarcity period respectively (Arouna *et al.*, 2017). Also, result from an assessment of the planting for food and

Jobs program showed that rice production had increased by 8.54% from 2016 to 2017 in the Northern, Brong Ahafo and Volta region of Ghana (Tasila *et al.*, 2018).

2.3 The concept of market

Market as defined by Kuang *et al.* (2018) “is the area within which the price of a good tends to uniformity and allowance made for transportation costs”. It involves various actors spreading out to perform diverse marketing activities. In spatial price linkage analysis, the degree to which agricultural markets are integrated can be used to determine the efficiency of the market under study. Most often, for one to adequately capture the concept of market, it is best to proxy the market with market integration and market efficiency since they are easy to study and explain.

For market efficiency, the market conduct, structure and performance are core vital elements. The extent of market competition or market efficiency has a great influence on the level of price formation in the market concerned. It in turn regulates the number of buyers and sellers, conditions for entry/exist and also the size of firms. Earliest researcher like McCorriston as cited by Cavicchioli (2018) modelled the market structure to exert some level of influence on the transmission of changes in prices. In their study, they show that market power reduced the extent of the transmission of price between those actors closer to the farm and retail section. Thus, price transmission will be complete if markets are imperfectly competitive in nature.

Market conduct can serve as an indicator of how agents in the market behave in relation to the determination of price, tactics to promote sales and to regulations introduced by the government. The way in which prices are formed is directly linked to these actions. When prices in the marketplace are formed based on the collusive activities of market agents, imperfect price transmission will occur within that particular market or between that market and other markets. This will result in inefficiencies in the marketing system as a whole. But prices generated from the

interactions of the forces of demand and supply is similar to that of a marketing system believed to be efficient.

The structure of a market together with the market conduct is representative of the performance of a market (Kanakaraj, 2010). Market performance is defined as how well a market uses the scarce resources available to meet the demand of consumers for goods and services. In an economy, where a price determined by a firm is just equal to its average cost, the market can be considered to be efficient or is performing its functions adequately. In the same vein, a less profit margin can also be taken as an indication of market that is efficient in performing its function. In other words, one can determine the efficiency of a particular marketing system through the price and profit margin levels of prices and the level of profit

2.3.1 Rice marketing system in Ghana

In Ghana, the marketing system of rice refers to the types of distribution channels which business and firms employ in the marketing of both local and imported rice. Basically, there are two main supply chains; the local rice marketing system and the imported rice marketing system (Amikuzuno, 2013), which is further described as Indigenous Distribution and Expatriate marketing Systems. Amikuzuno (2013) further explained that pre-liberalization of some Government policies and regulation has led to the involvement of a number of private traders in the rice marketing system. Hence prices of both local and imported rice are determined by market forces (supply and demand) to buyers in the hinterland along the imported rice supply chain

From Figure 2.2, the local rice supply chain involves a host of indigenous rice millers or processors. From these processors, the commodity may either be distributed to the sedentary and itinerant wholesalers and then to the rural/ urban retailers linking smallholder farmers and consumers. Imported rice from the country's port contrarily is temporarily stored in the storages

of importing companies and then distributed through sedentary wholesalers to the urban and rural retailers (Amanor-Boadu, 2012). The goods may then be either allotted directly to the end consumers or maybe dispensed via diverse means of retailing before reaching the ultimate consumer. Since the domestic production of rice is not able to keep up with growing demand, a greater percentage of rice consumed in Ghana is imported (DAI, 2015). Ghana imports rice from countries such as the Vietnam, U.S.A., China and Thailand. Traders in the rural and inner-city markets in Ghana often partake in the two supply chains concurrently by merchandising both local and imported rice. Both domestic and imported rice are sold on urban markets, nonetheless the inconsistency in the delivery of local rice causes imported rice to dictate the market system.

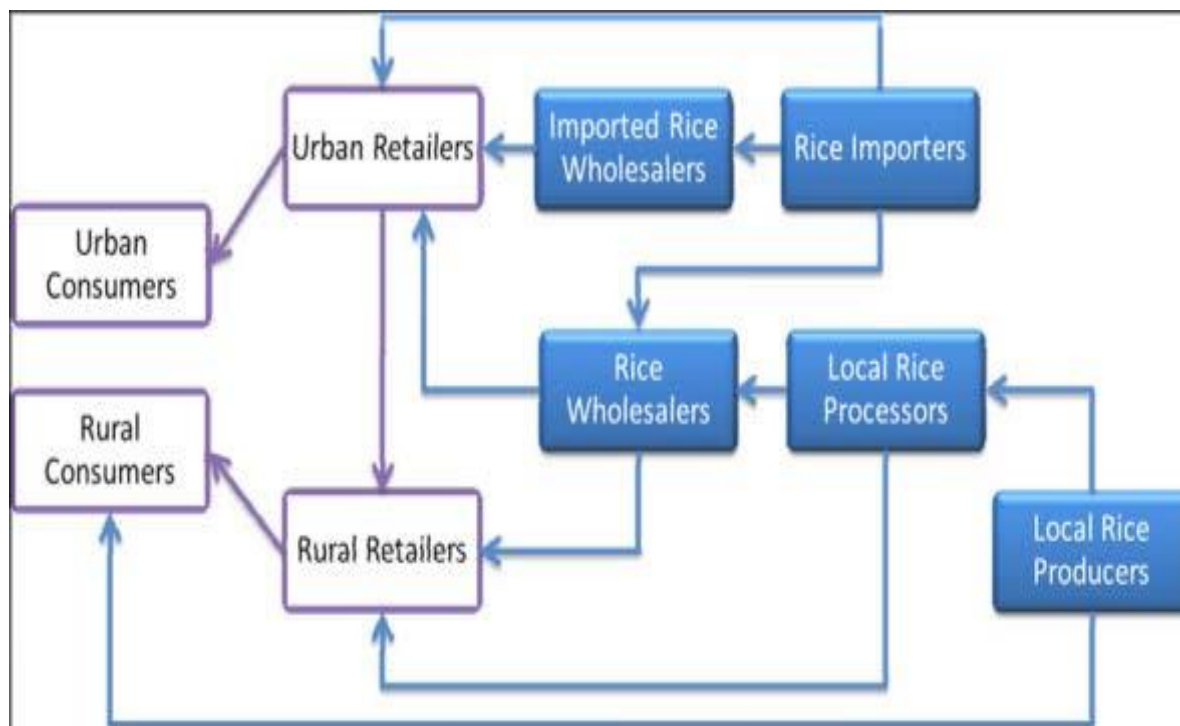


Figure 2. 2: Distribution network of both local and imported rice in Ghana

Source: Amanor-Boadu (2012).

2.3.2 Price transmission and market integration

The conceptualization of the price transmission and market integration is a broad one and for one to be able to adequately explain, it should be taken from various points of interest. Price transmission is the measure of the effect of prices in one market on prices in another market. As explained by Abunyuwah (2020) and Amikuzuno (2010), market integration and transmission depict a measure of how information is exchanged and how markets at geologically different settings share long-run price. Spatial market integration may also show the movement of prices for market pairs across different space and time. Also, it may give evidence to how the volatility in supply and demand in a market is transferred to different markets in distinct locations.

It is thought to spring from three underlining concepts (Balcombe & Morrison, 2002); *(i)* The concept of price co-movement and complete of adjustment, *(ii)* The concept of dynamic speed of adjustment and *(iii)* The concept of asymmetry of response. The first concept of price co-movement and complete of adjustment suggests that at any point in time variations in the prices of a commodity in a particular market are completely passed on to another market. While the second concept of dynamic speed of adjustment looks at the speed by which prices in a particular market is completely passed on to another market or level. The asymmetric concept identifies if the price transmission process among markets are characterized by symmetric or asymmetric relationships. That is, in other words are shocks that increase prices passed on faster than those that decrease market prices. The rate of adjustment and the degree of completeness can be characterized by relationships that are asymmetric in nature.

Mounirou (2016) pointed that spatial market integration is very significant in agriculture. He explained that, agricultural products are usually huge or and easily get spoilt and sometimes production might be greater in one area whereas consumption may be higher in another location,

which indicate costly transportation. It is therefore, very important for markets to function properly as it informs economic policies and decisions. If markets are not integrated spatially, there is restriction in transmission of price incentives and welfare. In addition, markets which are not perfectly integrated can transfer wrong information on price to producers and/or some players in the value chain which could lead to welfare loss (Bakucs & Ferto, 2007).

Amikuzuno *et al.* (2013) who examined the transmission of price signals between imported and local wholesale rice prices from 2006 to 2011 reported a long existing correlation between imported and local rice prices in Ghana. According to the study, over the long period of time, the two price categories co-move and may be driven by common stochastic processes including both local and possibly international price and output shocks. Similarly, Cudjoe *et al.* (2008) reported that the rice markets in Ghana are absolute but somewhat integrated. However, in a work done by Assuming Brempong & Osei-Asare (2008) on analyzing the possible connection between imported rice and local rice in Ghana using the Engle and Granger two-stage approach, they reported that the imported rice industry is segregated from the domestic rice sector in Ghana. The absence of market integration is called market segmentation.

A study by Gupta & Bansal (2020) also indicated that market integration is dependent on the act of agents and also on the location in which traders operate. This includes marketing infrastructure such as transportation, credit, communication and facilities for storage which generate huge margins in marketing due to transfer costs. Partly, this can shield local markets. The actions of Governments such as price stabilization, trade restrictions and stabilizations among others can also affect market both positively and negatively. Also, self-sufficiency status can be determined by the level of production surrounding a particular market. In essence, if there is wide variation in

markets with respect to their respective self-sufficiency position, then markets are more likely to be integrated.

2.3.3 Spatial arbitrage and market efficiency

In spatial price analysis, spatial agricultural market integration is also used as a proxy for productivity in agricultural markets. For example, "spatial market efficiency and spatial market integration" are interchangeably used (Negassa *et al.*, 2003). These words have been identified as related but not equal in the growing literature (Barrett & Li, 2002) and must therefore be differentiated. Spatial market efficiency is a condition of balance in which all potential profitable arbitration opportunities are eliminated. Without trade, a differential of spatial prices below transfer costs is equal to market efficiency. However, according to Negassa *et al.* (2003), the market is inefficient with or without trade if the spatial price difference is greater than the transfer costs.

2.3.4 Spatial arbitrage

The process of exchanging goods with a view to exploiting price differences that exceed the transportation costs is spatial arbitration (FAO, 1997). Spatial arbitration conditions ensure that differences in price between markets that trade with each other are equal to transportation costs for a homogenous product (Tomek & Robinson, 2003). Arbitration takes shape and profit seekers buy goods in surplus markets to deficit market if price differences over transfers are reached (Katengeza, 2009).

Considering two markets (A1 and A2) who are spatially different at time t and prices. Both markets are said to be integrated when the price is equal on both markets, and only the cost of transportation is correctional. Trade between these two markets will take place only if the price change is greater than the cost of transport. This methodology has been tested in the "Law of One Price" concept

using regression analysis from previous studies. The oligopolistic behavior and collusion of domestic traders is listed as an additional determinant of market integration by Rapsomanikis *et al.* (2003). Traders can retain price differences between markets based on transportation costs.

2.3.5 The law of one price

The Law of one price (LOP) is an economic approach used to measure spatial market integration. It states that a price change in a single market (instantly) shall be translated to another market linked by trade in a single homogenous commodity, provided efficient arbitration is established and that the two markets maintain a competitive balance. When trade flows from one market to the next, a strong LOP is met until the price variation between the two markets is equal to the cost of transfers between markets (Tanko & Amikuzuno, 2015). It is therefore a necessary condition for spatial price efficiency, since this is only possible if there are no barriers to trade or if transport costs are insignificant between markets.

In addition to conventional transaction costs, other factors that may prevent the validity of the LOP and for that matter, interfere with spatial arbitrage and then with price transmission include; domestic and border regulation policies, market power, product heterogeneity and perishability, exchange rate risks, imperfect flow of information and expectations are some of the factors that interfere with spatial arbitrage, and then with price transmission (Cioffi, 2010).

2.3.6 Spatial market efficiency

Spatial integration occurs when homogeneous commodity prices converge into a single market in spatially distributed markets. The presence of spatial integration ensures that macroeconomic policies, technological adaptation and adaptation of net export flows across space are successful (Adom, 2014). In other words, if homogeneity markets are not spatially integrated, the benefits or losses resulting from any policy changes that affect the market may not necessarily be an increase

to those markets outside the direct impact of the policy and equilibrium of the whole marketing system (Tanko & Amikuzuno, 2015).

Studies on spatial market integration try to answer questions on the characteristics of the price transmission process that occur among markets situated at different locations. This is done by answering questions on the patterns of causality among market pairs, dynamic interactions and the presence of a long-run balance.

2.4 Asymmetry in price transmission

Asymmetry in price is when prices in one market respond differently to the changes in prices in another. One could observe asymmetry through the extent or speed of the adjustment parameter. The former is concerned with the short-run elasticities while the later, asymmetry could be observed in the long-run parameter (Rapsomanikis, 2009; Mallick & Behera, 2020). Some researchers who have worked on asymmetry in price relied on the use of the asymmetric error correction model developed by Granger & Lee (1991) while other researcher used the threshold cointegrating model proposed by Enders and Granger. They concluded that asymmetry in price could either be positive or negative. Here, a positive asymmetric effect responds rapidly to an increase in price of another market of the same commodity than it will respond to a decrease I price while a negative asymmetric effect will act in the exact opposite manner. Here asymmetry in price will either enlarge margins or otherwise. Hepsag (2019) concluded that such effect determines the direction of welfare of the consumer.

Also, according to Alam *et al.* (2006), asymmetric price transmission is associated with agricultural prices. Studies like Meyer & von Cramon-Taubadel (2002) subsequently deployed the divisive method to establish asymmetry in price transfer. However, these studies preceded

cointegration developments hence, problems related to non-static series were not taken into consideration (Hassouneh *et al.*, 2012). The variable splitting technique was therefore included in the error correction representation to fix the non-stationary problem. Variants of this method have been commonly used since that time.

Meyer & von Cramon-Taubadel (2004) observed vertical asymmetry to occur in markets where price responses occur along the food supply chain and in spatial asymmetry when price responses occur between markets located in different areas. The direct meaning of asymmetric price transmission is that various markets actors are not enjoying the benefits they would have derived from reductions or increase in prices under conditions of symmetry. This is because under conditions of asymmetry the timing and/or size of the changes in welfare linked with changes in price are distorted (Meyer & von Cramon-Taubadel, 2004).

Amonde *et al.* (2009) noted market power to be a major cause of price asymmetry. Market power happens when individual player along the marketing chain are able to distort price by influencing the prices of the said commodities to remain same over a certain competitive level. Farmers and consumers in the agricultural sector especially, often believe that imperfect competition in processing and retailing provides an opportunity for middlemen to abuse market power. It is expected that this will often result in positive asymmetry however; it is not the only effect emanating from market power. Also, Ankamah-Yeboah (2012) point out that because of fear on the part individual in the oligopolistic market, they are hesitant to increase the price of their output.

Usman & Haile (2017) argued that management of inventory by traders is a possible cause of market asymmetry. He argued that instead of decreasing the price of output following a decrease in demand, firms rather increase their inventory level while in times when demand is high, they increase the prices of their goods. Such actions of the actors combined with the transactional costs

associated with the decreases and increase in inventory levels may result in prices being sticky upwards. Likewise, Frey & Manera (2007) pointed out that accounting approaches such as “FIFO (first in first out)” could result in unequal transfer of price.

Intervention role of the Government can be seen as an additional cause of price transfer asymmetry. This is clearly demonstrated by a political response, mainly as a floor price, in terms of price support in agriculture (Ankamah-Yeboah, 2012). The resulting asymmetry is if retailers or wholesalers believe that this intervention takes a long time, then increases in downstream price are passed on by traders easily and absolutely and slowly (Uchezuba *et al.*, 2010). The resulting asymmetry can be expected.

2.5 Review of theories underling price volatility and transmission analysis

Events like boom and bust (volatility) are characterized with agricultural markets and episodes of such inevitably triggers alarm whether consumers are food secured. According to Gouel (2012), the involvement of the public in food price stabilization has been a common practice for a long time. When the supply of a particular commodity falls short, their prices increase, consumption decreases and investment in production is stimulated. For agriculture markets to function well, a certain level of volatility is necessary (Minot, 2014).

Traditionally, there are two proposed theories to explain price dynamics in the agricultural sector. One which stem from real stock and the other which stem from forecasting errors. The former fits with the rational expectation framework whiles the later fit for the coordination issues with price (Gouel, 2012). However, in recent times the theory of food price volatility can be understood from different perspectives: (i) Cobweb Theory (ii) Storage Model (iii) Agricultural Price Fluctuation Model.

2.5.1 The Cobweb model

A filament of literature on the Cobweb focuses on the formation of expectations and their effect on the stability of equilibrium of price (Bohner & Hatipoğlu, 2019). The theory initially was developed under static price expectations where the predicted price equaled the actual price in the last period (Shone, 2002; Hommes, 2018). The Cobweb model is used to describe a prominent characteristic of agricultural markets; the production and supply decision of farmers and consumers. Here, production decision by the farmer is conceived before its implemented, thereby resulting in short-run inelastic supply.

A small elastic demand will cause a market disturbance with a considerable effect on price. From the rigid demand, prices must change substantially in order to cause significant demand change (Bohner & Hatipoğlu, 2018). This model is presented in a linear form in Table 2.1.

Table 2. 1: A linear Cobweb Model

$q_t^D = a - bq_t$	Demand	(2.1)
$q_t^S = c - dq_t + \epsilon_t$	Supply	(2.2)
$q_t^D = q_t^S$	Market equilibrium	(2.3)
$p_t = p_{t-1}$	Naïve expectation	(2.4)

Source: Gouel (2012)

Here, both curves for demand and supply are linear with the later having an error term (ϵ_t). Producers will at each stage of the production plan their future outputs based on the current market prices as seen in equation (2.4). In a study by Gouel (2012), the deterministic aspect of the dynamics was said to depend on the demand and supply slopes. He noted that any price equilibrium

that deviates from the deterministic steady state, will display dampened oscillation, explosive oscillation or steady oscillation ($\frac{d}{b} < 1, \frac{d}{b} > 1, \frac{d}{b} = 1$).

Other researchers like Darity et al. (2004), Gertchev (2007) and Gouel, (2012) were of the view that the Cobweb model suffers internal contradictions. They argue that diverging and oscillatory regimes will involve huge losses compared to profit for the producers. Explicit conclusions on how more producers are prepared to invest money in an unprofitable venture will require a simple economic model.

In other words, prices will be negative for explosive regimes. Guo (2013) thought supplies could not in the short run be so inelastic, but rather spectators stock grain surpluses in times of abundance, of which they will sell at higher rates later. The behavior of stockpiling tends to increase the elasticity of demand (supply) for low (high) prices, thereby stabilizing the market. Again, he noted that producers will not automatically or immediately follow a sudden change in prices, but will rather adjust slowly.

The adaptive expectation theory was formulated based on this point of view. Here the producer revises expectations following the previous forecasting errors.

$$\widehat{P}_t = (1 - w)\widehat{P}_{t-1} + wP_{t-1} \quad (2.6)$$

This includes the unknown term $w=1$. Also, farmers respond more (less) to changes in prices. Hence the new price will converge at $\frac{d}{b} < \frac{2}{w} 1$. Thaler (2016) observed a wasting attitude of producers since their activities does not follow economic theory. The non-linear dynamic models, notably the non-linear Cobweb model and heterogeneous agent model were developed to deal with the short comings of the linear Cobweb model.

