SPATIAL PRICE TRANSMISSION AND MARKET INTEGRATION ANALYSIS: THE CASE OF MAIZE MARKET IN GHANA

BY

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DECLARATION

I, Selorm Ayeduvor, author of this thesis titled "Spatial price transmission and market integration analysis: The case of maize market in Ghana" do here by declare that with the exception of the references duly quoted, this work was undertaken by me from August 2013 to July 2014 in the department of Agricultural Economics and Agribusiness, University of Ghana, Legon. I do hereby declare that, this work has not been submitted in part or whole for a degree or diploma in this University or anywhere.

Date:-----------------------------

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

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(Major supervisor)	(Co-supervisor)

DEDICATION

I dedicate this work to my wife Mrs. Stella Etornam Ayeduvor and my children Selinam Betty Ama Ayeduvor and Bertrand Seyram Yaw Ayeduvor.

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Glory be to God Almighty for his unending grace and love. All these years have been tough but due to the steadfast love of God which never ceases, I have been successful. I thank God for how far He has brought me.

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God richly bless us all.

ABSTRACT

This study presents an analysis of spatial price transmission and market integration of major maize markets in Ghana over the period 1995-2013. Monthly wholesale maize prices for the various markets were used for the analysis. The Augmented-Dickey Fuller test was used to test for the stationarity of individual price series and was confirmed by the KPSS test. All the price series data that were used tested for Unit Root. They were found to be non-stationary at levels but stationary after first difference at 1%, 5% and 10% significant levels. Johansen Maximum likelihood cointegration test was used to test the cointegration between the market pairs. It was found that all five market pairs were cointegrated. The proof of cointegration is also evidence for a common domestic maize market in Ghana, where inter-market prices adjust to achieve long-run, market equilibrium. The speed of adjustment and half lives from the vector error correction model shows that averagely, 8.2% of any disequilibrium was corrected within a month by the producer markets, while 12.4% of such shocks were corrected within a month by consumer markets. The net producer markets will return to equilibrium in 10 months while net consumer markets will return to equilibrium by 5 months after a shock. This means that shocks are quickly corrected by consumer market than by producer markets. Also adjustment to shock was characterized by asymmetry in that adjustments to price increases are corrected faster than price decreases. Two out of five market pairs exhibited asymmetry in price transmission while the remaining three were statistically not significant. The inventory and stock holding behavior of traders was the cause of asymmetry in price transmission. The evidence of price causation and leadership by Granger causality test shows Techiman as price leaders. In all, the findings indicate that major maize markets in Ghana are well integrated. It is therefore recommended that policy initiatives be directed towards ensuring efficient transportation of agricultural commodities across markets. These include investment in new transporting vehicles, rail/road construction and maintenance. These may contribute to reducing transaction costs and subsequently improving market integration and the imperfection observed in the maize market in Ghana. Also it is recommended that inventory and stock behaviour of traders be improved through investment in storage facilities by the government given the seasonal nature of the commodity. This can ensure even flow of maize throughout the season and enhance traders' response to both positive and negative shocks.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criterion
APT	Asymmetric Price Transmission
ARDL	Auto Regressive Distributedd Lag
AVECM	Asymmetry Vector Error Correction Model
BIC	Bayesian Information Criterion
BRM	Bivariate Regression Model
CPI	Consumer Price Index
ECM	Error Correction Model
ECT	Error Correction Term
EPA	Economic Partnership Agreement
FAO	Food And Agriculture Organization
FIFO	First-In-First-Out
FIML	Full Information Maximum Likelihood
GFDC	Ghana Food Distribution Corporation
GSS	Ghana Statistical Service
HQIC	Hannan-Quinn Information Criterion
ICT	Information Communication Technology
KPSS	Kwiatkowski, Philips, Schmidt and Shin
LIFO	Last-In-First-Out
LOP	Law of One Price
MFOA-SRID	Ministry of Food and Agriculture–Statistical Research Information Directorate

NAFCO	National Food Buffer Stock Company
OLS	Ordinary Least Squares
PBM	Parity Bound Model
PP	Philip Perron
SONACOS	la Société Nationale de Commercialisation des Oléagineux du Sénégal
SRM	Switching Regime Model
TAR	Threshold Autoregressive Model
VECM	Vector Error Correction Model
WTO	World Trade Organization

CHAPTER ONE

INTRODUCTION

1.1Background

Ghana was among countries which had embarked on economic reforms that led to privatization of state controlled sectors. The events that trigger agricultural market reforms were mostly dependent on the broader political and economic changes in most countries and hence the consequences are linked as well. Market reforms are intended to improve efficiency in the economy by enhancing the productivity of human talents and physical assets (Akiyama et al., 2003). Such market liberalisation measures are consistent with economic theory, which postulates that the proper functioning of markets based on comparative advantage theory and marketing channels is essential for optimal allocation of resources (Abdulai, 2000).

One of the most contentious debates in the last two decades has been whether or not the implementation of market reforms in developing countries that started in the 1980s improved price transmission between spatial domestic markets or not (Badiane and Shively, 1997). The purported ability of trade liberalisation to integrate markets–foreign to domestic markets and domestic markets to each other, through supply and demand forces and offer farmers high price incentives was a major economic need that led Ghana and most developing countries to subscribe to liberalisation policies (Amikuzuno, 2010).

Trade liberalisation and price transmission are complementally related. On the one hand, trade liberalisation has the potential of widening the size of domestic markets, and boosting their integration and efficiency by creating (export) price incentives; or of destroying domestic markets by discouraging market integration and efficiency through low import price disincentives. On the other hand, the ability of domestic markets in a country to transmit price signals between themselves and across the country's borders is the panacea for realizing the welfare impact of trade liberalisation (Winters et al., 2004).

The Ghana's Food and Agricultural Sector Development Policies over the past years following the subsequent political reforms have been striving modernizing agricultural markets, thereby forging linkages in the value chain and emphasizing the sustainable utilization of all resources and commercialization of activities in the agricultural sector with market-driven growth in mind (FASDEP I, 2002; FASDEP II, 2008; METASIP, 2011). The improvement in the efficiency of Ghana's agricultural markets is relevant for growth given that the country is basically agrarian hence agriculture contributing its share to the economy. With the sustained effort of developing and modernizing agricultural markets over the last decade and the subsequent emergence of Ghana from a low income country to middle income country raises the concern of the current state of performance and the response of spatially separated markets to each other.

Spatial price behaviour in cereal markets has been used by several authors as an indicator of cereal market performance in a number of countries. Alderman (1993), argues that there is a direct relationship between the ease with which stabilization policies can be implemented and the extent to which internal markets are integrated. Given that ecological conditions often influence differences in regional crop production patterns governments may be interested in knowing the relationship of price movements of staple foods in different ecological regions. Markets that are isolated may receive inaccurate price information that might distort producer–marketing decisions and contribute to inefficient product movements (Alderman and Shively, 1991) as in Abdulai 2000).

If agricultural markets are spatially integrated, producers and consumers will realize the gains from liberalization. As the correct price signals are transmitted through the marketing channels, farmers will be able to specialize according to long-term comparative advantage and the gains from trade will be realised through increase price and demand for their output. Moreover, since integration of markets implies that a deficit or surplus in one market will be transmitted to other markets through arbitrage, an improvement in spatial integration of food markets will ensure regional balance among food–deficit, food surplus and non-food crop producing regions. In addition, prices of a commodity in spatially separated markets move together and price signals and information are transmitted smoothly. Spatial market integration may be evaluated in terms of relationship between the prices of spatially separated markets (Madhusudan, 2011).

Spatial arbitrage should lower the price differences between markets to the level of transaction costs in a very competitive marketing system. However, certain characteristics of agricultural production, marketing and consumption such as inadequate infrastructure, market entry barriers, policy incoherence, unreliable markets and price information may render the process of arbitrage a risky activity for traders. In the absence of entry and exit barriers for traders, the degree of arbitrage between markets depends on both price difference and transaction costs. The major determinants of the magnitude of transactions costs include the quantity and quality of the physical and facilitating marketing infrastructure as well as market information (Fatchamps, 1992, in Abdulai 2000). Sustained efforts by market participant to exploit arbitrage opportunities can result in the maintenance of equilibrium relationship among commodity prices in spatially seperated markets.

Earlier studies such as Alderman (1993); Dercon (1995); and Badiane and Shively (1997) have assumed symmetric price responses in the sense that a shock of a given magnitude in the central market would elicit the same response in the local markets, regardless of whether the shock reflected a price decrease or increase. However, as documented in the literature on price relationships, certain characteristics associated with imperfect competition such asmarket concentration, government intervention, menu costs in the case of perfect competitive markets and inventory behaviour of traders can contribute to asymmetric price responses (Schere and Ross, 1990; Roberts et al., 1994). The co-integration models that were used in this analysis assume that the tendency to move toward a long-run equilibrium is always present. However, movement towards equilibrium may not occur in every period. This study adopts the Vector Error Correction Models (VECM) to examine the relationship between wholesale prices of maize in four principal maize markets in Ghana.

1.2 Problem Statement

Maize is produced mainly for domestic consumption in Ghana and is one of the staple food crops grown throughout the country. In 2012, it constituted 58% of domestic cereal supply and 48% of domestic cereal demand in the country (MoFA, 2012). Major maize producing areas are the Brong-Ahafo Region, Ashanti Region, Eastern Region and Northern Region with moderate production in Volta and Upper East Regions. An increase in maize production by Ghana is not only relevant for food security but also an increase in income generation. Maize crop in Ghana is grown in rural areas where road infrastructure and communication facilities are limited hence acting as a barrier to trade. Winter et al. (2004) have shown that transfer costs caused by poor quality of road infrastructure are usually high in developing countries compared to developed countries as price signals that are passed on to producers are completely different from the consumer price. In addition to that, economic signals are often lost completely in areas where markets are controlled by public agents or few traders which is very common in developing countries such as Ghana.

Price movement within a country or regionally is an area of importance to economists as it provides empirical analysis of how changes in prices from one domestic market can affect prices of the same commodity in another domestic market, its output, consumption and social welfare within the country where opportunity for trade exists. An understanding of price movements within a country and the degree to which prices are transmitted across regions is of economic significance to a country as it provides forecast information on how producers and consumers in the domestic markets will react in response to price changes from external market. Studies of price transmission can provide important information on how prices are transmitted, how markets are integrated domestically and regionally. This will also help inform agricultural marketing policy for intervention and implementation to improve market efficiency (Alderman 1993).

Economic transactions are conducted over spatial areas. Within the neoclassical paradigm, spatial arbitration is expected to ensure that prices of a commodity in two spatially separated markets will differ by an amount that is at most equal to the transfer costs in a perfect competitive condition. These consist of transport costs that are determined by distance and road quality, vehicle efficiency as well as other costs related to arranging a transaction. In a developing country such as Ghana, agricultural commodities are traded in an environment that is characterized by poor transport and communication infrastructure and old vehicles, giving rise to high transfer costs that may prohibit arbitration between two locations, thus resulting in fragmented food markets. Market integration, expressed as the Law of One Price has been the subject of a voluminous body of research in both regional and international trade (Fackler and Goodwin, 2001). Poor market integration among regions results in a reduction in the price information available to economic agents, thus restraining allocative efficiency and long run growth with important implications for food supply and availability. In addition, the extent to which regional markets are integrated also determines the extent of impact of trade liberalization on economic welfare, as well as the design of policies that aim in stabilizing commodity prices. A similar reasoning holds at the household level, where households that face high transfer costs due to distance, old vehicles and poor infrastructure, in general, result in limited marketing opportunities. High transfer costs may result in lower prices received by a selling household and higher prices paid by a buying household (de Janvry et al., 1991; Key et al., 2000). Such transaction costs, apart from the cost of transport, may include costs that are difficult to measure and are related to searching, quality inspection, supervision, risk, the absence of standardization and product homogeneity and other factors. However, distance and poor infrastructure may not only decrease the level of prices received by the farmer, by an amount equal to transport costs, but may also give rise to oligopoly or monopsony power, as it limits farmers' access to only those traders that are located close to their household.

Considering the importance of maize in Ghana, variation in price due to seasonality in production, bad road network, high transportation cost and other constraints of production may have several implications for the producers (farmers) and consumers. Boosting households maize consumption will necessarily entail wholesale and retail price reduction which is achievable only if the market operates efficiently. Since inefficiency in a marketing system at both intra- and inter- market levels is capable of jacking up delivered price, examining the Ghanaian maize markets for its extent of spatial pricing efficiency is crucial to achieving remunerative prices for producers and other market intermediaries and rendering retail prices affordable by final consumers. This is necessary for sustaining production and enhancing welfare of consumers.

The ability of a marketing system to efficiently carry out its function of contributing positively to the development of a country depends on the ease with which price changes and responses are transmitted spatially and temporally between markets for a homogeneous commodity. Owing to unavailability of data on transactions cost or low quality of such data in developing countries such as Ghana, synchronous price movement overtime has been accepted as a proxy for assessing marketing efficiency. A marketing system in which synchronous movement of prices is observed among spatially dispersed markets is considered as being integrated and market integration enhances efficient allocation of productive resources, static agricultural efficiency, short-term food price stability and long-term growth (Baulch, 1995).