Following naive expectations of farmers in a cobweb model, a monotonic supply and demand curves will result in the same quantitative behavior of farmers. Hence allowing for three (3) types of behavior: divergence; two-period cycles; and convergence. Any departure (in a form of non-monotonic curves) from this case will result in chaotic dynamics (Hommes, 2018). For instance, Hommes (2013) demonstrated that simple monotonic S-form are adequate for non-linear deterministic dynamics and adaptive expectations.

Table 2. 2: A non-linear cobweb model

$q_t^D = a - bq_t$	Demand	(2.1)
$q_t^S = \arctan(\lambda \widehat{p}_t)$	Supply	(2.2')
$q_t^D = q_t^S$	Market equilibrium	(2.3)
$p_t = (1 - w)p_{t-1} + wp_{t-1}$	Adaptive expectations	(2.4')

Source: Gouel (2012)

As seen in Table 2.2, focus is placed on the deterministic dynamics in trying to underline the endogenous nature of the fluctuations with no supply disturbance term involved. Many of the disparagements of the single “linear Cobweb model”, the nonlinear cobweb models are included. Commendatore & Currie (2008) establish that failing to include “borrowing constraints” in the model results in financial breakdown. On the other hand, it is too risky to introducing borrowing constraints.

The heterogeneous agent model was also developed in an attempt to address issues with both linear and non-linear cobweb models. This model is based on the balance between costly and reverse expectations (Coibion, 2018; Homs, 1997). If conceiving good prospects is expensive and agents make coherent choices based on their past performance between different expectations schemes,

complex dynamics arise. In times of restricted uncertainty, reasonable expectations are too expensive to be employed and agents turn to naive expectations that can destabilize the market. Stability reverts to the rational expectation if a sufficient number of actors return to the system. This scheme, developed by Brock and Hommes (1997), justifies the retrospective expectations as a rational compromise between good, but costly and bad but cheap forecasts.

When costly and dynamic expectations are complex, retroactive expectations become sustainable. There are various extensions for this model. Goeree & Hommes (2000) and Lasselle *et al.* (2005) generalized Brock and Hommes models by introducing nonlinear supply and supply curves and adaptive expectations. Backward-looking errors with a strong cyclical pattern are criticized. In chaotic circumstances one would expect better properties than linear dynamics. Also, a better pattern in the prediction of errors would be difficult to identify. The forecasting errors are strongly negative in their initial development and therefore show little consistency between expectations and achievements despite the chaotic dynamics of the non-linear cobweb models with reverse-looking expectations.

2.5.2 The storage model

This model restricts the dynamism to exogenous shocks around the steady state in a simple linear model with a production lag. Producers are always planning to produce the same quantities and actual production is only a disturbance around this stable level. Inventory speculation has a bearing on price dynamics. Schewe, Otto & Frieler (2017) noted a positive initial serial price correlation with storage model. During several periods, speculation smoothes shocks, thus the effect of the shock spreads over further time and results in a positive serial correlation. The simple rational expectations and cobweb models on the other hand produce zero and negative associations. The two are inconsistent with the actuals, which show strong positive autocorrelation. Storage model

helps to understand one of the principal characteristics of the product price series, and reintroduces dynamic features other than exogenous shocks in the production lag model.

It is difficult to technically and adequately treat the storage model because of its regime-switching behavior, since storage can either be positive or zero. This problem can be overcome if negative storage is possible. Following the negative constraint, the question of stock speculation under the rational expectation can be handled but without supply reactions. In the context of the open market and absence of distortion, the behavior of private storers coincides with governmental storage programme. The competitive storage model differs only slightly in rational expectations from the simple linear model.

As shown in Table 2.3, the storer will be holding positive inventories in equation (9) when the price for the period is expected to cover purchasing costs, marginal storage costs (function μ of stocks X_t), opportunity costs (at the rate r) and depreciation (at the continuous rate δ). There are no stocks when the anticipated profit is negative. The condition of market clearing in equation (7) takes stock into account. The total supplies are equal to the present production and inventories transferred from the preceding period after depreciation, while demand is made up of consumption and inventories exceeded. A non-negative limitation makes the model analytically unwieldy.

Table 2. 3: A storage model

$q_t^D = a - bq_t$	Consumption	(5)
$q_t^S = c - dq_t + \epsilon_t$	Production	(6)
$q_t^D = q_t^S + (1 - \delta)X_{t-1} - X_t$	Market equilibrium	(7)
$p_t = E_{t-1}(p_t)$	Rational expectation	(8)
$p_t \geq \frac{1-\delta}{1+r} \hat{P}_{t+1} - \phi(X_t) \perp X_t \geq 0$	Storage arbitrage	(9)

Source: Gouel (2012)

The study will dwell on the Agricultural Price Fluctuation Model.

2.5.3 Agricultural price fluctuation model

There are two schools of thought surrounding agricultural price fluctuation model. One which stem from the cobweb model while the second school from the rational expectation assumption. The former views fluctuation/volatility as originating from forecasting errors while the later views fluctuation as a result from real shocks. Here in price fluctuation, changes in price are obtained by the best actions of agents (competitive farmers and storers). Two questions arise from the use of these model. Is volatility exogenously determined by real stocks or fluctuations are endogenously driven by forecasting errors?

Researchers such as Chatrath *et al.* (2002) and Cashin *et al.* (2002) identified the non-linear cobweb to have a stylized fact on agricultural prices. They demonstrated agricultural prices to not being normally distributed but also having high level of autocorrelation (positive first order). They also noted these prices to be positively skewed with excess positive kurtosis. They asserted that clustering of uncertainty in price is evidential and asymmetrical cycles having more slumps compared to upturns are evidence.

Given that empirical failure of some models does not prevent other models belonging to the same family from having an empirical success, the mixed agent models seem statistically more reliable than non-linear models in cobweb. It fit the stylized facts more effectively. The relationship between rational manufacturers and retroactive producers generate the common sequence of bust, doldrums and booms.

2.6 Empirical studies on price volatility

A plethora of researchers have examined price volatility and its cause using different approaches over the years. Using the Ordinary Least Square (OLS) model, the Generalized Autoregressive Conditional Heteroscedasticity (GARCH), Exponential GARCH in mean (EGARCH-M) and GARCH-dummy models, Ghosh *et al.* (2010) deployed annual prices to examine fluctuations in supply response for maize, groundnut, rice, cotton and jowar. He concluded that agricultural commodities became unstable following the World Trade Organization (WTO) agreement in India. This violates the normal trend in agricultural commodity markets, where price volatility is normal.

In one of the unique studies of this kind, Zheng *et al.* (2008) employ an E-GARCH model to understand how unpredicted price impacts food price instability. The outcomes of their study showed that magnifying consequence of price is seen in 1/3 of the products. And so, they reason that when one increases the concentration of delivery and vending of food, price volatility is absorbed by the large firms.

Likewise, Swaray (2007) model a Threshold GARCH (TGARCH) and an Exponential GARCH (EGARCH) to assess the direct and indirect impact arising from the suspension of international commodity agreements on volatility and asymmetry persistence. They used monthly price data for coffee, tin, sugar, cocoa, and rubber. They concluded that there is a decrease in the persistence of volatility but a rise in asymmetry.

Also, with the use of high-frequency data of cocoa, Taylor (2004) applied the Period GARCH and Periodic Conditional Volatility (PCV) models to assess the periodicity in conditional return volatility. He noted that by not considering the periodicity in frequency data, one is bound to make spurious furcating in the return volatility. He then concluded that PGARCH model is less precise

comparing the results from PCV, but the former produces accurate and consistent VAR measures when deployed in a Value at Risk framework.

Roache (2010) in his study in explaining the drivers of low-frequency volatility of some selected commodities in the US used monthly spot prices to access the “Spline-GARCH model”. His research found that the slow movement in volatility has a strong link between the various commodities, which shows that common factors influence low-frequency volatility. He further demonstrates that since the mid-90s, inflation and exchange rates have the greatest impact on volatility.

Hayo *et al.* (2012) paper is another early article on this issue. They measured the price volatility of different commodities (agriculture, animals, energy and metals) with a GARCH model and its effect on U.S. monetary policy. They conclude that expected changes in the target rate and communications reduce volatility, while unexpected changes in the interest rate and innovative measures increase it.

By employing the exponential smoothing time series model, Hayat & Narayan (2010) survey the volatility in the growth of US oil stocks overtime. Overtime, volatility of the oil stock time was decreased. They also conducted a simulation of Monte Carlo to understand the decline. The fact that a decrease in oil inventory growth volatility is an artifact of the growth definition is supported in their findings. However, Hayat & Narayan (2011) applied the univariate time series models to investigate if the shocks in demand and supply explain the apparent decrease in U.S. oil stock growth volatility since the mid-1980s. They found that almost 70% of the growth in the US oil stock is based on its supply and demand factors and each of these shares around half.

Apergis & Reztis (2003b) use GARCH models “ECVAR and MVGARCH” in an attempt to understand volatility spillover effects across agricultural input and output prices and retail food prices in Greece. Using the Greece retail food price index (both agricultural input and output) between the periods of 1985 - 1999. They conclude that significant and positive effects were imposed by the volatility of both agricultural input and retail food prices on the volatility of agricultural output prices. Moreover, retail food prices have had a greater impact on output price volatility than input price volatility, which shows that demand-driven factors are stronger than cost drivers, influencing output price volatility. Based on their results they postulated that the impact of such volatility may increase market uncertainty and risk for producers and consumers of agricultural commodities.

The work of Apergis & Reztis (2003b) was criticized by Kostov & Mcerlean (2004). They believe that the Mixtures of Distribution Hypothesis (MDH) theoretically can better explain the reverse effect following other financial markets. Hence, they argue that an adequate model should include (own) volume to explain agricultural price volatility.

A prominent study conducted by Oleg (2011) on assessing the interrelationship between commodity futures and government bonds in China. He applied the Bivariate GARCH and ARCH approach in his modelling using a five-year data from China bond index, Shanghai Stock Index (SSI), and a series of commodities. The researcher found that the "conditional correlation falls in period of recession; namely, when market risk rises, which is good news to asset managers since it is precisely when market volatility is high that the benefits of diversification are most appreciated. On the other hand, the negative correlation between the Government 10-year bond and commodity futures Indices rises with the bond volatility, suggesting that, unlike stocks, a bond

and commodity portfolio should be tilted more towards commodity futures in periods of high bond volatility”.

In addition, Narayan & Narayan (2007) use the Exponential Generalized Conditional Heteroscedasticity (EGARCH) model with daily data for the period 1991–2006 to check for evidence of asymmetry and persistence of shocks. In their work, volatility in various sub-samples were defined to determine the robustness of their performance. In the different samples, the asymmetry and continuity of shocks and the entire sample period are shown to be inconsistent. They also show that shocks have permanent effects on volatility as well as asymmetric effects.

The regime-switching stochastic volatility concept was employed by Vo (2009) to explain the nature of volatility of crude oil prices in the West Texas Intermediate (WTI) market. That is the researcher in his study specifically modelled the volatility of return series as a stochastic volatility process whose mean is subject to shifts in the regime. On the other hand, Hou & Suardi (2012) use an alternative method to model and forecast oil price return volatility. They made use of a nonparametric GARCH framework. Using Brents and West Texas Intermediate (WTI) as their markets, he estimated and forecasted volatility of the nonparametric GARCH model. This yielded a more robust parameter relative to an extensive class of parametric GARCH models.

2.7 Empirical estimates of volatility and food security

Price volatility is a major issue of concern because of its' effect on food security in an economy. Viñas ivani (2013) pointed out that instability of agricultural commodity prices affects food security and health negative. The report says that households react to sharp increase in food prices by eating cheaper and less nutritious foods which can have a lasting impact on individual 's social, physical and mental wellbeing. The regular low prices reduce farmers' household revenue during the glut and harvest periods for cultivated crops which have low or no storage capabilities (FAO,

2011). Furthermore, the macroeconomic implications of food price volatility may result in political instability (Abbott, 2011).

The adverse effect of high rocketing food prices on poor people are assessed empirically by three main approaches: simulation (Ivanic *et al.*, 2012; FAO 2008), auto-reporting and real measuring. The simulation method uses elasticity parameters to envisage the outcome of price changes on income and consumption observed. To simulate pricing effects, different of market and economical models have been advanced. Using the home surveys and the elasticity coefficients the simplest simulation is done. On the other hand, the self-reporting approach depends on direct questions from households or individuals reporting on how their purchasing power, hunger occurrence and consumption have been affected by the food price crises. For instance, the frequency and size of meals taken daily or changes to the school enrolment of children may be included in the reported effects. The answer to aforementioned issues is very subjective and dictated by many uncontrollable factors. Even though it seems more reliable than simulation. For instance, it cannot be separated from the effects of the economic crisis and the food crisis.

The measurement approach also estimated the impact of pre- and post-crisis data. For instance, this approach can compare the rate of malnutrition in children before and after price swings. This is the most reliable way of assessing the impact of food prices, but it requires consistent ex ante and ex post information. Due to the differences between these three methods, researchers can come to various conclusions about the cost of volatility. In addition, ongoing processes including economic growth and technological change should include measurement and estimation of the cost of food price volatility. Triangulated evaluations of all three methods suggest the pros and cons of each approach.

A recent World Bank simulation suggests that 68 million people have become poor and 24 million have been driven out of poverty by the 2011 price increase (Ivanic *et al.*, 2012). Home level analysis also indicates that poor consumers are, as expected, much more vulnerable than wealthy households. A study conducted in eleven countries on the impact of high food prices shows that the most vulnerable families in urban and rural areas are the worst affected (Zezza *et al.*, 2008). An increase in the price of food often leads to a rise in food insecurity amongst a large majority of producers. The increase in domestic food prices in Pakistan in 2007–08, estimated at 35% (45% in cities and 33% in rural areas) increased poverty (Haq *et al.*, 2008). The net effects of food-price increases can be negative even in agricultural exporting countries. Thailand, for example, has fewer negative effects on poor food producers than on poor food consumers (Warr, 2008). Similarly, a study carried out in Sub-Saharan Africa by Wodon & Zaman (2008) shows that increasing food prices possibly lead to increase in food insecurity because their effect on average consumers outweighs producers' benefits.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Chapter three of the thesis looks at the theories and concepts, models and statistical techniques that were employed in order to achieve the objectives of the study. A meticulous and comprehensive guide through Time Series process is done followed by the development of the forecasting and volatility models and source of data.

3.2 Theoretical framework

The underlying theory of rice price volatility and price transmission pivot on knowledge of how market prices interact with each other in respond to changes in quantity of imported rice in the various markets in different locations. The study relies on the agricultural price fluctuation theory and the Law of One Price.

There are two schools of thought surrounding the theory of agricultural price fluctuation. One which steam from the cobweb model while the second school form the rational expectation assumption. The former views fluctuation/volatility as originating from forecasting errors while the later views fluctuation as a result from real shocks (Gouel, 2012). Here in price fluctuation, dynamics in price are regulated by the best responses of agents (competitive farmers, export, inventory and imports).

The law of one price propose that any price change in integrated markets will be harmonized within the integrated markets instantly (Chirwa, 2000). The spatial integration principle forecasts that differences in pricing for a homogeneous commodity for markets in different locations are almost

equal to transportation costs under competitive conditions. Situation of this nature represent a long-term concept. In the short term, prices may fluctuate due to array of shocks. In case a situation of imbalances arises, pricing signals stimulate transfer of goods from surplus markets to markets with shortage, thereby instilling equilibrium again. The occurrence of such a situation suggests the presence of a fixed term that seems stochastic, impermanent and deviates from long-run equilibrium.

One common characteristic of the stationary series is the fluctuation around and return to the mean. Simply put, provided the set (market price) is stationary, the average/mean price and variance will undergo oscillation but will eventually decay to a mean value in the long-run. These behaviors are closely linked to a long-term economic understanding of equilibrium. On this basis (theory), deficit markets for imported rice (high consumption) and surplus market (high production) are expected to be equalized in the long run even if short-term differences exist.

3.3 Conceptual framework

The speculation in commodity futures market, demand for biofuel and macroeconomic shocks have been identified in recent literature to be the cause of food price spikes. Following that these causative factors represent the totality of the supply and demand of world food, any offset in these factors will result in huge impact on food security. Recent literature has established the distinguishing effect each factor has on price changes by three groups; ‘internal causes’, ‘conditional causes’ and ‘root causes’ (see Figure 3.1).

The root causes are also known as exogenous shocks which relates to production shocks, economic shocks, extreme weather conditions, demand shocks and oil price shocks. These are autonomous and core factors noted to affect price volatility. The possible causality between the root cause factors and the agricultural sector is very minimal, hence the name exogenous factors. Even though

the exogenous factors are expected to cause food price fluctuation, their potential effect is largely dependent on the economic and political environment of a given nation.

To put it differently, a subsequent group of drivers relates more to the economic and political conditions; conditional drivers. This can inhibit or exacerbate exogenous shocks. Tadasse, Algieri, Kalkuhl, & Von Braun, (2016) found low transparency in commodity markets and high concentration of production to be the factors. They also reiterated that such factors are time invariant and so very difficult to measure. The last causative factor considered in Figure 3.4 is the endogenous shocks (internal cause). They include activities such as speculative, discretionary trade policies and declines in world food stocks. The present study focuses primarily on the internal and conditional shocks because they are factors which are under the control of economic agents. At the same time, special attention is given to the root cause factors.

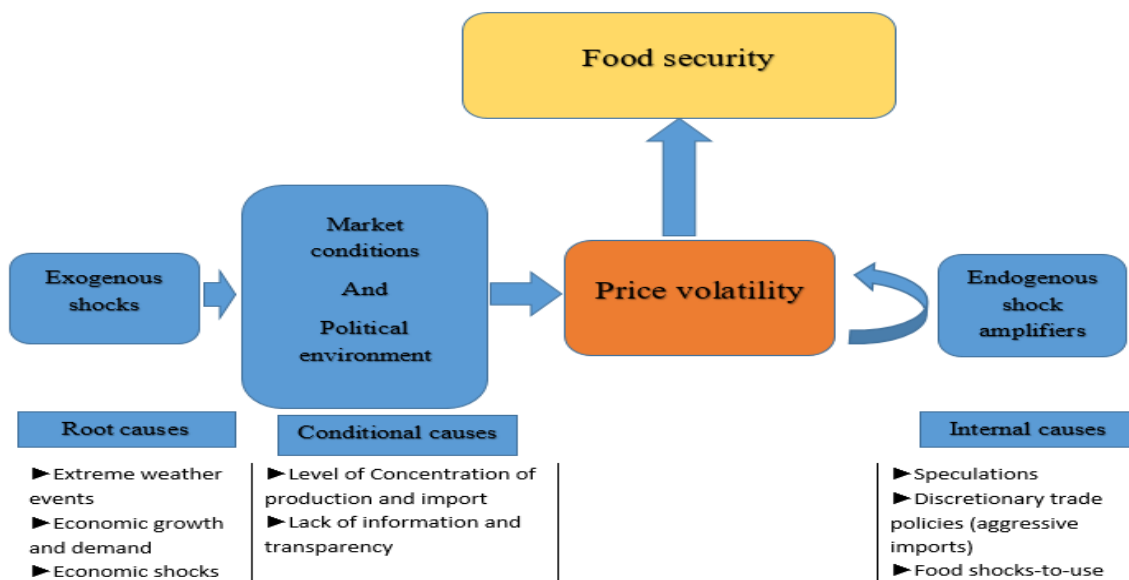


Figure 3. 1: Stylized framework of the causes of food price volatility and transmission
Source: Adopted from Kalkuhl *et al.*, (2016)

As much as this study is concerned, the categorization of the various drivers comes with a caveat: there is a very subtle line between the drivers. The factors are complexly intertwined with various back loops. As highlighted by Piesse & Thirtle (2009), supply, price expectation and activities of government in public storage are the cause of low stock levels. Additionally, the Trade and Development report indicated the presence of some level of correlations among different factors (UNCTAD, 2011).