Another concern that has driven the interest of stakeholders when dealing with how markets respond to each other is whether markets adjust symmetrically or asymmetrically to each other. Ben-Kaabia et al. (2002) indicated that symmetric relationships are often assumed to be representative of competitive markets, while asymmetric responses are linked with the existence of some market imperfections. These may relate to market power, oligopolistic behavior, adjustment/menu cost, policy intervention and transaction cost among others, which cause rational market participants to deviate from their preferred risk. The presence of asymmetry in price transmission implies welfare loss for some group of market participants since welfare distribution could be different under symmetry (Wlazlowski et al., 2009). Most previous methods for the analysis of price transmission are based on the assumption of symmetry relationship. However, recent developments allow testing for asymmetries in price responses making this a vital tool for the analysis of the maize market in Ghana.

Following Ghana's emergence as a model for free-market innovation in Africa in the 1990s and the liberalized grain marketing sector, the inter-temporal and inter-spatial distribution of maize has been a private sector activity carried out by traders in an informal way. Given the efforts of policy makers in the strive towards achieving market efficiency, the potential influence of traders on the conduct of the market and the differences in maize production regionally lead to the following key **research questions;**

(i) What are the variation and trends within wholesale maize prices in the markets under study?

(ii) What is the price linkage among local (producer) and central (consumer) maize markets in Ghana between 1995 to 2013?

(iii) How is market information and price exchanged along the marketing chain for maize in Ghana?

(iv) To what extent are maize markets in Ghana spatially integrated?

1.3 Research Objectives

Given that prices drive resource allocation and output mix decisions by economic actors, the main objective of the study is to examine spatial price transmission and integration between maize markets in Ghana.

Specific objectives are

i. To analyze the variation and trend between wholesale maize prices in the markets under study.

ii. To evaluate price linkages among Producer (local) and Consumer (central) maize markets in Ghana between 1995 to 2013.

iii. To determine whether price transmission between local and central markets are symmetric or asymmetric.

iv. To analyze the extent to which maize markets in Ghana are spatially integrated.

1.4 Justification of the Study

Maize is the most important cereal crop produced in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO, 2008; Morris *et al*., 1999). In Ghana, maize is produced predominantly by smallholder resource poor farmers under rain-fed conditions (SARI, 1996). However it is only the 4th largest agricultural commodity in terms of value of production in the year 2012 accounting for 6% percent of total agricultural production value (MOFA, 2012).

Ecological conditions influence the differences in regional maize production in Ghana. These conditions combined with other factors create disparity in the living standards especially between the deprived northern and the affluent southern regions. It is known that spatial market integration as an indication for market efficiency between regional markets is essential for bridging the disparity gap, ensuring food security by making sure food is made available from surplus to deficit areas, getting rural households out of poverty, enhancing technology adoption and effective pursuance of macro-level policies; thus ensuring the realization of welfare impacts from policies.

Given the importance of maize in Ghanaian economy, policy makers, producers and consumers will have to understand the dynamics of price movement between the producer and the consumer markets in other for consumers to gain from price reduction and also offer producers price incentives leading to increased production of maize.

This study will provide an analysis of the variation and trends of maize prices and price transmission between the producer markets and consumer markets and offer explanations to loss of economic signals between producer markets and consumer markets and its welfare effect in the country. The results of the study will be useful in designing strategic and plausible policies and measures to improve price transmission between spatial maize markets which is an indication of maize market efficiency. This will help to alleviate rural poverty and improve food security through offering correct price signal to both consumers and producers of maize in the country.

Knowledge of how spatial maize markets in Ghana are integrated is very important in the definition and selection of appropriate pricing policies.

1.5 Organization of the Study

This study is divided into five chapters. Chapter one which is the introduction section gives a background to spatial price transmission analysis. It discusses the importance of price transmission in the context of maize marketing in Ghana. This chapter also presents the problem statement, research objectives and justification of the study.

Chapter two presents a review of literature on market economy for maize in Ghana, models for estimating price transmission and empirical evidence of market integration and asymmetry in price transmission. Chapter three describes the theoretical framework and empirical framework in price transmission, the methods of analysis used in the study of price transmission that employs times series data. Chapter four present the result of the study while chapter five deals with summary and conclusions of the study and policy recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter provides discussion on relevant literature on the general overview of the maize economy in Ghana followed by the theoretical concepts in agricultural price transmission studies and finally some empirical evidence related to agricultural price transmission.

2.1 The Market Economy for Maize in Ghana

Maize is Ghana's most important cereal crop produced by a vast majority of households in all parts of the country except for the Sudan savannah zone of the far north eastern part of the country which makes up the Upper East Region (Yeboa, 2012). The cropping system and production technologies vary between the remaining four agro-ecological zones where significant amount of maize are produced. These include the Coastal Savannah Zone, the Forest Zone, the Transition Zone and the Guinea Savannah Zone (Morris et al., 1999). The main areas accounting for a higher percentage of maize production in Ghana are in the transitional zone which includes Brong Ahafo and parts of Ashanti and Eastern Regions of Ghana (WABS, 2008).

The maize market in Ghana comprises of the yellow maize mostly used in the poultry industry and the white maize for human consumption, industrial and also in the manufacturing of poultry feed. Imports and exports of white maize are minimal and are thought to have a net neutral effect on the maize market while limited amount of yellow maize is imported for the poultry feed industry with some cross border trade occurring with the Sahel countries which has not been sufficiently studied and quantified (Gage et al., 2012). According to Nyanteng and Asuming-Brempong (2003), Ghana is about 100 percent self-sufficient in maize production with only small volumes been imported irregularly. Maize prices are often high due to the high agricultural cost of production, high transaction costs of buying maize from the many scattered small scale farmers. The prices exhibit considerable monthly fluctuations caused largely by seasonal production and inadequate and poor storage facilities. Prices are generally low during major harvest periods and increase dramatically in the periods just before the next harvest. In the major production regions, maize has minor and major harvesting seasons where prices are low during the major harvesting season. Farmers generally sell their output immediately after harvest when moisture levels are higher and the maize more difficult to store associated with many losses, usually between August to October to meet their cash needs. The minor season harvest occurs in January and February when the harvested maize are drier and easier to store and sold between May and July when prices are very high (Armah and Asante, 2004). The northern regions however have only one growing season from May with the harvest period occurring in October and November (Gage et al., 2012). Given the dryer condition, storage is less of a problem in the area.

Maize marketing in Ghana is traditionally a private sector system which takes place in formal and informal markets. In the rural areas, farmers sell to local assemblers who also sell to wholesalers or commission agents. These wholesalers with reasonable resources often hold large stock of grains in the urban centers and hence have some control on when and how much to release into the market for retailers who also sell to consumers. The local assemblers and commission agents often act individually while the wholesalers organize themselves into associations under the leadership of market queens who do influence the conduct of the market (Langyintuo, 2010). This is a characteristic of imperfectly competitive market. However, Alderman and Shively (1996) indicated that maize market appears to be sufficiently competitive to prevent traders from enjoying excess margin; prices are generally determined through private negotiation between purchasers and traders (Abdulai, 2000).

Spatial arbitrage between regions is often the task of wholesalers in the maize market. In major maize production areas, wholesalers sometimes buy directly from farmers with whom they have long standing relationship (Abdulai, 2000), sometimes to the extent of giving farmers credit for maize production. With regional maize distribution in Ghana, the Eastern, Ashanti, Northern and Brong-Ahafo are considered net exporters (production regions) while Western, Central, Greater Accra, Upper East and Upper West are the net importers (consuming regions) of maize. Northern Region services Upper West and Upper East Regions, Eastern Region services Central Region while Greater Accra is supplied from Brong Ahafo, Ashanti and Eastern Regions (Langyintuo, 2010). The maize market was described as imperfectly competitive since the association of the wholesalers if successful; have the power to collude to maximize joint profits, where ineffective traders make strategic moves to maximize their individual profits. The involvement of the state in maize marketing in Ghana, however, depressed maize prices while reducing prices variability (Badiane and Shively, 1997). Operations ceased in the mid-1990s due to bad management but re-emerged under National Buffer Stock Company (NAFCO) in 2009.

The introduction of the Economic Recovery Program in 1983 led to complete liberalization of the maize market in the early 1990s. The policy reforms led to decline in real prices and improvement in the transport sector. Over the last decade, most urban roads have been put to good shape while significant feeder roads linking rural areas have been paved. However, these feeder roads are highly subject to deterioration during the rainy seasons rendering most roads impassable to the often old and heavily loaded trucks for transporting agricultural commodities. There has also been a significant improvement in market information system in the last decade with initiative like the Esoko where market prices are made accessible through mobile phones and the web to market stakeholders. Sankaran et al. (2011) indicated a mobile phone penetration rate in Ghana is about 73 percent and was expected to increase to 80 percent by the end of the year 2011. It has become a substitute for travel and a quicker and cheap means of accessing market information for commerce. Egyir et al. (2011) reported the significant contribution of mobile phones as the single most important ICT tool driving price transmission in the food commodity markets in Ghana. However, much attention needs to be given to complementary services such as good road surfaces and network, good condition cargo vehicles, adequate urban market spaces and facilities and low-cost packaging and handling services that limits market connectedness. Improvement in the infrastructure is a key determinant in the reduction of marketing costs associated with maize marketing.

2.2 Conceptual Definitions

The study of price transmission mechanisms implies referring to a number of economic concepts for which, unfortunately, no common definitions exist in the literature (Fackler and Goodwin, 2001). The most important ones are discussed briefly.

2.2.1 Market Integration and Price Transmission

The concept of market integration is broad and hence many policy makers and economist view it from a particular point of interest. According to Amikuzunu (2010) Spatial price transmission or market integration measures the degree to which markets at geographically separated locations share common long-run price or trade information on a homogenous commodity. Spatial market integration refers to the co-movement of prices across spatially separated markets or the extent to which demand and supply shocks arising in one market is transmitted to other markets in geographically different locations. Barrett and Li (2002), define market integration as the tradability and contestability between markets which includes market clearance process where demand, supply and transaction costs in distinct markets determine prices and trade flows jointly, and the transmission of price shocks from one market to the other. In the tradability view, trade flows are sufficient to signal spatial market integration but not necessarily implying price equalization and hence consistent with Pareto-inefficient distribution (Barrett, 2005). Thus, two markets can be integrated by belonging to a network or by a state institution that fixes prices adjusted to regional or national shocks making it possible for prices to be transmitted even in the absence of trade (Cirera and Arndt, 2006).

In the contestability notion, the focus is on full exploitation of arbitrage rents and competitive markets. Thus two markets are integrated when there are zero marginal profits to arbitrage which leaves markets agents indifferent about trading and therefore reaching a competitive equilibrium and a Pareto-efficient distribution (Barrett and Li, 2002). Spatial market integration is of high relevance to agriculture, as agricultural products are often bulky and/or perishable and that production may be concentrated in one location while consumption is concentrated in the other, which may imply expensive transportation cost (Sexton et al., 1991). Moreover, proper functioning of markets and marketing channels are essential for realizing the impact of different economic policies such as macroeconomic or trade policy. Markets that are segmented spatially isolate economic agents and households across space and limit the transmission of price incentives and the associated positive welfare impact as a result of lower prices or increased productivity. Imperfectly integrated markets may send wrong price information signals to producers and other actors in the marketing chain which may result in incorrect production and marketing decisions (Goodwin and Schroeder, 1991). The analysis of spatial market integration generally lies in the heart of spatial price equilibrium theory referred to as the Enke-Samuelson-Takayama-Judge model. This model assumes that price relationships between spatially separated competitive markets depend on the size of the transaction costs (Barrett, 2005).

The study of Goletti et al. (1995) indicates that market integration is determined by the action of traders as well as the operating environment. Among these are marketing infrastructure related to transportation, communication, credit and storage facilities which create large marketing margins due to transfer costs. This can partly insulate domestic markets. Government policies may also affect the functioning of markets through price stabilization policies, trade restrictions and regulations on credit, storage and transportation. These actions of the government may either have positive or negative effect on market integration. Also, the level of production of the area surrounding each market will determine its self-sufficiency status relative to other parts of the country. Markets are more likely to be integrated if there is wide variation in their respective self-sufficiency position.

2.2.2 Spatial Market Efficiency

In the study of spatial price analysis, spatial integration of agricultural markets is often used as a test for the efficiency of agricultural markets. For instance, the term "spatial market efficiency" and spatial market integration are sometimes used interchangeably (Negassa et.al. 2003). The growing body of literature recognize these terms to be related but not equivalent (McNew and Fackler, 1997; Barrett and Li, 2002) and hence needs to be distinguished. Spatial market efficiency is an equilibrium condition where all potential profitable arbitrage opportunities are exploited. In the absence of trade, a spatial price differential less than transfer cost is consistent with market efficiency. However, if the spatial price differential is greater than the transfer cost, the market is inefficient with or without trade (Negassa et.al. 2003).

2.2.3 Spatial Arbitrage

Spatial Arbitrage is the process of exchange of commodities with the objective of taking advantage of price differences that exceed transaction costs (FAO, 1997). The spatial arbitrage conditions ensures that, for a homogeneous product, the price differences between regions in a competitive market that trade with each other should equal the transaction cost, while at autarky price differences between two regions is less than or equal to the transaction cost (Tomek and Robinson, 2003). If price differences exceed the transfer cost, arbitrage is created and profit seeking merchants will purchase commodities from low price surplus markets and sell in the high price deficit market (Katengeza, 2009).