Despite the arguments made against the speculation in causing food prices higher in 2007–2008 by Irwin *et al.* (2009) and Wright's (2011), Robles *et al.* (2008) demonstrate the possibility of the speculative bubble hypothesis. He also noted that increasing speculative events increase future trade volume, leading to an increase in future prices and accumulation of inventories. According to him, the price will increase at the spot.

However, researchers like Martin & Anderson (2012) and Yang *et al.* (2008) noted that various restriction policies and bans by countries have the potential to cause panic and exacerbate price increase, as recorded in Thailand, China, India and Russia. Countries impose trade restrictions in order to limit the impact of transmission of global prices to local prices and to shield consumers (ensuring food security). These policies are seen to result in desired impact since local prices are safeguarded from the full effect of high price increase. But restrictive policies have a negative impact on the global market. When a lot of countries decrease their exportations, food is removed from the world market, and the cost of the food elevates than they are do when there are no mediations from the government. As the levels of stock play important part in pricing commodities as well as product prices which also have an effect at a low price, rational firms have a propensity to store certain product units, hence the overall demand will be equal to demand for current consumption plus demand by inventory holders. When the overall demand is much flexible

compared to current demand, there is a positive inventory. When there are increments in prices, it is not cost-effective to store products, inventory is at zero, and also overall demand is equal to current demand.

3.4 Method of analysis

The methods used in the analysis of the data for the study are discussed in this section. A diagnostic check was performed to see if the various model best suit for the series. The ADF was used to test the price series while the confirmatory test was conducted with KPSS test for stationarity. In addition to cointegration tests among price series pairs using the Johansen Maximum probability test, volatility/stability values for the various markets were determined using GARCH model. In order to evaluate the extent of price transmission on the rice market, the Vector Error Correction Model (VECM) was used. Finally, to determine the extent of integration in the respective markets to ensure accessibility, Granger causality test was conducted. The Asymmetric Vector Correction Model (AVECM) was applied to depict if transmission of price was asymmetric or symmetric. The following methods are discussed.

3.5 Model diagnostics

Unit root test

Central to time series analysis is the issue of stationarity. Stationarity in time series is where there is no trend or change in mean and variance with time. Stationarity in time series can either be strong or weak. A series is said to be weakly stationary (second-order stationary) if its first and second moments (mean and autocovariance) are independent of time while strong stationarity is observed if the mean, autocovariance, variance and all other higher moments at any lag say k , remain constant over time. Mathematically, it can be expressed as:

$$E(X_t) = \mu_t \quad (a \text{ constant}) \quad (3.1)$$

$$\text{Var}(X_{t1}) = \text{Var}(X_{t2}) = \text{Var}(X_{t3}) = \dots \text{Var}(X_t) = Y_0 \text{ (a constant)} \quad (3.2)$$

$$\text{Cov}(X_t, X_{t+k}) = Y_y(k) \text{ (Depends on only lag k)} \quad (3.3)$$

On the other hand, a non-stationary series is one that does not have constant variance and hence returns to a long-run mean. Therefore if Y_t is a non-stationary series, then

$$Y_t = \mu_t + e_t \quad (3.4)$$

$$\mu_t = f(t) \quad (3.5)$$

Where the mean (μ_t) is time-dependent with a weak stationary error (e_t) term.

A non-stationary time series can be made stationary by differencing. Differencing of non-stationary time series can be done many times to achieve stationarity. If a time series is made stationary after differencing it once, is said to be integrated of order one and can be written as I (1) or ΔY . However, If the non-stationary series is made stationary after being differentiated d times, it is said to be integrated of order d, denoted I(d) or $\Delta^d Y$. An initially stationary series is said to be of order zero, denoted by I (0). The essence of stationarity is to ensure that the autoregressive parameters in an estimated time series model are stable within a defined range as well as the moving average parameters in the model are invertible.

Hamilton (1994) noted that once stationarity condition is met, an estimation can be carried out and subsequently forecasting be done. The unit root test is performed to check for the existence or non-existence of stationarity. It intends, helps establish whether a stochastic or a deterministic trend is present in the series.

Various approaches for testing the stationarities and other time series data checks, including graphical and quantitative approaches, have been developed. The graphical approach is done

through visual inspection of the nature of the Autocorrelation function (ACF) plots. The series will be stationary if the ACF decay rapidly after few lags. However, if the ACF exhibits a strong and slow decaying pattern after several lags, then it presupposes that the series is non-stationary. In this study, two quantitative approaches were employed to test for unit root. These two quantitative methods include; the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The presence of a unit root indicates that the time series is not stationary and that differencing will make its stationarity.

Augmented Dickey-Fuller (ADF) test

The Augmented Dickey-Fuller test is an extension of the Dickey-Fuller test which was developed to address any form of serial correlations in a time series. As noted by Acquah (2012), Abdulai (2002) and De Jong *et al.* (1992), the ADF test is regarded as the overall best test for a unit root mainly because it does not suffer size distortions under extreme autocorrelation, over parametrizations, and increased sampling frequency, all in the presence of autocorrelated errors. Hence the ADF test works on the assumption that the series follows a random walk. By considering the first order Autoregressive AR (1) process given below

$$Y_t = \phi Y_{t-1} + \varepsilon_t \tag{3.6}$$

Where

Y_t denotes our variable of interest

Y_{t-1} lagged value of Y

t denotes time index

ϕ denotes model coefficient

ε_t denotes i.i.d $N(0, \sigma^2)$

Unit root will be present if ϕ equal one. If this happens, then equation (3.6) will assume a random walk model without drift and therefore becomes a non-stationary. The test is done simply by regressing the observed variable Y_t on its lagged value Y_{t-1} . This may include an intercept with a time trend. One can then estimate the value of ϕ and compare to see whether it would be equal to one or not. Equation (3.6) is then modified into:

$$\Delta Y_t = (\phi - 1)Y_{t-1} + \varepsilon_t = \delta Y_{t-1} + \varepsilon_t \quad (3.7)$$

Where Δ denote the difference in operator, meaning that $\Delta Y_t = Y_t - Y_{t-1}$ and $\delta = \phi - 1$. The null hypothesis ($\delta=0$) can be tested against the alternative ($\delta \neq 0$) from equation (3.7). If we fail to reject the null hypothesis, meaning $\delta=0$, then it implies that $\phi=1$, which confirms the presence of a unit root in the series. Based on the calculated value of the test statistic and the critical values of the ADF test, the null hypothesis may be rejected or not. The ADF test is plagued by the presence of serial correlations in the residuals which often leads to biases in drawing conclusions. Due to the plague associated with ADF test (presence of serial correlations in the residuals which often leads to biases in drawing conclusions), enough lagged dependent variables have to be included in the Autoregressive (AR) model to rid the residuals of serial correlation. The model (Equation 3.7) can, therefore, be rewritten as:

$$\Delta Y_t = \alpha + \beta_t + \delta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \dots + \gamma_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \quad (3.8)$$

Where α is a constant, β is the estimated value on-time trend series, $\gamma_1 \Delta Y_{t-1} + \dots + \gamma_{p-1} \Delta Y_{t-p+1}$ represent the summation of the lagged values of the dependent variable ΔY_t with p as the lag order of the AR process. By introducing a constraint ($\beta=0$ and $\alpha=0$) in the model, results in a random walk and using constraint $\beta=0$ corresponds to modelling a random walk with drift. By including

lags of the order p , the ADF formulation allows for higher-order AR processes. The ADF test is concerned with the value of the parameter δ . If $\delta=0$, it presupposes that the series contains unit root and hence non-stationary.

The ADF test statistic is given by

$$F_{\tau} = \frac{\hat{\delta}}{SE(\hat{\delta})} \quad (3.9)$$

Where

$\hat{\delta}$ denote the least square estimate and $SE(\hat{\delta})$ denote the standard error estimate of $\hat{\delta}$. We reject the null hypothesis ($\delta=0$) if the calculated value of the test statistic for the ADF is greater than the critical value.

Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test

The null hypothesis of KPSS states that a series is stational around the mean or a linear trend; and a non-stationary for the alternative due to the presence of a unit root. The KPSS has three major components in the test model. Namely: a random walk, deterministic trend and a stationary error term. A key assumption is that the point of departure is a data generating process of the form

$$Y_t = r_t + \varepsilon_t \quad (3.10)$$

Where r_t denotes a random walk process, $r_t = r_{t-1} + \mu_t$, ε_t is an error term, and μ_t denotes an error term of the random walk equation. It is assumed that μ_t is i.i.d $N(0, \sigma^2)$. The null and alternative hypotheses can, therefore, be stated as:

$$H_0: \sigma^2 = 0$$

$$H_A: \sigma^2 > 0$$

If the null hypothesis is true, then Y_t is made up of a constant term and a stationary term. Which implies the stationarity of Y_t . Hence the KPSS test statistic is given by;

$$KPSS = \frac{\sum_{t=1}^T S_t^2}{\sigma_\infty^2} \quad (3.11)$$

Where T denotes the number of observations, $S_t = \sum_{i=1}^t \varepsilon_i$, for $t=1, 2, \dots, T$, ε_i denotes estimated errors from the model Y_t . σ_∞^2 represent the estimator of the long-run variance of the error term, and it is given as:

$$\sigma_\infty^2 = \lim_{T \rightarrow \infty} T^{-1} Var(\sum_{t=1}^T \varepsilon_t) \quad (3.12)$$

$$\sigma^2 = \lim T^{-1} E[S_t^2] \quad (3.13)$$

Decision: Reject H_0 on condition that the computed test statistics is bigger than the critical, with respect to the significance level

Criterion for model selection

In selecting the most adequate model that best describes a time series data, several models can be fit to the data and hence the need for model selection criteria. Information criterion (IC) test is one of such means for gaging the goodness of fit of a particular model among other models (De-Graft, 2015; Abunyuwah, 2008). The rudimentary principle behind the IC tests is that in the process to find the model that best fits a data set with a minimal number of parameters, each model is subjected to the maximum likelihood with a penalty for its complexity. The information criteria (IC) include a penalty that is an increasing function of the number of parameters. The Akaike Information Criterion corrected (AICc), the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are some of the model selection criteria. This study, however, adopts the Akaike Information Criterion (AIC) designed by Akaike (1973) and the Bayesian Information

Criterion (BIC) as a measure of goodness of fit to choose the most suitable model. The penalty discourages overfitting, that is, increasing the number of parameters almost always improves the goodness of fit. The best model is the one with the smallest BIC or AIC values, given a set of candidate models (see Mitchell & McKenzie (2003)). The BIC and AIC are generally given by;

$$BIC = \log(\sigma_e^2) + \frac{k}{n} \log(n) \quad (3.14)$$

$$AIC = 2K - 2\ln(L) \quad (3.15)$$

L represent the maximized

k is the number of parameters in the model

σ_e^2 is the error variance

n is the number of observations in the data

3.6 Examine the relationship between the various markets for rice

3.6.1 Cointegration between markets to ensure availability and accessibility of rice

Cointegration investigates and establishes the long-run relationship between prices in a times series data. In terms of food commodity, cointegration in markets prices ensures the availability and accessibility of food in the market since economic agents are presented with equal price conditions of the food commodity in the market. There can be different levels of cointegration if prices in the markets of interest are non-stational (Gopal *et al.*, 2009). It implies that amid non-stationary series, any linear combination is stationary, hence the series converge to a long-run equilibrium association. In other words, deviation from market equilibrium is limited and hence prices move together. In general, to be able to establish cointegration within two are more series,

two conditions must be met. The conditions are; (i) price series must be integrated in the same level and (ii) there should exist a linear combination of the key variables.

According to Hansen & Juselius (1995), when a variable assumes stationary after the first difference, the resulting error term can be said to exhibit stationarity of the order zero I(0). Given the price series of rice for this study, the long-run relationship (cointegration) of order I(1, 0) can be represented as:

$$L_t = \alpha + P_{1t} - \beta P_{2t} \quad (3.16)$$

Where

P_{1t} and P_{2t} are stationary after the first difference and the error term is I(0). α is a constant, β estimate the long-run equilibrium relationship between the price series and L_t measures the deviation from the long-run equilibrium path. The economic explanation of the above equation is that in the long-run, the non-stationary series will closely move together over time with a constant difference that is stationary thereby eliminating glut in one market and shortage in the other. This ensures availability and accessibility to the commodity in subject in the various markets (Mohammed, 2005).

3.6.2 Testing for cointegration

Cointegration can be tested using two main approaches. The “Full Information Maximum Likelihood (FIML) test” (Johansen & Juselius 1990) and “Augmented Dickey-Fuller residual test”. In this research, due to its benefit the Johansen Full Information Maximum Likelihood Test was adopted. The biggest drawback of using the residual test is that it assumes a single vector cointegration. In other words, this method is improper in the case where the regression has more than one vector (Johansen & Juselius 1990). The Johansen method on the other hand allows for all

possible interaction and allows for the empirical determination of the number of cointegrating vectors.

3.6.3 Johansen test for cointegration

The Johansen Full Information Maximum Likelihood (FIML) test (Johansen & Juselius 1990) for cointegration in a series is based on the following vector autoregressive:

$$P_t = A_t P_{t-1} + \dots + A_k P_{t-k} + \mu_t \quad (3.17)$$

Where P_t is a vector ($n \times 1$) of I(1) variables (which is made up of both exogenous and endogenous variables), A_t is a matrix parameter ($n \times n$) and μ_t is an error (white noise) vector ($n \times 1$). Now assuming that P_t is non-stationary, then by rewriting equation (3.17) in the first difference form, it will be:

$$\Delta P_t = \pi P_{t-1} + \Gamma_1 \Delta P_{t-1} + \dots + \Gamma_{k-1} \Delta P_{t-k+1} + \mu_t \quad (3.27)$$

Where the short-run estimates are given by $\Gamma_1 = -(1 - A_1 - A_2 - \dots - A_i)$, ($i = 1, \dots, k - 1$) while $\pi = -(1 - A_1 - A_2 - \dots - A_k)$ gives the long-run estimates. In order to determine the number of cointegration that exist among the variables in P_t , one would have to rank the matrix π . If the result of the rank matrix falls within zero and n ; ie ($0 < r < n$), then there are r linear combinations of the variable P_t that are stationary. Thus, π can be decomposed into two matrices α and β where α is the error correction term and measures the speed of adjustment in ΔP_t and β contains r cointegrating vectors, that is the cointegration relationship between non-stationary variables. On the other hand, if the variables which are significantly I (0) in the long run affects the short-run model, then equation (3.17) will be rewritten as:

$$\Delta P_t = \Gamma_1 \Delta P_{t-1} + \pi \Gamma_{t-k} + r W_t + \mu_t \quad (3.18)$$

Where

W_t denotes the I(0) variable. The study adopted two Likelihood Ratio (LR) to test cointegrating vectors.

$$\Lambda_{trace} = -2\ln Q = -T \sum_{i=r+1}^p \ln(1 - \lambda_i) \quad (3.28)$$

The above equation tests the H_0 of q cointegrating vectors contrary to the H_A . The test in the second equation is known as the maximal–eigenvalue test.

$$\Lambda_{max} = -2\ln(Q:r + 1) = -T \ln(1 - \lambda_i) \quad (3.29)$$

Thus, the null hypothesis that there are q cointegrating vectors as against the alternative that there is $q + 1$ cointegrating vectors. Haris (1995) noted the trace test to be more robust in both skewness and excess kurtosis in the residuals than the maximal eigenvalue test. The error correction model in the equation (3.18) is based both on the difference and level of the series and thus the long-term relation between variables is not lost.

If a long-run equilibrium relationship is found to exist between time series data, then a vector error correction model (VECM) is used to assess the features of the co-integrated series in the short run. A VAR or ADRL model can be employed to evaluate the price dynamics in the short run if the time series data is not co-integrated. Moreover, the Johansen test also allows for the testing of restrictions on the cointegration relations β and the adjustment speeds α in the VEC model.

The Cointegration approaches proposed by both Johansen and Engle and Granger assume the adjustment mechanism is linear and symmetric and as such in the presence of asymmetric adjustment this test for cointegration and their augmentations become incorrectly specified and have low power (Enders & Siklos, 2001).

It should be noted that in using this method, the endogenous variables included in the VAR are all I(1), also the additional exogenous variables which explain the short-run effect are I(0). The choice of lag length is also important and the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) were used for the selection.

3.6.4 Test for Granger causality

The essence of Granger causality is to show the direction of a causal relationship. This is mostly after performing a cointegration test. Since establishing cointegration does not robotically imply causality, there is the need to provide the evidence of causality between the variables using Granger causality analysis. A rice price series in one market can be said to granger cause a rice price series in another market (location) if there is an improvement in the prediction of the lagged and current and values after controlling for past values of the former (Gelper & Croux, 2007). Following Rashid (2004), he also established that causality can be used to predict prices i.e. the movement of price in a particular market may be applied to predict variations in different markets' prices which can be analyzed within Johansen's co-integration framework. The causality model applied in the study are as follows:

$$P_t^l = \sum_{k=1}^n a_k P_{t-1}^o + \sum_{k=1}^n b_k P_{t-1}^l + \varepsilon_{1t} \quad (3.19)$$

$$P_t^o = \sum_{k=1}^n c_k P_{t-1}^l + \sum_{k=1}^n d_k P_{t-1}^o + \varepsilon_{2t} \quad (3.20)$$

Where P_t^l denotes the producer/local/supplier market which in this case Accra in Greater Accra Region and P_t^o denotes the central market (consumer) which in these case (Upper East, Northern, Bono East and Ashanti Regions). ε_{1t} and ε_{2t} are the uncorrelated error terms.

Causality may manifest in three major ways as unidirectional, bilateral or as independent (Gujarati, 2003; Gordon *et al.*, 2011). By rejecting the null hypothesis in the above model, one can establish

Granger causality in price series (P_t^l and P_t^o) in the market and implying that past values of the series are adding information in the model. If prices (P_t^l and P_t^o) Granger-cause each other in the various markets, then one can conclude the presence of a “Simultaneous Feed Back Mechanism” which is also known as bi-directional causality. Alternatively put, if causality occurs in one way, then it can be term as “unidirectional Granger-causality”. The market Granger-causing the other referred as a weak or strong exogenous market. The later occurs when there is no significance in the causality from other variables while the former there is a distribution (marginal) of P_{t-1}^o or P_{t-1}^l or both (Juselius, 2006).