Consider prices between two spatially different markets P_{1t} and P_{2t} at time t . The two markets are said to be integrated if price in the two markets are equal, corrected only by the transport cost T_c, thus $P_{1t} = P_{2t} + T_c$. Trade between the two regions occurs only if $P_{1t} - P_{2t} > T_c$. Earlier studies on spatial market integration tested this formulation in the concept of the "Law of One Price" using regression analysis. Rapsomanikis et al. (2004) list oligopolistic behaviour and collusion among domestic traders as another determinant of market integration; thus traders may retain price differences between markets in levels higher than those determined by transfer costs.

2.2.4 The Law of One Price (LOP)

The Law of One Price (LOP) directly follows from the spatial arbitrage condition: in markets linked by trade and arbitrage, prices expressed in the same currency will be equalized, net of transport costs. The LOP is based on international commodity arbitrage, implying that "in the assumed absence of transport costs and trade restrictions, perfect commodity arbitrage insures that each good is uniformly priced (in common currency units) throughout the world " (Isard, 1977).

For instance P_t^j *and* P_t^i are the respective contemporaneous prices of a homogenous commodity traded between an exporting market j and an importing market i. The LOP (in its weak form) requires that the price differences between i and j for the homogenous commodity be equal to the transfer costs incurred in moving the commodity from market j to i. It stipulates that whenever the price difference exceeds the transfer costs, arbitrage processes (including moving the commodity from the low price market to the high price market) work out to ensure equality between the inter-market price difference and transfer costs. The LOP mathematically states that:

$$P_t^i = P_t^j + C_t^{ij} + \mu_t \qquad 2.1$$

Where, C_t^{ij} is the transfer costs of moving the commodity between markets i and j; and μ_t represents short run deviations from the LOP due to instantaneous unexpected shocks (e.g. failure of transportation systems, natural disasters, policy incoherence). The equation (2.1) implies that:

$$\mu_t = P_t^i - P_t^j - C_t^{ij} \text{ or } E(\mu_t) = E(P_t^i - P_t^j - C_t^{ij}) \qquad 2.2$$

Earlier analyses of market integration that emphasized the concept of the LOP in the above form mistook any inter-market price relationship that failed to fulfill the LOP as market segmentation. Later studies, however, revealed that price series are mostly non-stationary due to transfer costs, market power and imperfect competition, and this does not strictly permit fulfillment of the LOP. This led to the modification of the concept of the LOP in cointegration and regime-switching models in which nonlinearities in price series are explicitly accounted for.

2.3 Models for Estimating price transmission and Spatial Market Integration

In the analysis of market integration, it is often preferred if all possible information such as prices and quantities produced and traded, data on costs or transaction costs are utilized to infer demand and supply mechanisms. However, due to data unavailability, researchers rely on assumptions guided by economic theory to make use of price based techniques such as price transmission econometrics or parity bound models that utilize more than price data in equilibrium representation (Abunyuwah, 2007). Some of these techniques relevant to the maize price transmission study are discussed below.

2.3.1 Static Price Correlation and Regression Models

The study of market integration started with the use of static price correlations to test for spatial market integration in agricultural markets. This approach involves the estimation of bivariate correlation and regression coefficients of homogeneous goods in distinct markets (Hossain and Verbeke, 2010). The intuition behind this approach is that there is co-movement of prices between integrated markets. Thus, high/low correlation coefficient is interpreted as market integration/segmentation. For instance, if P_t^i and P_t^j are two contemporaneous price series in markets i and j connected by trade for a homogenous commodity, the correlation coefficient, r, is obtained by:

$$r = \frac{\sum_{k=1}^{n}\left[(P_t^i - \bar{P}^i)(P_t^j - \bar{P}^i\right]}{\sqrt{\sum_{k=1}^{n}(P_t^i - \bar{P}^i)^2 \sum_{k=1}^{n}(P_t^j - \bar{P}^j)^2}} \qquad 2.3$$

Where $\bar{P}^i$ and $\bar{P}^j$ are mean values of P_t^i and P_t^j respectively

The bivariate regression models (BRM) of price transmission and market integration are commonly specified as:

$$P_t^i = B_0 + B_1 P_t^j + B_2 T_t + B_3 R_t + \varepsilon_t \qquad 2.4$$

Where P_t^i and P_t^j may be in their first-difference or logarithms form, T_t is transaction cost, R_t denotes other factors influencing prices. The $\beta_i s$ are the coefficients to be estimated and ε_t is the error term. Even though the static models are easy to estimate using only price data, their assumption of stationary price behaviour and fixed transactions costs make them underestimate the extent of market integration (Barrett, 1996; Baulch 1997). Recent developments in time series econometrics allow economist to test a more general notion of spatial market integration by analyzing long-run co-movement of prices leaving the LOP a testable hypothesis.

The static approach though simple, represents significant weakness and hence faces inferential dangers in drawing conclusions from parameter estimates. The principal weakness is that correlation does not imply causality (Cirera and Arndt, 2006). Timmer (1974) recognized that inter-seasonal flow reversals, which are common in areas with poor infrastructure make price spread observations unreliable indicators of market integration or competition because the spreads vary seasonally. Bivariate correlation analysis also masks the presence of certain factors such as government policy effects and general inflation (Golleti et al., 1995). The approach assumes instantaneous price adjustment and hence cannot capture the dynamic nature of the prices. Prices may tend to move together even in the absence of market integration and this has the tendency for spurious market integration (Ravallion, 1986) which can be influenced by general inflation, seasonality or autocorrelation.

This simple correlation analysis also fails to recognize the presence of heteroscedasticity common in price data. Also correlation test may overestimate lack of market integration if lag in price response is created by lags in market information (Barrett, 1996). It is limited to only a pair wise market analysis and cannot be used to evaluate the entire marketing system.

2.3.2 Delgado Variance Decomposition Approach

In an attempt to correct for some of the numerous problems in the bivariate correlation approach to measuring market integration, alternative model was developed by Delgado (1986). The Delgado approach according to Negassa et al. (2003) is a variance decomposition approach that tests market integration for the whole marketing system instead of a pair-wise test. Prior to the test for market integration, common trends and seasonality present in price series are removed and transport and transaction costs are assumed to be constant. Then, the equality of spatial price spreads between pairs of markets for a given season gives an indication of spatial integration. The problem with this approach is that it is based on contemporaneous price relationships and does not allow dynamic relationships for a given pair of distinct markets.

2.3.3 The Ravallion Dynamic Model

The Ravallion (1986) approach became the most prominent technique for measuring spatial market integration, which distinguished between short-run and long-run market integration and segmentation after controlling for seasonality, common trend and autocorrelation (Negassa et al., 2003). The motivation behind this model is due to the sluggish nature of agricultural markets when a shock is invoked, that may require considerable time lags. The incorporation of dynamic considerations in this model helps avoiding the inferential danger pointed out in the static model discussed in section 2.3.1.