The Granger causality tests serves as a confirmation test to identify the long run balance in price pairs as well as to understand which of the prices are used to inform others. It also allows us to comprehend the results with respect to where the causality is directed as well as the degree of market integration in markets. This study uses the vector error correction model (VECM) as its basis for the variant of the Granger causality tests.

3.7 Adjustment to long-run equilibrium and symmetry in ensuring accessibility of rice

Asymmetry in market pairs shows how prices in the various market responds to diverse level of transmission. For this thesis, the test on symmetry/asymmetry is to determine if consumers in the different markets are presented with equal information on the market price of imported rice to allow the consumer access the food commodity.

Primitive experiential designs (Wolffram, 1971 and Houck, 1977) modeled asymmetry as a splitting variation of a variable. This method split the error correction estimate into both positive and negative constituents. This method of analysis has been used extensively after its introduction to model the spatial price transmission of various food commodities in an attempt to explain

asymmetric price adjustments. Following the same framework used, if the price of good one responds to another good two, then one can estimate the asymmetric effect as follows:

$$\sum_{t=1}^T \Delta P_{1t} = B_0 + B^+ \sum_{t=1}^T \Delta P_{2t}^+ + B^- \sum_{t=1}^T \Delta P_{2t}^- + \varepsilon_t \quad (3.21)$$

Given ΔP^- and ΔP^+ are the negative and positive differences in prices respectively. The estimated co-efficient are B_0 , B^+ and B^- . While T represent the current time period. Hence in order to test for asymmetry in price, it is given as; $B^+ = B^-$. Some analyst introduced long term in ΔP_{2t}^+ and ΔP_{2t}^- to be able to separate between symmetry in the long-run as well as in the short-run. The Long run symmetry is evaluated by finding out if the summation of the co-efficient in the polynomials are equal, whereas the short run symmetry is evaluated by establishing also, if there is any similarities in the polynomials. Cramon – Taubadel & Loy (1997) established the fact that, the method is basically not compatible with a long-run equilibrium between two price series. Granger & Lee (1986) also modified the ECM to be able to allow for asymmetric adjustment by applying a split method. The resulting asymmetric Error Correction Model is specified as

$$\Delta P_{1t} = \alpha_0 + \sum_{i=1}^n \phi \Delta P_{1,t-1} + \sum_{i=1}^n P_{2,t-1} + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + \varepsilon_t \quad (3.22)$$

$$\Delta P_{2t} = \alpha_1 + \sum_{i=1}^n \phi \Delta P_{1,t-1} + \sum_{i=1}^n P_{2,t-1} + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + \varepsilon_t \quad (3.23)$$

Where $\varepsilon_t \dots N(0, \sigma^2)$, ECT_{t-1}^+ and ECT_{t-1}^- measures the various positive and negative adjustment to price shocks. Since $ECT_1^+ + ECT_1^- = ECT_t$, the model nests the VECM and a proper evaluation of asymmetry hypothesis is: $H_0 = \beta_2^+ = \beta_2^-$. A joint F-test can be used to determine symmetry or asymmetry of the price transmission process. By this, the doubt farmers express about the increment in prices by producers that are carried on quicker than producer price reduces can be subjected to the verification with ECT values, where positive ECT are corrected quickly compared to negative ECT.

The speed at which parameters adjust may then be expressed as half-life (T_{half}). This shows the duration it takes to correct deviation partly from long-run estimates. The half-life is calculated using the formula: $T_{half} = \ln(0.5)/\ln(1 + \beta)$, where β represent the adjustment value from the AVECM. Following that the observation are captured in monthly, the values of T_{half} are calculated in months.

3.8 Analyze of the degree of price volatility/stability in rice market

The study deployed the generalized autoregressive conditional heteroskedasticity (GARCH) to compute volatility or stability in the diverse price series. The GARCH was developed as an extension from the Autoregressive Conditional Heteroskedasticity (ARCH) model.

The disparities associated with the models used in volatility estimation over the years can be linked to the way the variance of the error term is revealed with time (Tsay 2005). Two schools of thought on conditional heteroscedastic models come up. The first uses the original functions in determining the variance over time while the second school employs a stochastic equation to determine the change in variance over time. This study, therefore, adopts GARCH-family models that fit into the first school of thought.

The ARCH and GARCH models were chosen due to the restrictions of Ordinary Least Squares (OLS); i.e. constant variance of error terms ($V(\varepsilon_t) = \sigma^2$) also known as homoscedasticity. The ability of ARCH/GARCH-family models to take into account volatility clustering, heteroscedasticity and their mean-reverting nature place the models in a better and ideal position for price modelling.

3.8.1 ARCH model specification

An Autoregressive Conditional Heteroscedastic (ARCH) process is a mechanism that includes past variance in the explanation of future variances (Engle, 2004). The Autoregressive Conditional Heteroscedastic model has become the fundamental approach to studying volatility associated with time. In the ARCH specification, the focus is on the mean and its variance, which helps provide understanding the magnitude of volatility in a series of data. The conditional variance in the ARCH is modelled as a linear function of the previous change in the explaining future variances (Engle, 2004). Hence with a model say X_t , the variance is conditioned on X_{t-i} . Assuming a mean-corrected return $\{X_t\}$, ε_t is the Gaussian error with zero mean and unit variance ($\varepsilon_t \sim WN(0,1)$) and S_t^- be the information set at time t given by $S_t^- = \{X_1, X_2, \dots, X_{t-1}\}$, then the ARCH model can be specified as

$$X_t = \sigma_t \varepsilon_t$$

$$\sigma_t = \alpha_0 + \alpha_1 X_{t-1}^2 + \alpha_2 X_{t-2}^2 + \dots + \alpha_h X_{t-h}^2 \quad (3.24)$$

Where $\alpha_0 \neq 0$, $\alpha_i \geq 0$, $i = 1, \dots, h$

and

$$E(X_t | S_t^-) = E[E(X_t | S_t^-)] = E[\sigma_t E(\varepsilon_t)] = 0 \quad (3.25)$$

$$V(X_t | S_t^-) = E(X_t^2) = \sigma_t^2 = \alpha_0 + \sum_{i=1}^h \alpha_i X_{t-i}^2$$

the error term is

$$E(X_t | S_t^-) = 0$$

$$Var(X_t | S_t^-) = 1$$

According to Amos (2010), from the above equations, one can conclude that the ε_t exhibit conditional standardized martingale difference. While $\{X_t\}$ assumes a martingale difference condition that lag of $\{Y_t\}$ is zero (Amos, 2010).

The ARCH mechanism allows a present conditional variance to be impacted upon by any errors/(squared) accompanying the past m periods. Inferring from the above structures, it can be noticed that present uncertainty is a quadratic value of its lagged values. Therefore, large conditional variance of X_t^2 will follow X_{t-1}^2 in either direction thereby creating a volatility clustering behavior.

The lags are the ARCH terms which symbolizes an AR process. The order of the ARCH model specified in equation (25) is of order h and it is written ARCH (h). Determining the order of an ARCH (h) is a prerequisite for modelling the ARCH.

The equation model (3.25) considers an expectation based on all information up to period $t-1$. It can be observed that past fluctuations affect the variance of the present fluctuation. Therefore, news of volatility from previous periods may be construed as the ARCH terms.

Information criteria (examples of which include the AIC, BIC, H-Q criteria) or the Sample Partial Autocorrelation function (PACF) are two measures employed in selecting the best h . The PACF is ideally used to select possible values of h , provided under normal circumstances that it tails off to values closer to zero after the h th lag. The AIC as used in this study is to select the best order. An ARCH (h) model with the minimum AIC value is selected as the best ARCH model for modelling a data set.

3.8.2 GARCH model specification

The Generalized ARCH (GARCH) specification takes an extension of the ARCH model by introducing the conditional variance to depend on the past and squared innovations of the ARCH model. This prevents the violation of the principle of parsimony since the GARCH model only involves a few numbers of parameters for modelling. Specifically, while the ARCH model is not complex, but it demands a number of parameters since a large lag value is also necessary in computation. This will violate the parsimony principle. A GARCH model is therefore preferable to an ARCH model based on the parsimony principle.

Assuming a mean-corrected return $X_t = r_t - \mu_t$, where r_t is the return of a series and μ_t as the conditional mean of X_t , then a GARCH (h,m) model of $X_t = \sigma_t \varepsilon_t$ is

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^m \alpha_i X_{t-i}^2 + \sum_{j=1}^h \beta_j \sigma_{t-j}^2 \quad (3.26)$$

Where $\varepsilon_t \sim \text{i.i.d N}(0,1)$, and $\alpha_i, i = 0, \dots, m$ and $\beta_j, j = 0, \dots, h$ such that $\alpha_i \geq 0$ and $\beta_j \geq 0$; $\sum_{i=1}^v (\alpha_i + \beta_j) < 1$, where $v = \max(h, m)$ and $\alpha_i = 0$ for $i > m$ and $\beta_j = 0$ for $j > h$.

When we establish equation 3.26, it is found that the current variation depends on all previous square variance with an effect that decreases exponentially over time. Some parameter restrictions are required in the new GARCH specification to ensure that the time series is variant.

For instance, in the above conditions, the constraint imposed on $\alpha_i + \beta_j$ implies that the unconditional variance of the model is finite but the conditional variance evolves. Again $(\alpha_i + \beta_j) < 1$ ensures stationarity in the variance of the specification.

Equation 3.26 specifically demonstrates that the value of the variance of the conditional disturbance depends on the prior values of the shocks as well as the past values. So, the simplest GARCH model with $h = 1$ and $m = 1$ is GARCH (1,1) and a simple parsimonious GARCH (1,1) model can be represented as;

$$\sigma_t^2 = \alpha_0 + \alpha_i X_{t-i}^2 + \beta_j \sigma_{t-j}^2 \quad (3.38)$$

An advantage of using the GARCH specification is its ability to fully capture the thick tail returns and volatility clustering. However, some restrictions are imposed on the model to avoid the negativity of the coefficients of the squared innovations and the squared returns. Over the years the GARCH specification has been modified into various forms to enable overcome the various gap associated with its use and to also incorporate the stylized facts exhibited by financial asset returns and asymmetric effects.

3.8.3 Distributions of error terms in volatility models

The “heavier” tailed student t-distribution and the standard normal distribution are the two types of error distributions considered in this analysis.

The density function for a normally distributed random variable say ε is

$$f(\varepsilon_t) = \frac{1}{\sqrt{2\pi\varepsilon_t^2}} e^{-\frac{(\varepsilon_t - \mu_t)^2}{2\varepsilon_t^2}}, \varepsilon_t \in (-\infty, \infty) \quad (3.27)$$

And a t-distribution function will be

$$f(\varepsilon_t) = \frac{\Gamma(\frac{v+1}{2})}{\Gamma(\frac{v}{2})\sqrt{v\pi}} \left(1 + \frac{\varepsilon_t^2}{v}\right)^{-\frac{v+1}{2}}, \varepsilon_t \in (-\infty, \infty) \quad (3.28)$$

Where

v denotes degrees of freedom

$\Gamma(\varepsilon) = \int_0^\infty y^{\varepsilon-1} e^{-y} dy$ denotes the gamma function

The student's t-test distribution is however adopted in this study as the rice price returns are likely to exhibit heavier tailed compared to the standard normal

3.9 Source and type of data

The data deployed in this thesis is a secondary data on the monthly retail 'imported rice' prices. Five local rice markets were selected in conjunction with the World price (rice) for the study; namely Accra (Greater Accra Region), Kumasi (Ashanti Region), Techiman (Bono East Region), Tamale (Northern Region) and Bolgatanga (Upper East Region). The various markets were selected based on data availability, levels of consumption and geographical location. A greater percentage (about 90%) of rice imported into the country is through the Tema harbor in Accra. This places Accra market where there is high volume/quantity of rice than other markets. The imported rice is bagged into various sizes (1kg, 2kg, 5kg, 10kg, 50kg and 100kg) in Accra before onward transportation/distribution to the other markets. Therefore, Accra is considered to be the reference or central local market along which other markets are compared. Also, in establishing the relations between world market and local market, Accra market is used since the other markets do not have any direct link (importation) with the world market.

The study used monthly retail prices of imported rice constituting 72 observations from January 2013 to December 2018. The price data were accessed from the Statistics, Research and Information Directorate of the Ministry of Food and Agriculture (SRID-MOFA) and world-bank commodity price data (<http://ghana.opendataforafrica.org/hhiehleg/world-bank-commodity-price-data-pink-sheet-monthly-update>). Following the high importation of rice from Vietnam (71% of total imports), the source of world price data used for the study was that of import prices from Vietnam.

All the data on prices obtained from SRID-MOFA were on per kg of rice. Prices of imported rice used for data analysis in the study were converted to Ghana Cedi (GHC). Hence prices presented in this work can be interpreted as GHC/1kg. Also, the data set was adjusted for inflation using the consumer price index-based in 2013. Hence the data used for the analysis was real retail rice price from the various markets.

The returns time series data is used instead of the raw data (price) for the analysis of this thesis. As noted by Christiano *et al.* (2002) the use of returns time series gives complete and scale-free data. This is also much easier in terms of analysis compared to the raw price process, as the former depicts a time-varying nature, exhibit stylized facts and uncorrelated, which are all characteristics of asset prices. If volatility is present in the return series, then it is more apparent compared to the raw price process. The natural logarithm of the returns is used due to its satisfaction in the model's implementation in most cases. Thus; the log-returns (r_t) can be defined $r_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$ (3.34)

Where: P_t is the monthly average price at time t.

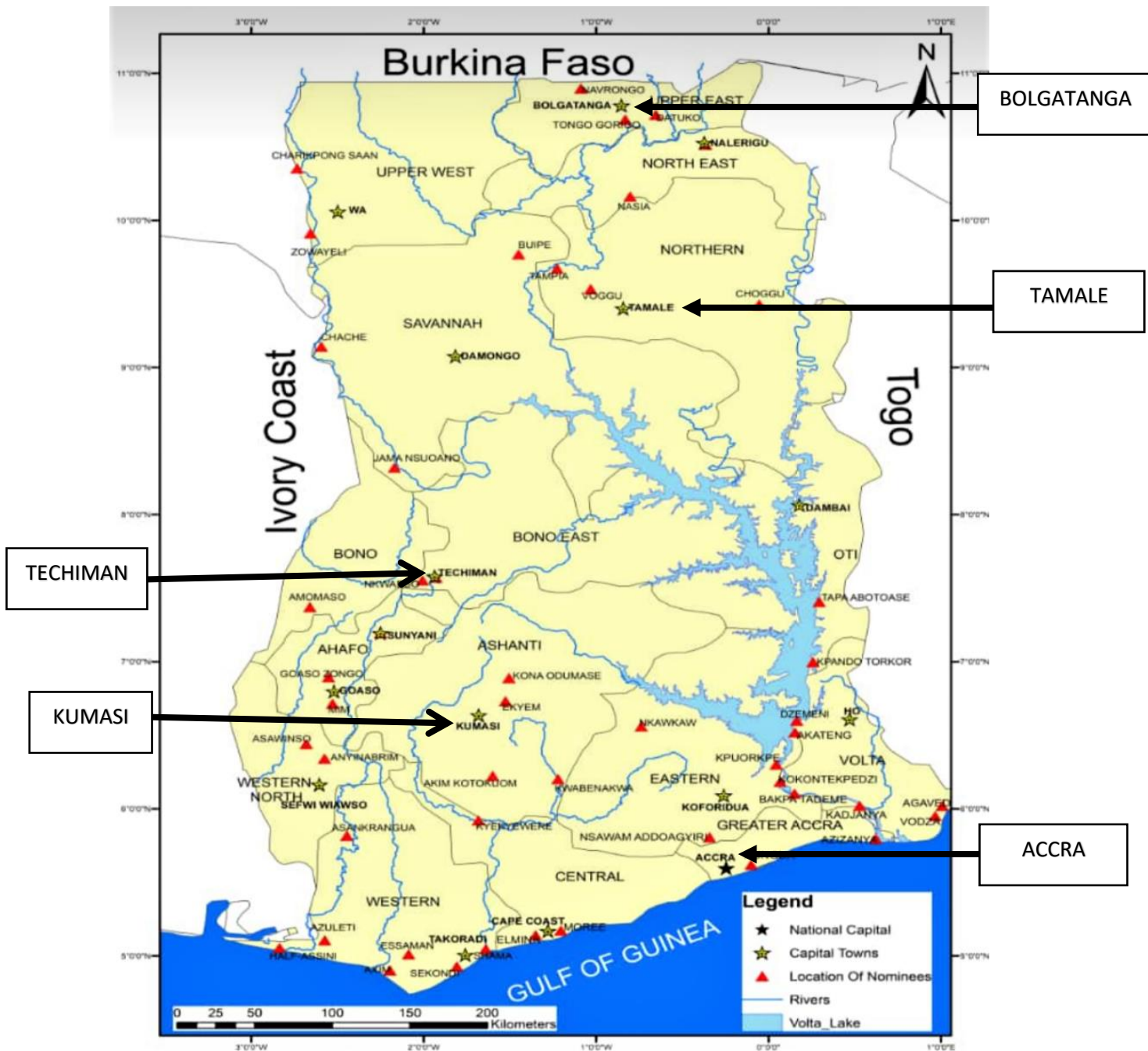


Figure 3. 2: Map of study area

Source: Ezilon Maps (<http://www.ezilon.com/>)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This section presents results from the study. Discussion on imported rice market is presented in section 4.1. Sections 4.2 inspects the existing association between the world and local market for imported rice in Ghana to ensure availability of rice. The extent of price transmission in the domestic market to ensure accessibility of imported rice is presented in section 4.3. Section 4.4 and 4.5 discuss the adjustment speed to long-run equilibrium, level of symmetry in ensuring accessibility of rice and the effect of rice price changes on the stability of imported rice in Ghana.

4.2 Analysis of imported rice market

Changes observed in agricultural prices and quantities at different points in time may often be attributed to variations in yield, government policies, condition of infrastructure, seasonality and the behaviours of consumer and other market partakers. Furthermore, buyers' behavior has direct influence on other players, and the subsequent dynamic process allows prices and quantities to be determined at different times. It is imperative that we have a clear idea of the degree of fluctuation in agricultural prices and quantities over time and across space and the sources of these variations before we analyse price linkages (Ankamah-Yeboah, 2012). Table 4.1 & 4.2 and Figure 4.1 show a descriptive summary of imported rice prices and import quantities in the study areas.

4.2.1 Annual rice import volumes

As it is observed in Figure 4.1, the quantity of rice imported into Ghana between the period of 2000 – 2018 has increase on the average even though there are years with decrease in quantity of import. In the year 2000, total rice import was a little below 400,000MT. This quantity reduced for the years 2001 – 2002 and then increased to a little over 450,00MT in 2005. The quantity of

rice further reduced to a little above 315,000MT in 2007 – 2008. This is because there was a global price crisis during the same period. Global prices for rice rose dramatically between 2007 and 2008. The increase was caused by an increase in petrochemical and oil demand and restrictions on exports. The countries where Ghana imports rice like Vietnam and India had export restrictions, thereby limiting their export quantity. This led to a reduction in the volume of rice imported into the country in those same periods. After the global crisis period, import quantity increased to about 560,000MT in 2012. The years 2013 – 2018 recorded a further increase in total volume of rice imported. Rice consumption (current per capita consumption is 35kg) in Ghana has increased across years due to rapid growth in population, income growth and increase consumer taste for imported rice (Ayeduvor, 2018).

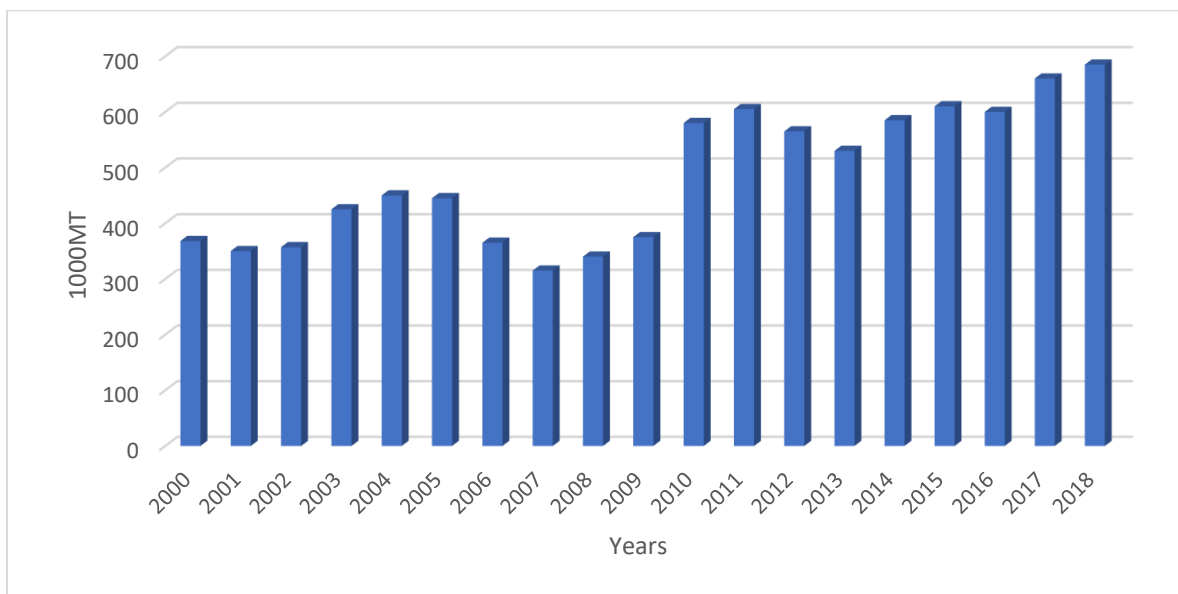


Figure 4. 1: Volume of rice import in Ghana
 Source: Own computation from imported rice data (2000-2018)

Given that rice is the second most important food commodity in Ghana, undoubtedly demand for rice will offset local production. From the rice import trend in Figure 4.1, the quantity of rice imported into Ghana has increased to fill the supply deficiency (over 55%) of the local rice

produced. Between the period under study, there has been high volume of imported rice in the various market centres for trading in Ghana. This has led to a unremitting stock of rice throughout the year. The increased in the quantity of rice import ensures availability of rice to consumers in Ghana.

4.2.2 Descriptive analysis of real price in rice markets

The price of imported rice varies significantly across the various markets of interest (International/world and local markets) and across time (2013-2018). On the world market (in Table 4.1), the average price of rice is GHC 1.45 per kilogram. It recorded a price of GHC 0.89 and GHC 2.04 per kilogram as minimum and maximum value respectively. The average variability in the world prices as shown by the coefficient of variation is 22.54% and this indicates how prices fluctuates around the mean price of imported rice.

Table 4. 1 Descriptive analysis of world price of rice (2013-2018)

Variable	Mean	Std. Dev.	CV	Min.	Max.	Obs.
World	1.446	0.326	22.544	0.89	2.04	72

Source: Own computation from imported rice price data (2013-2018).

In Table 4.2, prices across the local markets are high compared to the world prices. Across the local markers, the highest average retail prices are recorded in Techiman and Tamale markets (GHC 4.86 and GHC 5.01), with lowest and highest value of GHC 2.57 & GHC 7.61 and GHC 1.76 & GHC 9.17 respectively. Following the two markets in the northern Ghana, prices for imported rice are higher in Tamale when compared to Bolgatanga. This is so because there is high level of production in terms of local rice in Bolgatanga. Hence, there is high availability of local rice in Bolgatanga causing an impact on the price of imported rice.

Table 4. 2 Descriptive statistics of retail prices (GH/kg) of imported rice (2013-2018)

	Accra Market	Tamale Market	Techiman Market	Bolgatanga Market	Kumasi Market
Mean	4.603	5.008	4.860	4.611	4.583
Std. Dev.	1.113	1.688	1.259	1.458	1.075
CV	24.180	33.706	25.905	31.62	23.456
Minimum	2.460	1.760	2.570	1.990	1.300
Maximum	6.640	9.170	7.610	9.410	10.790
Observations	72	72	72	72	72

Source: Own computation from imported rice price data (2013-2018). ***, **, * represents the significance of the coefficients at the 1%, 5% and 10 % significance level

The lowest average retail price is recorded in Accra and Kumasi (GH¢ 4.6 per kilogram). This is because there is high quantity (supply) of imported rice in Accra followed by Kumasi. That is almost all rice imported into the country is assembled/ bag into various marketable sizes (1kg, 2kg, 5kg, 25kg and 50kg) in Accra and then transported/distributed to the other markets in Ghana. From an economic point of view, when high quantities of production/assembling have no depreciable impact on the price of rice, arbitration can be suspected (Mafimisebi, 2012). In Ghana, rice distributors in southern and northern Ghana, particularly traders from Kumasi, Techiman and Tamale, visit Accra's high assembling, bagging and distribution centers to buy and assemble imported rice for transport to the other market centres (Kumasi, Techiman and Tamale). Such continued arbitrage in supplies between the country's high assembling markets and low-producing areas prevent gluts in high assembly areas and shortage the low producing markets.

From Table 4. 2, variability in the average retail price of imported rice was quite high for the period under study. It varied from 23.46% for Kumasi Market to 33.71% for Tamale Market. The average variability in the local markets was computed at 27.77% for the same period. The high variability

in retail prices of imported rice in the various local marketplaces implies that the price of the said commodity fluctuated widely within the period under study (2013 to 2018). And as such, changes in prices of imported rice has not been quite stable for the periods under study even though supply of imported rice has increase in the markets analysed.

The variations in prices may be linked to price fluctuations in the various markets under study which normally gives rise to temporal deficit from time to time. One can again attribute this phenomenon to the high demand for imported rice all year round. The long-run effect will be a reduction in volumes of rice. This can be harmful to the welfare of consumers especially in countries like Ghana where poverty is still a problem and expenditure on food make up a larger portion of household's disposable income (Kalkuhl, 2016).

4.2.3 Annual drifts in retail prices of imported rice in Ghanaian markets

Consumers are able to predict the nature of the futures market based on information on the prices of a product in the past. An observation of price and trends could be a good starting point. Figure 4.2 illustrates the yearly movement in real prices of imported rice. The trend plots exhibited on the world market, Accra, Kumasi, Tamale, Techiman, and Bolgatanga show a similar pattern; that is these prices generally follows a steady increase (trending upwards) in the retail prices of imported rice over time. Regarding Figure 4.2, each market begins with prices being at their lowest for the start of January 2013 and gradually rise and fall. On the world market, rice has constantly increased since 2013, reaching its highest price of GHC 2.04 per kilogram. The reverse relationship between food price elasticity and income, together with income growth around the world, means that global food demand is increasingly less elastic and thereby offering changes causing higher price volatility in turn, since demand does not deteriorate even when supply declines (Abler, 2010; HLPE, 2011)



Figure 4. 2: Trend in retail price of imported rice

Source: Own computation from imported rice price data (2013-2018).

Given that rice is the next principal food in Ghana after maize, clearly commodity demand will outweigh supply in the markets which will result in high prices. There is a similar price movement among the various markets under study. Techiman, Tamale and Bolgatanga retail prices were in general the highest over time. This is perhaps due to the high demand and high transportation cost in those markets. On the other hand, prices in Accra are lower, due to its location to the assembling/bagging point. See Figure 4.2.

The volatility in the price of imported rice may be mainly due in large part to high variations in the level of demand and supply, import tariffs and high transport costs. Food price instability is a

major food security issue (HLPE, 2011). Food price fluctuations have a direct influence on the welfare of the poor, who spend much on food. Lower food prices are generally beneficial to consumers and can boost the economic development, but can also reduce the incomes of producers and reduce landless worker jobs if these low prices do not account for lower production costs and better productivity.

4.3 The relationship between world and domestic markets for rice

Diagnostic check: Unit Root Test

The Augmented-Dickey fuller (ADF) and Kwiatkowski, Phillips Schmidt and Shin (KPSS) test in eqn (3.10) and eqn (3.12) were estimated for each market.

Table 4. 3 Results of ADF test on monthly imported rice prices (real)

Market	Augmented-Dickey fuller (ADF)			KPSS test	Shapiro-Wilk (W) test	
	Levels	First Difference				
	C only	C only	C and trend	Test Statistic	Critical Value	
World	-1.051	-8.872***	-8.809***	0.0429	0.739	.979
Accra	-1.826	-9.629***	-10.584***	0.0696	0.739	.988
Tamale	-2.307	-12.859***	-12.767***	0.0445	0.739	.969
Techiman	-2.319	-10.498***	-10.510***	0.0729	0.739	.964
Bolgatanga	-3.236	-10.932***	-10.878***	0.053	0.739	.653***
Kumasi	-2.419	-9.658***	-9.582***	0.0627	0.739	.977

Source: Own computation from imported rice price data (2013-2018). ***, **, * represents the significance of the coefficients at the 1%, 5% and 10 % significance level

Visually examining the graphical plot of the various markets under the study in Figure 4.2 shows the questionability of a non-varying mean for the series in levels and justification for incorporating a constant in the unit root test equations in the graphic plot of the various markets in the study. There is, however, no evident, persisting trend behavior in the graphical plot that causes a determinist trend to be omitted in the stationarity test. The ADF test may be conducted under the null of either trend stationarity or level stationarity. The ADF fails to reject the alternative hypothesis.

At first difference, all the prices in the various markets were stationary at 1%. Therefore, the price used are in the first-difference. This means that prices have no unit root and also, they are integrated of degree I (1). The result suggests that all pricing series are generated by similar stochastic processes and can demonstrate a long-term equilibrium tendency. The KPSS test confirms the findings by dismissing the null hypothesis of price stationarity in levels and failing to do so for the corresponding first differences for all consumer price sequences. Thus, one can say that all individual rice price series are integrated of order one, I (1) and hence allows one to run cointegration and other analysis. See Table 4.3.

Furthermore, Shapiro-Wilk (W) test was performed conditioned on a null hypothesis of normally distributed residual (at 1% significance level). The results from the W-test failed to reject the null hypothesis. Hence the residuals are normally distributed in the market series since in all cases except Bolgatanga market, are significant as demonstrated in Tables 4.3.

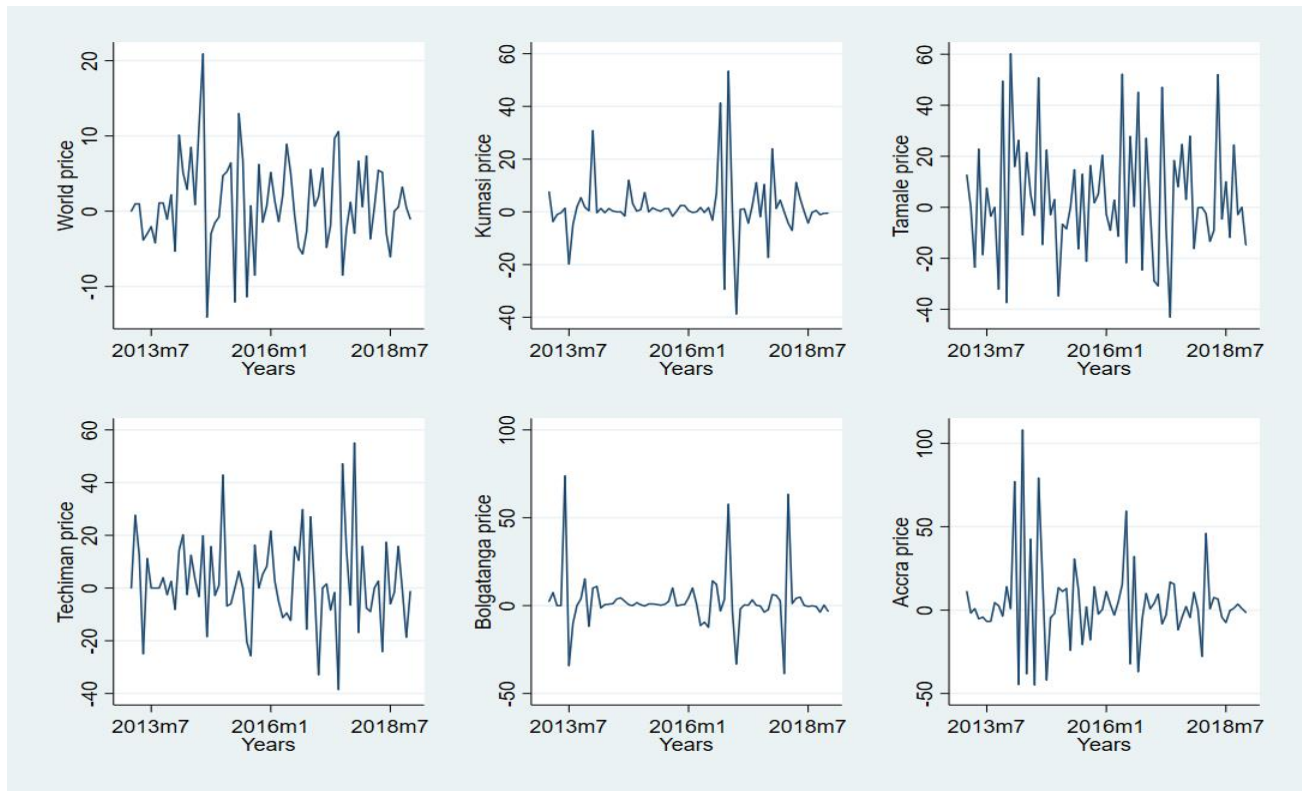


Figure 4. 3: Trend in return retail price of imported rice

Source: Own computation from imported rice price data (2013-2018).

As a requirement for this thesis, the returns prices were computed. The returns series (see Figure 4.3) are characterized by rapid changes, random and are technically said volatile. As put by FAO *et al.* (2011), the impact of higher prices is dependent on a given level of price volatility. Volatility in all price series seems to change over time. This can be observed in the world market for instance, where market experienced a relatively sedate period from 2013 to 2014. Then the price returns become much more volatile until early 2017. High volatility in 2014 and 2017 is observed on the Kumasi market (price). Accra appears to have high volatility between 2013 and 2014, while in Techiman, volatility ranged from 2013 to the end of 2017. The return in prices appears to be more volatile. It is obvious in the graphs that price returns show volatility clusters for the returns of the

world and all local markets are evident. This is a sign that ARCH and GARCH models can be mobilized to tackle this form of volatility (Tamilselvan & Vali, 2016).

4.3.1 The extent of price transmission between world and local (Accra) market

Analysis using Johansen's multiple cointegration approach was used to ascertain the relationship between the world market and Accra (local) market. A combination of two non-stationary prices implies that the two series are linear, and therefore, prices usually move together and along the same route on a long-term basis. The selection of lag lengths (1) in all tests is based on the Schwarz Bayesian Criterion (SBC), Hannan-Quinn criterion (HIC) and Akaike Information Criteria (AIC). See Appendix 1.

Table 4.4 presents the results for the test of cointegration among the market pairs. The results show that the pairs of rice markets under study are cointegrated. The null hypothesis of $r=0$, which implies a lack of a cointegrational relationship, is rejected at a significant rate of 1% for the market pairs. The null hypothesis of one relationship between the world (net producer) and net consumer market (Accra) cannot be dismissed. Therefore, the pair of net producers and net consumer prices measured on a monthly basis, and their implication among the market systems under consideration, has at least one stationary co-movement relationship ($r = 1$). The findings indicate that closely related stochastic processes can be stimulated by efficient information flow and drive price dynamics within the market system being studied (Motamed *et al.* 2008). Thus, price of rice does not drift apart in the long term in producer and consumer markets. The proof of co-movement is evident between the World and Accra rice market, where inter-market prices adjust to achieve long-run, market equilibrium. This ensures the effectiveness of trade (cross-border linkage) between the world and Accra. Hence there is smooth movement of rice product. This corroborates with Amanor-Boadu (2012) where they found that rice market in Ghana is not independent of the

world market. This means that changes in the price of rice on the world market are transmitted (equally or otherwise) to the local market, all other things being equal.

Table 4. 4: Test for co-movement between the world market and local market (Accra)

Market Pairs	Lags	Null Hypothesis	Trace Statistics	Decision
World -Accra	1	$r=0$	17.55.4237***	Cointegrated
		$r\leq 1$	1.197	

Source: Own computation from imported rice price data (2013-2018). *** signify 1% significant levels.

4.3.2 Test for long-run relationship between world and local (Accra) market

The outcomes of the econometric estimate of the VECM for the World (net producer) and Accra (net consumer) rice market pair is presented in Table 4.5. This indicates that there exists a long-run relationship or equilibrium between markets under consideration which ensures availability of rice. There may be an imbalance in the short run, of course. Hence, the error term is regarded as an 'equilibrium error.' This error term was used in the study to link the short-term price behaviour to the long-term price value for rice (import). There are different degrees of price relationships between the long-term ratio and the rate of price adjustment for transmission measuring the response to the world price shock.

The results in the VECM estimates (Table 4.5) show that monthly, 15.05% of the disequilibrium in price of rice between the short-run and long-run in the two markets are corrected back to equilibrium to ensure continuous availability to imported rice. This value is significant at 5% confidence level with a corresponding standard error of .0751. The long-run estimate is also significant at 1% significance level, indicating that a 1% increase in the international price for rice is likely to increase imported rice price in Accra by 27.38% in the long-run. This will take about

four and a half months for any deviations (disequilibrium) in price between the two markets to be corrected in the rice market. The longer duration in transmission of rice price from the world to the local market is as a result of longer time in shipment of rice and also longer time for clearing goods at the port (long bureaucracy process).

The inability of local rice production to meet the high demand for rice in Ghana has forced the country to rely on the importation of rice to close the supply deficiency gap. The trade of rice between the world market and local market has been enhanced due to the co-movement and long-run equilibrium existing in the two markets. This is because as a result of the long-run relationship existing between the world market and domestic market for imported rice, prices do not drift apart (increase in world price rice is counter cross with same increase in prices on the local market for the same commodity). Hence the price movement led to a continuous trade between the two markets resulting in a constant import of rice (availability) in Ghana. Finally, one can argue on the basis of evidence that the world market and Accra market are strongly co-integrated and this ensures availability of imported rice in Ghana.

Table 4. 5: Vector Error Correction Results (VECM)

Parameter	Estimates
α	-.1505 ** (.0751)
β	-.2738 *** (.0338)
Half-life	4.25
Number Obs.	70
AIC	-75.738
SBIC	-57.750

Source: Own computation from imported rice price data (2013-2018).

Model diagnostic checking for VECM

Tables 4.6 summarize the Godfrey LM and Jarque-Bera normality test for the adequacy of the VECM model.