The Ravallion model rules out the possibility of inter-seasonal flow reversals and assumes constant inter-market transfer cost. If the transfer costs are complex or time varying, inference will be biased in favour of failing to reject the hypothesis of segmented markets (Barrett, 1996; Cirera and Arndt, 2006). This method posits a radial spatial market structure between a group of local markets and a single central market where local price formation is dominated by trade with the central market. Assuming P_{1t} and P_{2t} represent local and central markets prices respectively, the model can be expressed as:

$$P_{1t} = \sum_{j-1}^{n} \alpha_j P_{1t-j} + \sum_{j-0}^{n} \beta_i P_{1t-j} + \gamma X_t + \varepsilon_t \qquad 2.5$$

j is the lag lengths and X represents the constant, seasonal, time and policy variables. From the above model, the restriction $\beta_i = 0$ for all j indicate complete market segmentation, short-run integration is tested from the restriction $\beta_0 = 1$ and $\alpha_j = \beta_j = 0$ for j = (1,...n). Failing to reject this hypothesis implies that changes in the central market are completely transmitted to the local market in a single time period. Since price changes in spatially distinct agricultural markets may take time to influence other markets, Ravallion tests the long-run integration from the restriction $\sum \alpha_j + \beta_j = 1$, thus price shocks in the central market take more than a single time period to be transmitted to the local market which may be due to inadequate infrastructure.

2.3.4 Cointegration Models

One characteristic of price series used for testing market integration with the use of conventional measures is that the series are often nonstationary and hence tests are invalid. As a result of this problem, Engle and Granger (1987), and Engle and Yoo (1987) introduced the concept of Co-integration and defines it as the existence of long-run relation among different series. The absence of co-integration between two market price series indicates market segmentation, otherwise is an indication of market interdependence. The analysis of co-integration involves determining the order of integration using the appropriate unit root test, constructing the co-integration regression if price series are integrated of the same order and finally testing for stationarity of the residuals from the co-integration regression. The absence of stochastic trend in the residuals indicates the existence of long run relationship between the two series (Negassa et al., 2003). The Engle and Granger approach does not allow testing for all possible cointegrating vectors in a multivariate system which led to the development of the Johansen (1988) cointegration approach.

The Johansen method uses maximum likelihood to test for cointegrating relationships among several economic series. In evaluating the short-run dynamics, Engle and Granger (1987) suggest the use of error correction models, if there is the existence of cointegration relation between variables under consideration. The error correction representation sheds more light on the adjustment process in both short-run and long-run responsiveness to price changes which generally reflects arbitrage and market efficiency (Abunyuwah, 2007). The use of cointegration and error correction models help to explore further notions such as completeness, speed and asymmetry of price relationships as well as the direction of causality between two markets.

Barrett (1996) indicates that co-integration among price series is neither necessary nor sufficient for market integration. According to Negassa et al. (2003) and Barrett (1996), if transaction costs are nonstationary, failure to find cointegration between two markets' price series may be completely consistent with market integration. Co-integration is insufficient because a negative coefficient of the central market price implies divergence instead of comovement as indicated by the concept of market integration. The magnitude of the cointegration coefficient may be implausibly far from unity which contradicts the intuition behind market integration. Also, market segmentation can result from either market margins been larger than or less than transfer costs which both implies the absence of efficient arbitrage; however co-integration tests identify only the former (Barett 1996; Goletti et.al., 1995). It is worth noting that all the above models of market integration ignore the significant role of transaction costs. Recognition of transaction costs data permits substantial improvement in market integration modeling techniques. This led to the use of models often referred to as switching regime models in recent analysis of market integration.

2.3.5 Switching Regime Models (SRM)

Usually, prices are related nonlinearly, contrary to the assumption in much of the premier price transmission literature that linear price relationships exist. The realisation that price relationships may be nonlinear due to transactions costs motivated the introduction of a class of models collectively called switching regime models (SRM). Four classes of SRM are widely used in the literature for price transmission analysis – the error correction models (ECM), threshold autoregressive (TAR) models; parity bound models (PBM) and Markov-switching models (MSM).

2.3.5.1 The Error Correction Models (ECM)

The ECM is an extension of the cointegration model. If P_t^i and P_t^j are cointegrated, then the equilibrium relationship between them can be specified as: $P_t^i - \beta P_t^i - \beta_0 = \varepsilon_t$. And ε_t the error term, is assumed to follow an autoregressive (AR) process, then $\varepsilon_t = \alpha\varepsilon_{t-1} + e_t$. This means the equilibrium relationship between P_t^i and P_t^j can be expressed as:

$$P_t^i - \beta_1 P_t^j - \beta_0 = \alpha\varepsilon_{t-1} + e_t \qquad 2.6$$

The above equation implies that the long run relationship (cointegration) between P_t^i and P_t^j is a function of the autoregressive process ε_{t-1}, where ε_{t-1} is the deviation from long run equilibrium, and called the error correction term (ECT), while α measures the response of P_t^i and P_t^j to deviation from equilibrium. The standard ECM has been extended to asymmetric error correction (EC), vector EC and switching vector EC models.

2.3.5.2 Parity Bound Models (PBM)

Early studies that developed the PBM were Spiller and Haung (1986) and Spiller and Wood (1988). This was further developed and applied by other researchers such as Sexton et al. (1991), Barrett and Li (2002), Baulch (1997) among others. According to Abunyuwah (2007), the development of the parity bound model represents an attempt to utilize all available market data (prices, transfer cost, trade flows and volumes) to describe markets along their long-run conceptual settings. The model assumes that transaction costs determine the price efficiency band (parity bounds) within which the prices of a homogenous good in two spatially distinct markets can vary independently (Baulch, 1997; Barrett and Li, 2002).

The PBM assesses the extent of market integration by distinguishing among three possible trade regimes. Regime I occurs at the parity bound where inter-market price differential equals transfer costs. In this case, trade will cause prices between the two markets to move on a one-for-one basis and spatial arbitrage conditions are binding when there are no impediments to trade between the two markets. Regime II is inside the parity bound where inter-market price differential is less than the transfer costs. This implies that trade will not occur and spatial arbitrage conditions are not fulfilled. Regime III is outside the parity bound where inter-market price differential exceeds the transfer costs; spatial arbitrage conditions are violated whether trade occurs or not (Baulch 1997; Sanogo, 2008). The model determines the probability that an observation will fall into one of the three regimes and hence requires establishing the upper and lower parity bounds for spatial arbitrage conditions between the designated markets. The model relies on exogenous transaction cost data to estimate the probability of attaining inter-market arbitrage conditions and the use of the maximum likelihood based estimator copes well with trade discontinuities and time varying transaction cost (Barrett, 1996). Though the PBM model attempts to improve the measurement of market integration by incorporating exogenous transactions costs, there still come with it certain weaknesses. According to Barrett (1996), transaction costs can be difficult to measure. There are significant unobservable components to trading margins, and in the presence of nontrivial risk premia or positive profits, transaction costs can be underestimated which biases the PBM results away from finding market segmentation. Baulch (1997) also recognizes that since only contemporaneous spreads are used in estimation, accounting for the lagged price adjustment postulated by causality and Ravallion models is hardly attainable. Also the violation of spatial arbitrage condition indicates lack of market integration but do not point out its causes.