The results show that for Godfrey LM testing, the null hypothesis of non-serial autocorrelation of 1 lag is accepted, as the associated p-value is higher than the value of 0.05, and thus rejects the null hypothesis that serial autocorrelation exists at 1 lag. There is no serial autocorrelation. That is the repeating lagged version of a variable does not influence its future level. In the Jarque-Bera test, the null hypothesis is rejected for the Accra market but failed to reject for all residuals which indicate normality. This means residuals in the models are distributed normally. In addition, robustness controls show strongly that the VECM model is well designed and has no economic problem.

Table 4. 6: VECM model diagnostics

Type of test	chi2	df	Prob > chi2
LM autocorrelation test	5.5706	4	0.23359
Normality Test			
D_World Market	6.556	2	0.03770
D_Accra market	.985	2	0.61109
ALL	7.541	4	0.10990

Source: Own computation from imported rice price data (2013-2018).

4.4 Price transmission in the domestic market to ensuring accessibility of imported rice.

The Johansen technique is used to evaluate the rank of a matrix (cointegration). The results are presented in Table 4.7. The trace statistic either rejects the null hypothesis of no co-movement

among the domestic markets or do not reject the null hypothesis that there is one co-movement relation among the domestic markets. Results from the study make available prove in favour of co-movement among the four market pairs in the study. The co-movement between market pairs assume one lag, i.e. rank (r) =1. The market pairs include Accra – Techiman, Accra – Kumasi, Accra – Tamale and Accra – Bolgatanga.

The results presented in Table 4.7 suggest that there is a co-movement between Accra and Techiman market pair. This can be seen as the trace statistics is significant at 5% significance level and with a lag value of one (1). Similar observation can be seen in the Accra – Kumasi, Accra – Tamale, and Accra – Bolgatanga market pairs.

Table 4. 7: Johansen tests for cointegration between local markets

Market Pairs	Null Hypothesis	Trace Statistics	Lags	Decision
Accra – Techiman	$r=0$	23.0407	1	Cointegrated
	$r \leq 1$	3.6061 **		
Accra – Kumasi	$r=0$	17.281	1	Cointegration
	$r \leq 1$	3.645**		
Accra – Tamale	$r=0$	19.9905	1	Cointegrated
	$r \leq 1$	3.3846 **		
Accra – Bolgatanga	$r=0$	25.3656	1	Cointegrated
	$r \leq 1$	3.3618 **		

Source: Own computation from imported rice price data (2013-2018). *** and ** denote 1% and 5% significant levels respectively.

This suggests that there exist at least one stationary cointegration relations between the pairs of net assembler and net consumer prices. The existence of cointegration/co-movement in the imported

rice market in Ghana imply possible efficient information flow among the markets involved and hence adjustment to inter-market prices ensure long-run market equilibrium and thereby removing excess glut in one market and excess shortage in another. This ensures that imported rice is equally available in all markets under consideration, along with equal access to the commodity under in concerned.

Market causality in ensuring accessibility of rice

It is important to establish links between various markets to aid in policy designing since knowledge about the market playing the leadership role in the formation and transmission of prices helps in effective and efficient policy designs in ensuring accessibility of rice. As already documented in the literature, such leading markets exist in the same integration order of homogeneous commodity market with no tendency to drift off from the long-run equilibrium. Results from the causality test (Granger), which also indicates the direction of causality between various markets (if any) are presented in Table 4.8. The result reveals that most of the rice markets granger cause other rice markets.

Table 4. 8: Result of Granger-causality Test

Null Hypothesis	Chi2	Decision	Comment
Accra does not Granger-cause Tamale	1.4806	Failed to reject	Unidirectional
Tamale does not Granger-cause Accra	7.006***	Reject	
Accra does not Granger-cause Techiman	10.849***	Reject	Unidirectional
Techiman does not Granger-cause Accra	.0104	Failed to reject	
Accra does not Granger-cause Bolgatanga	3.649*	Reject	Unidirectional
Bolgatanga does not Granger-cause Accra	.8190	Failed to reject	
Accra does not Granger-cause Kumasi	9.48***	Reject	Bidirectional
Kumasi does not Granger-cause Accra	5.984**	Reject	

Source: Own computation from imported rice price data (2013-2018). ***, ** and * 1% 5% and 10% significant levels respectively

As shown in Table 4.8, however, there is a unidirectional causality between the following market pairs; Accra – Bolgatanga, Accra – Tamale and Accra – Techiman. This means that there is only one direction of causality; Accra granger cause Bolgatanga, Tamale and Techiman. The lag/past price values in Accra market is used to predict the present price in these other markets. This means that past price information on rice is transmitted from the Accra market and factored in the formulation of market price of rice in Bolgatanga, Techiman and Tamale but does not allow a vice versa mechanism. Accra – Kumasi exhibits a bilateral causality which implies that Accra granger causes Kumasi and vice versa. In this market pair, price information is transmitted and also factored during formation of prices in the two markets.

Hossain & Verbeke (2010) argued that the failure of one price to predict the another as seen in a unidirectional causality is an indication of information inefficiency in the market system. That is when Accra market is predictive of Tamale, Techiman and Bolgatanga markets but the afore mentioned three (3) markets are not able to predict Accra market (due to unidirectional causality), then it can be said that one market is not incorporating the price information of the other market.

Negassa *et al.* (2003) also observed that, the Supply and demand fluctuations in a big market say Accra market will have a large impact on the aggregate demand and supply of consumer markets like Techiman, Tamale and Bolgatanga. Thus, one will expect Accra market to have a great influence on the prices of imported rice in another market. And by considering the market pairs exhibiting unidirectionality in causality, Accra-Bolgatanga, Accra – Tamale, and Accra to Techiman, the trade volumes in Accra is greater when compared to that of Bolgatanga, Techiman and Tamale in terms of demand and supply of imported rice, leading to Accra prices Granger causing Bolgatanga, Tamale and Techiman prices but not vice versa.

Price transmission study provides insight into market performance alongside the welfare of the producer and consumer. On the basis of the dominant unidirectional causality in the imported rice market in Ghana, the market for imported rice is organized around the central market (Accra). This deviates from what is experienced in markets of the developing countries which are characterized by a radial configuration (Hossain & Verbeke, 2010). This situation leads to the creation of periodic arbitrage since prices in the central market for imported rice is different from that which is in the consumer markets from time to time in the short-run. The differences in price for the markets under consideration may leads to shortage in one market while there is a glut in the other market. This market condition creates uncertainty around the market price of imported rice for the economic agent. The resulting impact is a reduction in accessibility of imported rice due price fluctuations.

4.5 Adjustment to long-run equilibrium and symmetry in ensuring accessibility of rice.

In order to examine the influence of price shocks on the price change in ensuring rice accessibility, the indication of co-integrating vectors between market pairs for imported rice is a necessary condition. However, since the Vector Error Correction Model (VECM) is incorporated into the Asymmetric Vector Error Correction Model (AVECM), AVECM is used in the price adjustment impact, as well as assessing extent of asymmetry.

It is believed that markets are characterized by asymmetry in the price transmission process where sellers react quickly to shocks that reduce their marketing margin than to those that stretch them. That is traders quickly adjust (increase) the market price for their goods (here imported rice) in the case where there is an increase in price of the said commodity due to factors beyond the control of the traders but slowly or do not adjust (reduce) their price in situations where there are shocks leading to a decrease in commodity prices, The evidence of asymmetry/symmetry in the

transmission of price signals between the central market (here Accra) and consumer markets is both necessary and sufficient condition in ensuring accessibility of rice over a period of time in the markets.

Accra-Techiman market pair as seen in Table 4.9, in terms of elasticities a subsequent positive shockwave that creates disequilibrium, 53% of such shocks are eliminated within a month and it will take only 0.92 months for the system to return to equilibrium to ensure continuous access to rice. This is significant at 1% significant level. In the events of a negative shock, 19% of such deviations will be corrected within a month and the system returns to long-run equilibrium in 3.23 months. The results also reveal that there is symmetry occurring in the price transmission between the Accra-Techiman market pair implying that positive and negative shocks were transmitted equally at the same speed and time between these two markets, thereby removing glut and shortage. The results from the estimation affirm the assertion that price increases are passed on to consumers equally in both markets. As seen by many scholars, for instance Ivanic & Martin (2008); DeHoyos & Medvedev (2011); Ivanic *et al.* (2012); Wodon & Zaman (2008); Jacoby & Janger (2013), the passing of such prices (increase) to consumers increases food insecurity level, since majority of these consumers spend a large portion of their incomes on food.

Similar observation can be seen in the Accra- Bolgatanga market pair. About 54% of the disequilibrium caused by positive shocks in the marketing of imported rice is corrected and the system restored to equilibrium in 0.89 months. This is significant at 1% significant level. In the case of negative shocks to rice marketing, 34% of the created disequilibrium is corrected in a month and the system returns to equilibrium in 1.7 months. The absence of asymmetry in the markets can be taken to mean the nonexistence of imperfections present in the market, Ben-Kaabia

et al. (2007). Thus, the Accra- Bolgatanga market for imported rice is efficient in ensuring quick adjustment of prices in the local markets to allow accessibility of rice.

Table 4. 9: Results of the AECM Model

Market Pairs	ECT_{t-1}	T_{half}	ECT_{t+1}	T_{half}	Asy
Accra-Kumasi	-.3108*	1.86	-.1628	3.9	.2394
Accra- Techiman	-.1912	3.23	-.5298***	.92	.9177
Accra- Bolgatanga	-.3361	1.69	-.5430***	.89	.3825
Accra – Tamale	-.3479	1.62	-.3685*	1.51	.0033

Source: Own computation from processed rice price data (2013-2018). *** *represents the significance of the coefficients at the 1% significance level*

In the market pair of Accra-Tamale, 36% of shocks are removed within one month following a positive shock which creates disequilibrium, and it takes one and half months for the system to return to balance. Again, 35% of deviations are corrected within one month in the event of a negative shock and the system will return to balance in 1.6 months. The results also reveal that there is no symmetry occurring in the price transmission between the Accra- Tamale market pair implying that positive and negative shocks to price are not transmitted at the same speed and time.

The existence of asymmetry in the transmission of price shocks means that there are some losses in welfare for several market participants since consumers do not have equal access to imported rice in the market pair under consideration (Wlazlowski *et al.*, 2012). This is however the case in the Accra – Tamale market pair for imported rice which was characterized by asymmetric relationship. One can therefore say that there exists arbitrage in the two markets, hence resulting

in periodic lower quantities of imported rice in Tamale market, leading to decrease in accessibility to imported rice in this market. Base on the findings, accessibility of imported rice in Tamale is low.

The speeds of adjustment for positive and negative deviations recorded in the Accra – Bolgatanga market is the highest and it was followed by Accra – Techiman. Bonsu *et al.* (2011) found a speed of adjustment of 27.73% and summed up that there is weak integration among the markets. Thus, it can be concluded for this thesis that there is a relatively strong integration among the markets. As such cointegrated rice markets are be able to respond more quickly to market shocks thereby correcting price deviations from the market price. Also, traders can efficiently and effectively distribute imported rice from surplus to deficit markets and hence ensuring a long-run and accessibility of imported rice in the various markets for consumers. See Table 4.9.

4.6 Examine the effect of rice price changes on the stability of rice in Ghana.

Diagnostic test: ARCH-LM test for return series

The ARCH model family is better suited to modelling price fluctuations / volatility for the rice returns series. At this stage, the ARCH-LM test is used to double check whether or not we run the ARCH model family. This test is conducted under the null hypothesis that the residuals of our ARIMA model have no ARCH effect on the ARCH effect alternative.

Table 4. 10: Autoregressive Conditional Heteroscedasticity Lagrange Multiplier Test

Lags	ARCH – LM Test	
	Test-Statistics	Prob > chi2
6	16.086	.013
12	14.469	.272
24	22.29	.562
36	36.0	.468
48	24.0	.998

Source: Own computation from imported rice price data (2013-2018).

From Table 4.10, we observed that the test statistics from ARCH-LM test has a corresponding significant p-value. We therefore reject the null hypothesis of no ARCH effect in the returns series of rice. This is significant at lag (6). Several ARCH family models are thus fitted to our returns ARIMA model's residuals series with a mean equation of ARCH-GARCH (1,1). Estimated results of the ARCH-GARCH (1,1) model suggest that most parameters of the different price series are significant.

Table 4. 11: Estimates of the ARCH-GARCH (1,1) model

	World Market	Accra Market	Tamale Market	Techiman Market	Bolgatanga Market	Kumasi Market
α	.487***	.773***	.115**	.181***	.439***	.935***
β	.185*	.171***	.552***	-.301	.105***	.05**
Prob > chi2	0.000	0.0326	0.081	0.007	0.0915	0.007
AIC	1334.50	1840.37	1943.53	1801.29	1592.81	1458.01
BIC	1345.81	1851.69	1954.84	1812.60	1604.12	1469.32

Source: Own computation from imported rice price data (2013-2018). ***, **, * represents the significance of the coefficients at the 1%, 5% and 10 % significance level

From the ARCH – GARCH (1,1), results shown in Table 4.11 indicate a robust model for estimating the conditional volatility for the various markets. Since the positive limitations for GARCH model is met, we are sure to conclude that the ARCH-GARCH model (1, 1) estimated is adequate. As expected, α (ARCH effect) and β (GARCH effect) are higher than zero and are positive to ensure that the conditional variance is non-negative; therefore, the GARCH model's

positive constraints will not be violated. α and β at different significant levels are both positive and statistically significant. The β indicates that the variance from the previous period is important to influence the volatility of the present period. Likewise, α indicates that the effects of old news on volatility is quite important in understanding current volatility alongside its implications on the stability and sustainability of imported rice in Ghana.

There are significant GARCH effects for Accra, Kumasi, Bolgatanga, Tamale and the World markets of the rice prices. The ARCH effect parameters are significant for World market, Accra, Bolgatanga, Techiman, Tamale and Kumasi markets.

The value of the GARCH effect of World price is statistically significant, demonstrating that higher variance in the World market for rice dampens market activity for rice. The coefficient of the α is positive and statistically significant indicating also that a 1% increase in past period volatility of World market price will lead to 0.47% increase in present period volatility. Again, from the coefficient of β , a 1% increase in past period variance will result in 0.18% increase in present volatility. This is consistent with Moffitt & Zhang (2020) hypothesizes that “volatility in the current time is related to its value in the previous period”.

In the domestic markets (Accra, Tamale, Bolgatanga and Kumasi), the β coefficient value recorded shows that previous period variance results in increase in current spikes by 0.171%, 0.55%, 0.11% and 0.05% respectively. On the other hand, the influence of past period volatility (α) on current price for imported rice in Accra, Tamale, Techiman, Bolgatanga and Kumasi markets is seen to be higher (0.77, 0.11, 0.18, 0.44 and 0.94). As indicated, higher instability in the trade of imported rice inhibits market activities for imported rice. High trade deficits create uncertainty on an economy's overall health and their market activities have adverse repercussions on the stability of

imported rice. The ARCH effects are significant for all the domestic markets, this indicates that there is significant volatility spill over from past period prices in these big markets. Intuitively we can expect this positive spill over effect to occur in these markets given that Ghana's over-dependency on imported rice. See Table 4.11.

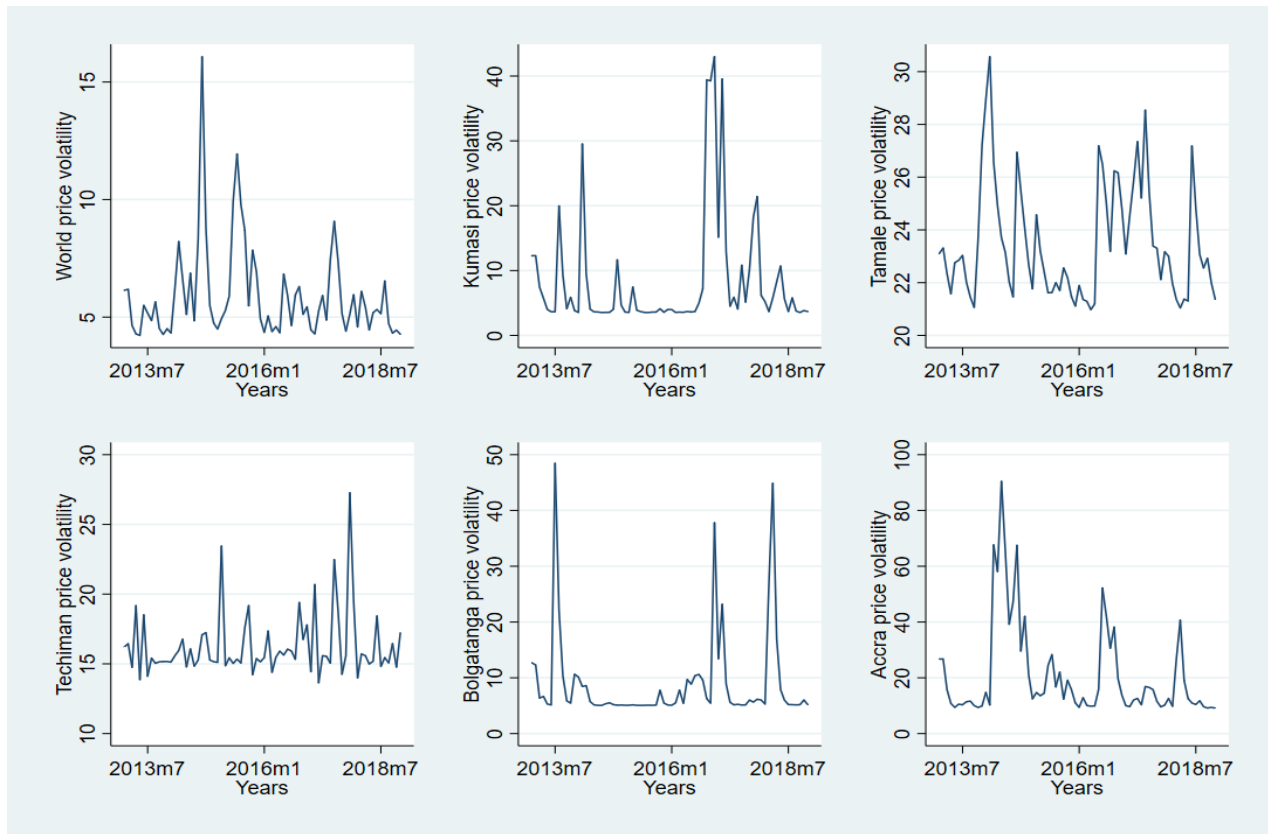


Figure 4. 4: Conditional volatility in various markets
Source: Own computation from imported rice price data (2013-2018).

The conditional volatility of rice imports in all markets is marked by increases in volatility, both in the first months of 2014 as well as in 2017 and in some months of 2018. It should be noted that these volatilities were significant during the said period, indicating that in addition to leading to a delayed clustering of the volatile content on different Ghana markets, the imported rice price episode was probably exacerbated by domestic factors as well. Although the volatility in Ghana

was generally significantly above world market volatility during the 2013 – 2018 period, the price increase has adversely affected consumers the most in terms of the instability of imported rice.

The net trade share of households for goods as endorsed by Ivanic & Martin (2008) is a generally accepted measure of the short-term / long-term impact of variations of commodity prices on household welfare. A household that is a net seller of goods is advantaged, if the price of the good goes up. In contrast, a household that is a net purchaser of food in Ghana is disadvantaged when the price goes up.