2.3.5.3 Threshold Autoregressive Models (TAR)

The use of threshold autoregressive models in the study of price transmission mechanisms is often based on the assumption that, the models recognize thresholds which are caused by transaction costs that deviations must exceed before provoking equilibrating price adjustments which lead to market integration (Goodwin and Piggot, 1999). Unlike the Engle and Granger (1987), and Johansen (1988) approach which assumes a linear adjustment relationship between variables, the dynamic responses arising from the threshold effects may be nonlinear in nature. The threshold effects occur when shocks above some critical threshold bring about different response than shocks below the threshold. The thresholds are normally thought of as a function of transaction and adjustment costs or economic risks that prevent agents from continuously adjusting to changes in markets (Rapsomanikis and Karfakis, 2007).

The notion of nonlinear threshold time series according to Goodwin and Piggot (1999) and Hassouneh et al. (2012) was introduced by Tong (1978). Tsay (1989) proposed the method to test for threshold effects and modeling threshold autoregressive processes while Balke and Fomby (1997) extended the threshold autoregressive models to cointegration framework. The use of threshold vector error correction model was proposed by Goodwin and Holt (1999). Variants of threshold hold models have been used in empirical studies such as the Enders and Granger (1998), and Enders and Siklos (2001). The Enders and Siklos approach is based on a one threshold, two regime model while other studies may employ a multiple threshold modeling approach. Though this approach is an improvement in the techniques for measuring market integration by recognizing transaction cost constraint, it still presents some weaknesses.

The limitation is the assumption of constant transaction costs which imply a fixed neutral band over the period under study (Abdulai, 2007). Attempts to address this weakness involves the inclusion of time trend in both the threshold and adjustment parameter and then modeling the threshold as a simple linear function of time (Van Campenhout, 2007). Otherwise, the introduction of different sub-samples to represent the changing policy and economic environment to capture potential variation in transaction costs as a result of different policy regimes (Abdulai, 2007).

The threshold autoregressive models as mentioned earlier account for potential nonlinearities and asymmetries in the price adjustment process and provides more information regarding the data dynamics (Abdulai, 2007). It also provides a measure of the degree to which the market violates spatial arbitrage condition as well as a measure of the speed with which it eliminates these violations (Fackler and Goodwin, 2001). Asymmetries in price adjustment have generated greater interest by different groups of people. For instance, consumers are concerned about why traders respond differently to positive and negative shocks of market prices (downstream and upstream prices). According to Manera and Frey (2005), economic theory offers limited number of justifications for price asymmetries. A limitation worth noting of all the approaches discussed is that, they assess the nature and degree of price transmission without addressing the underlying causes of the degree of transmission.

2.4 Asymmetry in Price Transmission: Evolution, Types and Causes

When the response of market at one level responds differently to a decrease and increase in price at a different level, then asymmetry exist. Asymmetry could exist in the magnitude or the speed of adjustment or both. In the former, short-run elasticities of price transmission differ according to the sign of the initial change while in the latter, long-run elasticity differ (von Cramon-Taubadel, 1998). Asymmetry can also be classified as positive (when one price responds fully or quickly to an increase in another price than to a decrease, thus price movement that squeezes the margin is transmitted more rapidly and/or completely than the movement that stretches the margin). Otherwise, negative (when one price responds fully or quickly to a decrease in another price than to an increase; thus rapid and/or complete transmission to price movements that stretch the margin). This determines the direction of welfare transfer (Meyer and von Cramon-Taubadel, 2004). Asymmetry can also be considered to be vertical if determined along the food supply chain (e.g. from farm level to wholesale level) or spatial when determined between two geographically separated markets.

Asymmetric price transmission has long been associated with agricultural prices with the idea starting from Tweenten and Quance (1969) that used dummy variable to split input prices into increasing and decreasing input prices. Following this, studies such as Wolfram (1971), Houck (1977) and Ward (1982) used variants of the variable splitting technique to capture asymmetry in price transmission. These studies, however, predated the development of cointegration and did not consider the problems related to nonstationary series (Hassouneh et al, 2012). Granger and Lee (1989) therefore incorporated the variable splitting technique into the error correction representation to correct for the problem of nonstationarity. Since then, variants of this approach have been used extensively in applied work (Von Cramon-Taubadel and Fahbusch, 1994; von Cramon-Taubadel and Loy, 1996).

Other studies (Engle and Granger, 1998; Enders and Siklos, 2001 and Abdulai, 2000) also have captured asymmetry using threshold models, where price movements above or below certain thresholds trigger different response. A number of potential causes but limited have been attributed to asymmetries in price transmission. Among studies addressing this issue include Meyer and von Cramon-Taubadel (2004), Frey and Manera (2005) and Abdulai (2000). Some of the potential causes of asymmetry discussed in literature include market power. Market power refers to the ability of an enterprise or a group of enterprises to raise and maintain price above or below a competitive level (Amonde et al., 2009). In non-competitive market structure where there is considerable degree of market power, market agents react quickly and/ or more completely to shocks that squeeze their marketing margin than to corresponding shocks that stretches them, resulting in positive asymmetry. Positive asymmetry is, however, not the only resulting effect of market power. Ward (1982) indicates that oligopolists can be reluctant to increase market prices for the risk of losing market share. The positive asymmetry appears to be reasonable in pure monopoly while both positive and negative asymmetries are conceivable in the more common oligopolistic context (Meyer and von Cramon-Taubadel, 2004).

Another similar argument by Frey and Manera (2005) is the case of tacit collusion in oligopolistic markets. When whole sale prices increase, firms signal their competitors by quickly increasing their selling price to show they are adhering to the tacit agreement. However, when wholesale prices fall, price adjustment is slow due to the risk of signaling that it is cutting its margins and diverging away from the agreement.