The conditional volatility in the world market is estimated to be 5.9%. This indicates that an increase in international market uncertainty will lead to a fall in market volatility by 5.9%. On the other hand, conditional volatility in the domestic market is higher. It ranged from 8% in the Kumasi market (Accra) to 23% in the Tamale market. The findings on the transmission of volatility from the World market to the domestic markets indicate that volatility of imported rice price is not only caused by volatility in prices and stock on the World market, but an effect of other internal macroeconomic variables such as tariffs and interest rates. Hence the rice markets are affected by the state of the economy. The study must caution that the result can also mean that increased uncertainty in prices for imported rice reduce the level of activity in these markets.

The above results suggest that a significant upward pressure on the domestic prices for imported rice was observed in Ghana (Accra, Tamale, Techiman, Bolgatanga and Kumasi) during the study period. Taking into account the volatility estimates shown in Table 4.12, it can be linked to the evidence found by Ivanic & Martin (2008) that higher prices leads to increasing food insecurity. The high rate of instability of price of imported rice of is growing faster with food prices rising as so many households spend very large amounts of their income on food. In terms of imported rice

in Ghana, prices are not stable across the various domestic markets and therefor contributing to food insecurity.

Table 4. 12: Results of Conditional Volatility

Market Price	Mean volatility	Std. Dev.
World	5.89	1.99
Accra	21.00	17.07
Techiman	16.25	2.30
Kumasi	8.37	9.19
Tamale	23.51	2.21
Bolgatanga	9.00	8.49

Source: Own computation from imported rice price data (2013-2018).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The study summary, conclusions drawn from the research and policy recommendations are presented in this chapter.

5.2 Summary and major findings

The study sought to examine rice price volatility and transmission; implications for food security in Ghana. The main objective of the study was to examine price volatility, how it is transmitted in rice markets and its implications for availability, accessibility and stability of rice in Ghana. The specific objectives are to examine the relationship between world and domestic markets for imported rice in ensuring availability of the commodity, examine the extent of price transmission in the domestic market to ensuring accessibility of imported rice, determine whether price transmission between the local and central markets are symmetric or asymmetric to ensure accessibility of imported rice and examine the effect of rice price changes on the stability of imported rice in Ghana using monthly imported rice data between 2013 and 2018. STATA 15 software was used for data analysis.

The study deployed Johansen Cointegration test, Granger causality test and Error Correction model (ECM) to examine the price transmission processing the various markets to ensure the availability of imported rice. Also, the asymmetric vector error correction model was used to compute the long-run adjustment and so ascertain whether there is symmetry in the various markets in ensuring accessibility of imported rice. Lastly, the study employed the use of ARCH/GARCH model to

capture the conditional volatility in the various market to help understand their impact on the stability of imported rice in Ghana.

On average during the 2013-18 period, Tamale market recorded the highest retail price of rice while Accra and Kumasi had the lowest retail price. The World prices in general was low as compared to the domestic prices. Also, the variability in imported rice market prices as estimated by the coefficient of variation on the average was found to be 22.5%, 24.2%, 33.7%, 25.9%, 31.6%, and 23.5% for international market, Accra market, Tamale market, Techiman market, Bolgatanga market and Kumasi market in that order. High fluctuation in the imported rice market over the study period is an indication that prices are relatively unstable.

All the price series for imported rice in both world and local markets were integrated of the order one I (1), which means that comparable stochastic processes were stationary at levels. There was evidence of cointegration in the world – Accra market pair, Accra – Kumasi market pair, Accra – Techiman market pair, Accra – Tamale market pair and Accra – Bolgatanga market pair for imported rice. This indicate that prices in the various market pairs move together to allow circulation of rice between the markets in concern, thereby ensuring the availability of imported rice. The presence of Unidirectionality and bidirectionality in causality indicates that some of the markets had some level of integrated with the Accra market.

The results of the error correction model indicate that there exist a long-run relationship or equilibrium between the World market (net producer) and Accra market (net consumer), with a speed of adjustment of .151. Any disequilibrium in these markets are corrected within four and half month. This allows efficient trade of imported rice commodity from the world market to the local market. This can be seen in the high trade import of rice over the years.

The asymmetric vector error correction model (AVECM) indicate that positive shocks in all market pairs were corrected faster than negative shocks. The speed of adjustment in the Accra – Bolgatanga is the fastest when compared to the other market pairs. Likewise, the adjustment mechanism for these markets after a shock were characterized by symmetry. This is sufficient and necessary in ensuring efficient and effective distribution of imported rice from surplus to deficit markets and hence ensuring a long-run accessibility of imported rice in the various markets for consumers.

By modeling the price of imported rice using ARCH-GARCH, the effect of macroeconomic uncertainty on stock to prices in rice markets in Ghana is estimated. Results from the estimates shows that at the world (International) level, volatility is highly influenced by the volatility of the last month (0.18%) and also by the errors squared of last month at (0.49%).

Likewise, in the domestic markets (Accra, Tamale, Bolgatanga and Kumasi) for imported rice, the β coefficient value recorded shows that previous period variance results in increase in current spikes by 0.171%, 0.55%, 0.11% and 0.05% respectively. On the other hand, the influence of past period volatility (α) on current price for imported rice in Accra, Tamale, Techiman, Bolgatanga and Kumasi markets are seen to be higher (0.77, 0.11, 0.18, 0.44 and 0.94). As indicated, higher volatility in the trade deficit of imported rice dampens market activities for imported rice. Such conditions create uncertainty about the general health of an economy and its markets activities negatively impact the stability of imported rice.

In terms of effect of price spikes on the stability of imported rice in the various markets, results for Accra, Kumasi, Techiman, Tamale and Bolgatanga shows that volatilities in these markets are higher (21.0, 9.0, 8.37, 16.0 and 23.5) compared with the world market (5.9). This implies that increased uncertainty in world rice price amplify volatility on the imported rice markets in Ghana.

This result is interesting in the case of rice given the high level of rice import to the Ghanaian economy.

5.3 Conclusion

As examined from the study, the accessibility, stability and sustainability dimension of food security from the lens of agricultural market linkages and prices volatility was investigated. And based on the findings, the following conclusion are made:

The world and domestic markets for imported rice are highly integrated with prices adjusting to achieve a long-run equilibrium. Prices in the world market and domestic market co-move together thereby ensuring a continuous trade of rice and hence ensuring availability of imported rice in the country. There is a good transmission mechanism in the domestic markets for imported rice. This ensures a well-integrated market with a stable long-run relationship which ensures accessibility of imported rice in various local markets. The domestic market for imported rice exhibits symmetry in price, thereby eliminating arbitrage in the marketing of imported rice. This ensures equal accessibility of imported rice by consumers in the various markets. Positive shocks in all market pairs are corrected faster than negative shocks

There is high fluctuation in prices, implying that prices of imported rice are not stable across all markets. Volatility in the domestic markets is highly influenced by the volatility of the last month and also by the errors squared of previous month. Also, World price fluctuations are not the only cause of high volatility of rice price in the domestic markets in Ghana but rather other internal factors such as import tariffs and government policy interventions may also influence. This negatively impacts stability of imported rice for consumers as it translates into a reduction in the purchasing power of consumers leading to food insecurity.

5.4 Recommendations

The following are recommendation in relation to the study objectives.

An intriguing finding of this study has to do with integration of the world market with local markets. Government should strengthen trade policies and other bilateral agreements with the countries where we import rice in order to maintain the relation and the benefits that comes with it. Government and other stakeholders along the imported rice value chain should increase investment in building better infrastructure (transportation system, warehouses and market) in order to ensure better trading of imported rice between the various local markets.

Most markets examined exhibited sharp price volatility with transmission being faster, as “bad news” affects the markets faster than “good news”. Panic and badly thought-out policies often tend to accelerate the transmission of price spikes and exacerbate their impact on the domestic markets. To ensure timeliness and cost effectiveness of intervention, policies should be directed to Accra market (leader) since most changes in price will be transferred efficiently to markets which are follower.

Volatility in rice price is higher in the local markets compared to the world price, this is an indication that other elements could be attributed to such occurrences in the domestic market like; policy intervention and supply shortages. To avoid that, Government should strive to become more self-sufficient by increasing internal production of rice across the country.

References

- Abbott, P. (2009). Development Dimensions of High Food Prices. OECD Food, Agriculture and Fisheries Working Papers No. 18, Paris: OECD.
- Abbott, P., & Borot de Battisti, A. (2011). Recent global food price shocks: Causes, consequences and lessons for African governments and donors. *Journal of African Economies*, 20(suppl_1), i12-i62.
- Abdulai, A. (2000). Spatial Price Transmission and asymmetry in the Ghanaian Maize Market. *Journal of Development Economics*, 63, 327-349.
- Abdulai, A. (2002). Using Threshold Cointegration to estimate asymmetric Price Transmission in the Swiss Pork Market. *Journal of Applied Economics*, 34, 679-687.
- Abler, D. (2010). Demand growth in developing countries.
- Abunyuwah, I. (2008). Market Integration Analysis and Time Series Econometrics-Conceptual Insights from Markov-Switching Models. Doctoral Dissertation: Faculty of Agricultural Sciences Georg-August University of Göttingen, Germany.
- Abunyuwah, I. (2013). Implications of Conceptual and Data Complexities on Time-Series Econometric Applications in Market Integration Analysis. *Studies in Agric Economics*, 115(1) 33-38.
- Acquah, De G. H. (2012). A Threshold Cointegration Analysis of Asymmetric in the Ghanaian Maize Markets. *Russian Journal of Agricultural and Socio-Economic Sciences*, 8(8).
- Acquah, H. D. G., & Dadzie, S. K. N. (2010). An application of the von Cramon-Taubadel and Loy error correction models in analyzing asymmetric adjustment between retail and

- wholesale maize prices in Ghana. *Journal of Development and Agricultural Economics*, 2(4), 100-106.
- Acquah, H. D. G., Micah, J. A., & Owusu, R. (2012). Price transmission in domestic agricultural markets: Evidence from selected cassava markets in Ghana. *Journal of Sustainable Development in Africa*, 14(5), 218-228.
- Addison, M., Sarfo-Mensah, P., & Edusah, S. E. (2015). Assessing Ghana's initiative of increasing domestic rice production through the development of rice value chain.
- Adom, P. K. (2014). Determination of Spatial Integration and Substitution of Foreign Rice for Local Rice in Ghana. *Review of Agricultural and Applied Economics (RAAE)*, 17(395-2016-24329), 49-64.
- Alam, P., & Brown, C. A. (2006). Disaggregated earnings and the prediction of ROE and stock prices: a case of the banking industry. *Review of Accounting and Finance*.
- Amanor-Boadu, V. (2012). Rice price trends in Ghana (2006–2011). *Department of Agricultural Economics, Kansas State University. METSS-Ghana Research and Issue Paper Series*, (02-2012).
- Amikuzuno, J. (2010). *Spatial price transmission analysis in agricultural markets: Does the data frequency improve our estimation?* (No. 308-2016-4994, pp. 1-19).
- Amikuzuno, J., Issahaku, G., & Daadi, E. B. (2013). Price Transmission between Imported and Local Rice Markets in a Liberalised Economy: Are Ghana's Rice Wars Just Much I Do about Nothing? *Computer Engineering and Intelligent Systems*, 4(20), 109–119.

- Amonde, T., McDonald, L., & Barrett, K. (2009). An economic enquiry into the causes of the perceived asymmetric price transmission in markets for specific consumer goods in Jamaica. *The Fair Trading Commission (FTC) of Jamaica, April*.
- Ampadu-Ameyaw, R., Omari, R., & Owusu Essegbey, G. (2017). Development and Analysis of the Rice Value Chain for the Hohoe and Jasikan Districts of the Volta Region, Ghana. *FARA research Results, 1*(1), 48.
- Angelucci, F., Asante-Poku, A., & Anaadumba, P. (2013). Analysis of incentives and disincentives for rice in Ghana: Technical notes series. *MAFAP, FAO, Rome, Italy*.
- Ankamah-Yeboah, I. (2012). Spatial price transmission in the regional maize markets in Ghana.
- Archibald, D., & Taylor, J. (2019). Ghana Grain and Feed Annual 2019 Report.
- Arouna, A., Lokossou, J. C., Wopereis, M. C. S., Bruce-Oliver, S., & Roy-Macauley, H. (2017). Contribution of improved rice varieties to poverty reduction and food security in sub-Saharan Africa. *Global Food Security, 14*, 54-60.
- Ashitey, E., & Archibald, D. (2018). A report on the assessment of commodity and trade in Ghana, os-10(1), 60–62. <https://doi.org/10.1177/025576148701000123>
- Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., ... & Reynolds, M. P. (2015). Rising temperatures reduce global wheat production. *Nature climate change, 5*(2), 143-147.
- Asuming-Brempong, S., & Osei-Asare, Y. B. (2008). *Has Imported Rice Crowded-out Domestic Rice Production in Ghana? What has Been the Role of Policy?* (No. 307-2016-4959, pp. 71-77).

- Ayeduvor, S. (2018). Assessing Quality Attributes that Drive Preference and Consumption of Local Rice in, (May).
- Bakucs, L. Z., & Ferto, I. (2007). *Spatial Integration on the Hungarian Milk Market* (No. 689-2016-47280).
- Balcombe, K. G., & Morrison, J. (2002). Commodity price transmission: A critical review of techniques and an application to selected export commodities. *A study for the Food and Agricultural Organization (ESCR) of the United Nations, Rome, Italy.*
- Bekkers, E., Brockmeier, M., Francois, J., & Yang, F. (2017). Local food prices and international price transmission. *World Development*, 96, 216-230.
- Ben-Kaabia, M., & Gil, J. M. (2007). Asymmetric price transmission in the Spanish lamb sector. *European Review of Agricultural Economics*, 34(1), 53-80.
- Boansi, D. (2013). Response of rice output to price and non-price factors in Ghana.
- Bohner, M., & Hatipoğlu, V. F. (2018). Cobweb model with conformable fractional derivatives. *Mathematical Methods in the Applied Sciences*, 41(18), 9010-9017.
- Bohner, M., & Hatipoğlu, V. F. (2019). Dynamic cobweb models with conformable fractional derivatives. *Nonlinear Analysis: Hybrid Systems*, 32, 157-167.
- Brock, W. A., & Hommes, C. H. (1998). Heterogeneous beliefs and routes to chaos in a simple asset pricing model. *Journal of Economic dynamics and Control*, 22(8-9), 1235-1274.
- Cashin, P., McDermott, C. J., & Scott, A. (2002). Booms and slumps in world commodity prices. *Journal of development Economics*, 69(1), 277-296.

- Cavicchioli, D. (2018). Detecting Market Power Along Food Supply Chains: Evidence and Methodological Insights from the Fluid Milk Sector in Italy. *Agriculture*, 8(12), 191.
- Chatrath, A., Adrangi, B., & Dhanda, K. K. (2002). Are commodity prices chaotic?. *Agricultural economics*, 27(2), 123-137.
- Christiano, L. J., Gust, C., & Roldos, J. (2002). *Monetary policy in a financial crisis* (No. w9005). National Bureau of Economic Research.
- Coibion, O., Gorodnichenko, Y., & Kamdar, R. (2018). The formation of expectations, inflation, and the phillips curve. *Journal of Economic Literature*, 56(4), 1447-91.
- Commendatore, P., & Currie, M. (2008). The cobweb, borrowing and financial crises. *Journal of Economic Behavior & Organization*, 66(3-4), 625-640.
- Cudjoe, G., Breisinger, C., & Diao, X. (2008). *Food price transmission and poverty impacts in Ghana* (Vol. 842). Discussion Paper No.
- Danquah, B. I., & Egyir, I. S. (2014). Factors that Influence Household Demand for Locally Produced Brown Rice in Ghana, 5(7), 14–25.
- Darity, W., Leeson, R., & Young, W. (2004). From Hayek to Vernon Smith: Prices, the cobweb, and game theory. In *Economics, Economists and Expectations* (pp. 20-37). Routledge.
- Dawe, D., & Morales-Opazo, C. (2009). How much did developing country domestic staple food prices increase during the world food crisis? How much have they declined. *Agricultural and Development Economics Division (ESA) Working Paper*, 09-09.

- De Hoyos, R. E., & Medvedev, D. (2011). *Poverty Effects of Higher Food Prices: A Global Perspective*. *Review of Development Economics*, 15(3), 387–402. doi:10.1111/j.1467-9361.2011.00615
- De-Graft Acquah, H., & De-Graft Acquah, J. (2015). An application of the error correction model in analyzing the long run equilibrium between Ghana's exports and imports. *APSTRACT: Applied Studies in Agribusiness and Commerce*, 9(1033-2016-84286), 57-62.
- DeJong, D. N., Nankervis, J. C., Savin, N. E., & Whiteman, C. H. (1992). The power problems of unit root test in time series with autoregressive errors. *Journal of Econometrics*, 53(1-3), 323-343.
- Diouf, J. (2008). UN warns of food price unrest. *Financial Times*. Accessed August.
- Enders, W., and P.L. Siklos. (2001). Cointegration and Threshold Adjustment. *Journal of Business and Economic Statistics*. 19(2), 166–176.
- Engle, R. (2004). Risk and volatility: Econometric models and financial practice. *American economic review*, 94(3), 405-420.
- FAO (Food and Agriculture Organization of the United Nations). (2008). *The State of Food Insecurity in the World 2008*.
- FAO (International Rice Commission, & International Year of Rice (Program)). (2005). *Rice is Life: International Year of Rice 2004 and Its Implementation*. Food & Agriculture Org.
- FAO. (2001). *The State of Food and Agriculture 2001* (No. 33). Food & Agriculture Org..
- FAO. (2011). *Safeguarding food security in volatile Global markets*.
- FAO. (2015). *Regional overview of food insecurity: African food security prospects brighter than ever*.

FASDEP I (2002): Food and Agriculture Sector Development Policy, Ministry of Agriculture, Ghana.

FASDEP II (2008): Food and Agriculture Sector Development Policy, Ministry of Agriculture, Ghana.

Foster, V., & Briceno-Garmendia, C. (2010). Africa's Infrastructure: A Time for Transformation, A Co-publication of the Agence Française de Développement and the World Bank, The International Bank for Reconstruction and Development/The World Bank, Washington, DC.

Frey, G., & Manera, M. (2007). Econometric models of asymmetric price transmission. *Journal of Economic surveys*, 21(2), 349-415.

Gelper, S., & Croux, C. (2007). Multivariate out-of-sample tests for Granger causality. *Computational statistics & data analysis*, 51(7), 3319-3329.

Gertchev, N. (2007). A critique of adaptive and rational expectations. *The Quarterly Journal of Austrian Economics*, 10(4), 313-329.

Ghosh, P., Tripathi, V., & Kumar, A. (2010). Customer expectations of store attributes: A study of organized retail outlets in India. *Journal of Retail & Leisure Property*, 9(1), 75-87.

Ghoshray, A. (2008). Asymmetric Adjustment of Rice Export Prices: The Case of Thailand and Vietnam. *International Journal of Applied Economics*, 5(2), 80-91.

Goeree, J. K., & Hommes, C. H. (2000). Heterogeneous beliefs and the non-linear cobweb model. *Journal of Economic Dynamics and Control*, 24(5-7), 761-798.

- Gopal, M. S., Shanmugam, T. R., Raveendaran, N., Rajan, G. K. (2009). "Co integration and Market Integration": An Application to Indian and International Black Tea Auction Markets. *Journal of Asian Business Management*
- Gordon, A., Pulis, A., & Owusu-Adjei, E. (2011). Smoked marine fish from Western Region, Ghana: a value chain assessment.
- Gouel, C. (2012). Agricultural price instability: A survey of competing explanations and remedies. *Journal of Economic Surveys*, 26(1), 129–156. <https://doi.org/10.1111/j.1467-6419.2010.00634.x>
- Granger, C. W., & Lee, H. S. (1991). An introduction to time-varying parameter cointegration. In *Economic Structural Change* (pp. 139-157). Springer, Berlin, Heidelberg.
- Gujarati, D. N. (2003). *Basic Econometrics* (3rd ed.). McGraw Hill Publishing Company.
- Guo, Y. (2013). *Chinese wheat price analysis-with application of cointegration and Granger causality test* (Doctoral dissertation, Georgia Institute of Technology).
- Hall, S. G. (1991). The effect of varying length VAR on the maximum likelihood estimates of cointegration vectors. *Scottish Journal of political economy*, 38, 317-323.
- Hamilton, J. 1994. *Time series analysis*. Princeton University Press, Princeton.
- Hansen, S. and Juselius, K. (1995). *Cats in rats: cointegration analysis of the time series estimates*. Evanston, Illinois.
- Haq, Z. U., Nazli, H., & Meilke, K. (2008). Implications of high food prices for poverty in Pakistan. *Agricultural Economics*, 39, 477-484.

- Harris, R. (1995). *Using cointegration analysis in econometric modelling*. Prentice hall, Harvester Wheatsheaf.
- Hassouneh, I., von Cramon-Taubadel, S., Serra, T., & Gil, J. M. (2012). Recent developments in the econometric analysis of price transmission. *TRANSFOP (Transparency of Food Pricing) Working Paper, 2*.
- Hayo, B., Kutan, A. M., & Neuenkirch, M. (2012). Communication matters: US monetary policy and commodity price volatility. *Economics Letters, 117*(1), 247-249.
- Headey, D. (2011). Rethinking the global food crisis: The role of trade shocks. *Food Policy, 36*(2), 136-146.
- HLPE. (2011). Price volatility and food security HLPE Report 1, (July).
- HLPE. (2020). Food Security and Nutrition: Building a Global Narrative towards 2030. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Research Guides. Retrieved from <https://research.un.org/en/foodsecurity/key-un-bodies>
- Hommes, C. (2013). *Behavioral rationality and heterogeneous expectations in complex economic systems*. Cambridge University Press.
- Hommes, C. (2018). Carl's nonlinear cobweb. *Journal of Economic Dynamics and Control, 91*, 7-20.
- Hommes, C. H. (1997). Models of complexity in economics and finance. *System Dynamics in Economic and Financial Models, Wiley Publishers*, 3-41.
- Hossain, M. I., & Verbeke, W. (2010). Evaluation of Rice Markets Integration in Bangladesh. *Lahore Journal of Economics, 15*(2).

- Hou, A., & Suardi, S. (2012). A nonparametric GARCH model of crude oil price return volatility. *Energy Economics*, 34(2), 618-626.
- Houck, J. P. (1977). An approach to specifying and estimating nonreversible functions. *American Journal of Agricultural Economics*, 59(3), 570-572.
- Inman, J. (2011). Upper Midwest organic grain and feedstuffs report. *NW_GR113 8/24/2011*.
- Irwin, E. G., Bell, K. P., Bockstael, N. E., Newburn, D. A., Partridge, M. D., & Wu, J. (2009). The economics of urban-rural space. *Annu. Rev. Resour. Econ.*, 1(1), 435-459.
- Ivanic, M., & Martin, W. (2008). *Implications of higher global food prices for poverty in low-income countries*. The World Bank.
- Ivanic, M., Martin, W., & Zaman, H. (2012). Estimating the short-run poverty impacts of the 2010–11 surge in food prices. *World Development*, 40(11), 2302-2317.
- Jacoby, M. B., & Janger, E. J. (2013). Ice cube bonds: allocating the price of process in Chapter 11 bankruptcy. *Yale LJ*, 123, 862.
- Johansen, S. and Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration with application to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52(2), 169-210.
- Juselius, K. (2006). The co-integration VAR model: methodology and applications. Oxford University Press (manuscript), Oxford.
- Kalkuhl, M., Von Braun, J., & Torero, M. (Eds.). (2016). *Food price volatility and its implications for food security and policy*. Springer Open.

- Kanakaraj, M. V. (2010). An empirical validity of market integration hypothesis with special reference to the pepper market in Kerala.
- Keller, K. L. (2009). Building strong brands in a modern marketing communications environment. *Journal of marketing communications*, 15(2-3), 139-155.
- Kostov, P., & McErlean, S. (2004). Agricultural price volatility spill-over effects: a comment. *European Review of Agricultural Economics*, 31(4), 481-485.
- Kotler, P., & Keller, K. L. (2009). Marketing management.
- Kotler, Philip & Keller, Kevin Lane (2009) *Marketing Management* Pearson Education International, 13. Edition
- Kranjac-Berisavljevic, G., Blench, R. M., & Chapman, R. (2003). Rice production and livelihoods in Ghana. *Multi-Agency Partnerships (Maps) For Technical Change In West Africa*.
- Kuang, X., Dvorkin, Y., Lamadrid, A. J., Ortega-Vazquez, M. A., & Zuluaga, L. F. (2018). Pricing chance constraints in electricity markets. *IEEE Transactions on Power Systems*, 33(4), 4634-4636.
- Lasselle, L., Svizzero, S., & Tisdell, C. A. (2005). Stability and cycles in a cobweb model with heterogeneous expectations.
- Mafimisebi, T. E. (2012). Spatial equilibrium, market integration and price exogeneity in dry fish marketing in Nigeria: A vector auto-regressive (VAR) approach. *Journal of Economics Finance and Administrative Science*, 17(33), 31-37.
- Mallick, L., & Behera, S. R. (2020). Does trade openness affect economic growth in India? Evidence from threshold cointegration with asymmetric adjustment. *Cogent Economics & Finance*, 8(1), 1782659.

- Mensah-Bonsu, A., Agyeiwaa-Afrane, A., & Kuwornu, J. K. (2011). Efficiency of the plantain marketing system in Ghana: A co-integration analysis. *Journal of Development and Agricultural Economics*, 3(12), 593-601.
- Meyer, J., & von Cramon-Taubadel, S. (2002). *Asymmetric price transmission: a survey* (No. 723-2016-48812).
- Meyer, J., & Von Cramon-Taubadel, S. (2004). Asymmetric price transmission: a survey. *Journal of agricultural economics*, 55(3), 581-611.
- Ministry of Food and Agriculture (MoFA). (2016). Agriculture in Ghana. Facts and Figures 2015. Statistics, Research and Information Directorate (SRID) of MoFA.
- Minot, N. (2011). Transmission of World Food Price Changes to Markets in Sub-Saharan Africa, (January). Retrieved from <http://www.ifpri.org/publication/transmission-world-food-price-changes-markets-sub-saharan-africa>
- Minot, N. (2014). Food price volatility in sub-Saharan Africa: Has it really increased?. *Food Policy*, 45, 45-56.
- Mitchell, H., & McKenzie, M. D., (2003). GARCH model selection criteria, *Quantitative Finance*, 3:4, 262-284.
- MOFA (2009), “National Rice Development Strategy (NRDS)”
- Moffitt, R. A., & Zhang, S. (2020). *Estimating Trends in Male Earnings Volatility with the Panel Study of Income Dynamics* (No. w27674). National Bureau of Economic Research.
- Mohammed, R. (2005). The art of pricing. *New York: Crown Business*.

- Morrison, J., & Sarris, A. (2016). Food Staple Market Volatility and Food Security in Eastern and Southern Africa: what role for intra-regional trade and market policy?. *Africa's Progress in Regional and Global Economic Integration-Towards Transformative Regional Integration*, 18, 159.
- Moseley, W. G. (2017). A risky solution for the wrong problem: why GMOs won't feed the hungry of the world. *Geographical Review*, 107(4), 578-583.
- Motamed, M., Foster, K. A., & Tyner, W. E. (2008). Applying cointegration and error correction to measure trade linkages: maize prices in the United States and Mexico. *Agricultural Economics*, 39(1), 29-39.
- MOUNIROU, I. (2016). Spatial Integrations and Maize's Prices Transmissions on Markets of Collines' District in Benin: Debates-Stakes and Perspectives.
- Narayan, P. K., & Narayan, S. (2007). Modelling oil price volatility. *Energy policy*, 35(12), 6549-6553.
- Negassa, A., Myers, R. J., & Gabre-Madhin, E. Z. (2003). *Analyzing grain market efficiency in developing countries: review of existing methods and extensions to the parity bounds model* (No. 596-2016-40025).
- Nerlove, M., & Bessler, D. A. (2001). Expectations, information and dynamics. *Handbook of agricultural economics*, 1, 155-206.
- Nwanze, F. K., Mohapatra, S., Kormawa, P., Keya, S. O., & Bruce-Oliver, S. (2006). Perspective. Rice Development in sub-Saharan Africa.
- Oleg, M. (2011). Volatility interrelationship between commodity futures, Shanghai stock and 10 year bond indices in China. *International Journal of Economics and Finance*, 3(6), 265.

- Olila, D. O., Wanjau, K., Pambo, K., Chimoita, E. L., & Odipo, T. (2016). Testing for Co-Integration and Granger causality: Evidence from selected indigenous egg markets in Kenya. *Journal of Marketing and Consumer Research*, 19, 80, 94.
- Onyuma, S., Icart, E. and Owuor, G. (2006). Testing market integration for fresh Pineapples in Kenya. *Poster Paper Prepared for Presentation at the International Association of Agricultural Economist Conference*, Gold Coast, Australia, 12 – 18August, 2006. pp. 1 – 16.
- Ragasa, C., Takeshima, H., Chapoto, A., & Kolavalli, S. (2014). Substituting for Rice Imports in Ghana.
- Rakotoarisoa, M. A. (2006). *Policy distortions in the segmented rice market* (No. 596-2016-40045).
- Rapsomanikis, G. (2009). *The 2007-2008 food price swing: Impact and policies in Eastern and Southern Africa*. Rome: Food and Agriculture Organization of the United Nations.
- Rapsomanikis, G., Hallam, D., & Conforti, P. (2003). Market Integration and Price Transmission in selected food and Cash crop markets of Developing countries. *FAO Commodity Market Review*, 2004.
- Rashid S., (2004). Spatial Integration of Maize Markets in Post-Liberalised Uganda. Markets, Trade and Institutions Division (MTID) of IFPRI Discussion Paper No. 71.
- Rashid, S. (2011). Intercommodity price transmission and food price policies: an analysis of Ethiopian cereal markets. *IFPRI-Discussion Papers*, (1079).
- Ray, D. K., Gerber, J. S., MacDonald, G. K., & West, P. C. (2015). Climate variation explains a third of global crop yield variability. *Nature communications*, 6(1), 1-9.

- Reidsma, P., König, H., Feng, S., Bezlepkina, I., Nesheim, I., Bonin, M., ... & Brouwer, F. (2011). Methods and tools for integrated assessment of land use policies on sustainable development in developing countries. *Land Use Policy*, 28(3), 604-617.
- Roache, S. K. (2010). *What explains the rise in food price volatility?* (No. 10-129). International Monetary Fund.
- Robles, M., Cuesta, J., Duryea, S., Enamorado, T., Gonzales, A., & Rodríguez, V. (2008). Rising Food Prices and Poverty in Latin America: Effects of the 2006-2008 Price Surge. *Washington DC: Inter-American Development Bank*.
- Sarris, A., Conforti, P., & Prakash, A. (2011). Using futures and options to manage price volatility in food imports: theory. *Safeguarding food security in volatile global markets*, 403-420.
- Schewe, J., Otto, C., & Frieler, K. (2017). The role of storage dynamics in annual wheat prices. *Environmental Research Letters*, 12(5), 054005.
- Shone, R. (2002). *Economic Dynamics: Phase diagrams and their economic application*. Cambridge University Press.
- Swaray, R. (2007). How did the demise of international commodity agreements affect volatility of primary commodity prices?. *Applied Economics*, 39(17), 2253-2260.
- Tadasse, G., Algieri, B., Kalkuhl, M., & Von Braun, J. (2016). Drivers and triggers of international food price spikes and volatility. In *Food price volatility and its implications for food security and policy* (pp. 59-82). Springer, Cham.
- Tanaka, T., & Guo, J. (2020). How does the self-sufficiency rate affect international price volatility transmissions in the wheat sector? Evidence from wheat-exporting countries. *Humanities and Social Sciences Communications*, 7(1), 1-13.

- Tanko, M., & Amikuzuno, J. (2015). Effects of rice importation on the pricing of domestic rice in Northern Region of Ghana. *ABC Research Alert*, 3(2), Ghana-Ghana.
- Tasila Konja, D., Mabe, F. N., & Alhassan, H. (2019). Technical and resource-use-efficiency among smallholder rice farmers in Northern Ghana. *Cogent Food & Agriculture*, 5(1), 1651473.
- Taylor, M. P. (2004). Is official exchange rate intervention effective?. *Economica*, 71(281), 1-11.
- Thaler, R. H. (2016). Behavioral economics: Past, present, and future. *American Economic Review*, 106(7), 1577-1600.
- The World Bank, (2016). Poverty and equity data.
- Timmer, C. P. (2008). *Causes of high food prices* (No. 128). ADB Economics Working Paper Series.
- Tiwari, S., & Zaman, H. (2010). *The impact of economic shocks on global undernourishment*. The World Bank.
- Tsay, R.S. (2005). *Analysis of Financial Time Series*, Second Edition. A John Wiley and Sons Inc.
- Uchezuba, I. D., Jooste, A., & Willemse, J. (2010). *Measuring asymmetric price and volatility spillover in the South African broiler market* (No. 308-2016-5023, pp. 1-26).
- Ulimwengu, J. M., Workneh, S., & Paulos, Z. (2009). *Impact of soaring food price in Ethiopia: Does location matter?* (Vol. 846). Intl Food Policy Res Inst.
- United Nations Conference on Trade and Development. (2011). *Price formation in financialized commodity markets: the role of information*. UNCTAD.
- USDA, (2018). *Grain and Feed Update*. [online] Available at: <https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Gr>

[ain%20and%20Feed%20Update Accra Ghana 2-2-2018.pdf](#) [Accessed 12 February 2020].

- Usman, M. A., & Haile, M. G. (2017). *Producer to retailer price transmission in cereal markets of Ethiopia*. *Food Security*, 9(4), 815–829. doi:10.1007/s12571-017-0692-0
- Vaughan, D. A., Morishima, H., & Kadowaki, K. (2003). Diversity in the *Oryza* genus. *Current opinion in plant biology*, 6(2), 139-146.
- Viñas, J. M. S. (2013). The volatility of the agricultural markets and the world food crisis. *Cuadernos de estrategia*, (161), 142-169.
- Vo, M. T. (2009). Regime-switching stochastic volatility: Evidence from the crude oil market. *Energy Economics*, 31(5), 779-788.
- Von Braun, J. (2014). Aiming for food and nutrition security in a changed global context: strategy to end hunger. *Alternative Development Strategies for the Post-2015 Era*, 163.
- Von Braun, J., Ahmed, A. U., Asenso-Okyere, K., Fan, S., Gulati, A., Hodinott, J., ... & van Rheenen, T. (2008). *High food prices: the what, who, and how of proposed policy actions* (No. 599-2016-40121).
- Von Cramon-Taubadel, S., & Loy, J. P. (1999). Identifikation asymmetrischer Preisanpassungsprozesse für integrierte Zeitreihen/The Identification of Asymmetrie Price Transmission Processes with Integrated Time Series. *Jahrbücher für Nationalökonomie und Statistik*, 218(1-2), 85-106.
- Warr, P. (2008). World food prices and poverty incidence in a food exporting country: A multihousehold general equilibrium analysis for Thailand. *Agricultural Economics*, 39, 525-537.

- Webber, H., Ewert, F., Olesen, J. E., Müller, C., Fronzek, S., Ruane, A. C., ... & Ferrise, R. (2018). Diverging importance of drought stress for maize and winter wheat in Europe. *Nature communications*, 9(1), 1-10.
- Westerhoff, F., & Reitz, S. (2005). Commodity price dynamics and the nonlinear market impact of technical traders: empirical evidence for the US corn market. *Physica A: Statistical Mechanics and its Applications*, 349(3-4), 641-648.
- Wiredu, A. N., Asante, B. O., Martey, E., Diagne, A., & Dogbe, W. (2014). Impact of NERICA adoption on incomes of rice-producing households in northern Ghana. *Journal of Sustainable Development*, 7(1), 167-178.
- Wlazlowski, S., Giulietti, M., Binner, J., & Milas, C. (2012). Price transmission in the EU wholesale petroleum markets. *Journal of Business & Economic Statistics*, 30(2), 165-172.
- Wodon, Q., & Zaman, H. (2008). *Rising food prices in sub-Saharan Africa: Poverty impact and policy responses*. The World Bank.
- Wolffram, R. (1971). Positivistic measures of aggregate supply elasticities: Some new approaches: Some critical notes. *American Journal of Agricultural Economics*, 53(2), 356-359.
- World Bank (2010) Large-scale land acquisition study
- Wright, B. D. (2011). The economics of grain price volatility. *Applied Economic Perspectives and Policy*, 33(1), 32-58.
- Yang, J., Qiu, H., Huang, J., & Rozelle, S. (2008). Fighting global food price rises in the developing world: the response of China and its effect on domestic and world markets. *Agricultural Economics*, 39, 453-464.

- Zereyesus, Y. A., Embaye, W. T., Tsiboe, F., & Amanor-Boadu, V. (2017). Implications of non-farm work to vulnerability to food poverty-recent evidence from Northern Ghana. *World Development*, *91*, 113-124.
- Zeza, A., Davis, B., Azzarri, C., Covarrubias, K., Tasciotti, L., & Anriquez, G. (2008). The Impact of Rising Food Prices on the Poor ESA Working Paper No. 08-07. *FAO Rome*.
- Zheng, Y., Kinnucan, H. W., & Thompson, H. (2008). News and volatility of food prices. *Applied Economics*, *40*(13), 1629-1635.

Appendix

Appendix 1: Lag length selection in accessing the relationship between the world and local market.

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-73.51	0.031	2.22	2.25	2.286			
1	43.39	233.82*	4	0.000	.0011*	-1.099*	-1.022*	-.9040*
2	45.62	4.45	4	0.348	0.001	-1.047	-0.918	-0.721
3	48.24	5.24	4	0.263	0.0012	-1.007	-0.826	-0.550
4	50.82	5.15	4	0.272	0.0013	-0.965	-0.732	-0.377

Appendix 4: Lag length selection

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-445.102	0.386321	13	13.303	13.40			
1	-282.495	325.21	25	0.000	.0067*	9.191*	9.579*	10.170*
2	-260.812	43.366	25	0.013	0.008	9.289	10.000	11.0838
3	-246.142	29.341	25	0.250	0.011	9.592	10.627	12.2036
4	-227.147	37.989*	25	0.046	0.013	9.769	11.127	13.1962