Another cause of asymmetry is adjustment/menu costs. Adjustment cost refers to costs a firm incur when it changes its quantities and/or prices of inputs and/or outputs. If the costs are associated with price changes, then such adjustment costs are termed menu costs (Meyer and von Cramon-Taubadel, 2004). Menu cost includes the cost of changing nominal prices, printing catalogues, inflation cost and dissemination of information about price changes. Such costs may be asymmetric with respect to increasing and decreasing prices. For instance traders may not adjust prices when input costs decrease due to the menu costs associated especially when the input costs changes are perceived to be temporary (Kovenock and Widdows, 1998). Menu cost can cause asymmetry in the presence of inflation (Ball and Mankiw, 1994). Under these conditions, Abdulai (2000) indicates that shocks that increase a firms desired price leads to larger responses than shocks that decrease it since firms will take advantage of the positive shocks to correct for accumulated and anticipated inflation.

Inventory management or stock behaviour of traders is a potential cause for asymmetry in price transmission in many markets. Firms usually increase inventory in periods of low demand instead of reducing prices while in periods of high demand, prices are rather increased. In combination with asymmetry in costs related to high and low inventory stocks and the fear of stock out may lead to positive asymmetry (Reagan and Weitzman, 1982). Frey and Manera (2005) also argue that asymmetry could arise due to the accounting principle used by firms. For instance the First In First Out (FIFO) accounting criteria does not allow firms to adjust output rapidly to cost changes until inventory is depleted whiles the Last In First Out(LIFO) criteria allows firms to adjust prices rapidly in response to changes in input costs. Hence the accounting principle has influence on the speed of adjustment since FIFO results in longer lags than the LIFO principle.

Consumers incur cost such as transportation or fuel cost and cost in terms of the time taken when searching for competitive prices, such costs are termed search costs. Imperfect market characterized by information asymmetry may result in asymmetry in price adjustment (Cutts and Kirsten, 2006). Due to the presence of search costs, consumers may have no option than to accept prices offered to them or to search for alternative prices in their locality. Since consumers may have limited knowledge of prices offered by firms elsewhere, sellers exploit them by adjusting quickly when prices rise and slowly when prices fall. Meyer and von Cramon-Taubadel (2004) indicate the role perishability of a product plays in causing asymmetry in price transmission. Ward (1982) argues that traders might hesitate to raise prices for perishable products for fear of spoilage which leads to negative asymmetry. Another counter argument from Heien (1980) is that changing prices is more of a major problem for products with long shelf life than the perishable ones. This is because with the former, changing prices brings about higher time cost and loss of good will.

Another factor causing asymmetry in price transmission is the interventionist role of the Government. This is much evident in political intervention in the form of price support in the agricultural sector mostly introduced as floor price (Kinnukan and Forker, 1987). The resultant asymmetry occurs if retailers or wholesalers are made to believe that the intervention is for an extended period, then downstream price increases are passed on quickly and completely by traders while decreases are passed on slowly (Uchezuba et al., 2010).

2.5 Empirical Evidence of Market Integration and Asymmetry in Price Transmission

The Ghanaian agricultural markets have been subjected to extensive study on price behaviour and their response to each other most especially the maize market. Earlier studies began with researchers such as Alderman (1993), Shively (1996), Badiane and Shively (1998) among other publications. On the quest for knowledge about how information is transmitted across markets in Ghana and whether government policies in a single market can be achieved in a broader arena, Alderman (1993) employs the Ravallion dynamic model and the standard cointegration technique to find out if price movements for maize are fully transmitted to other regions. However, imperfections in how market information is processed were noted. The findings of the dynamic model show functional inefficiency in Ghana using monthly wholesale prices from 1977 to 1990.

In another study of prices and markets in Ghana by Alderman and Shively (1991), the authors use monthly food prices between 1970 and 1990 and adopt a variant of the Ravallion model developed by Timmer (1974). They also indicated in their findings that, markets in Ghana appear to function reasonably well with the exception of rice. Markets integrate in the long-run through prices in the major markets do not transmit instantly to other markets. The findings indicate that price stabilization in one market would contribute to stability in other markets, especially with maize price movements influencing that of millet and sorghum. However, rice marketing channel in Ghana appears to break between the savannah producers and coastal markets.

Badiane and Shively (1998) investigated the respective roles of market integration and transport costs in explaining price changes in Ghana using dynamic model of price formation and cointegration techniques. With wholesale maize price data over the period 1980-1993, they showed that the price-adjustment process in local market is determined by the degree of interdependence between that market and the central market in which the price shock originates. Thus, reductions in local prices and local price variance following the introduction of economic reforms in 1983 can be traced to both local and central market forces, as did arbitrage costs between Techiman and the other outlying markets. A common characteristic of the above studies is that, all use Techiman market in the Brong Ahafo Region as the reference market for which prices transmit to other markets (most often Makola in Greater Accra Region and Bolgatanga in the Upper East Regions). In a similar study as those discussed above, Abdualai (2000) utilizes the threshold cointegration method to examine price linkages between the principal maize markets in Ghana. Results indicate that wholesale maize prices from 1980 to 1997 in the local markets (here Accra and Bolgatanga) respond more swiftly to central market price increases than decreases. Also, Accra market reacts faster than Bolgatanga market to changes in Techiman market prices.

Asuming-Brempong and Osei-Asare (2007) used the Engle and Granger residual based test to show that imported rice market is segmented from the domestic rice market in Ghana. Egyir et al. (2011) also investigated the gains from Information Communication Technology (ICT) based market information services in the Ghanaian food commodity markets using the Ravallion-Timmer model in 11 selected markets. The study revealed that mobile phone has been the single most important ICT tool facilitating the speedy transmission of marketing information. Due to lack of other complementary services, market integration is limited; thus market connectedness values show the presence of short run market integration for groundnut but not for maize and yam. An application of the Johansen cointegration approach in assessing the efficiency of plantain marketing in Ghana by Mensah-Bonsu et al. (2011) indicates arbitrage is working given the presence of short- and long-run relationship between the central consumption market (Accra market), assembly markets (Kumasi, Sunyani and Koforidua markets) and the production markets (Goaso, Begoro and Obogo markets). However, the speed with which prices get transmitted across the markets is relatively weak, that is 27.7 percent. The study uses monthly wholesale prices of plantain between 2004 and 2009.

Amikuzuno (2009) points out the conflicting results of the speed of price transmission in the tomato market in Ghana when the standard TAR and the extended TAR (estimates the speed of transmission as a time varying parameter) are used in a high and reduced tariff periods following trade liberalization in Ghana. The standard TAR shows deterioration in the speed of price transmission (45 percent and 49 percent for high and reduced tariff periods respectively), while the extended TAR indicates an improvement in the speed of price transmission (65 percent and 70 percent for high and reduced periods respectively) in the tomato market. In testing for market integration between the north and south of Ghana's groundnut market, Mockshell and Egyir (2010) found that markets are segmented both in the long and short run. Traders in the groundnut subsector ranked transportation difficulty, lack of standardization in the local market and inadequate credit as the major constraints.

Several authors have done work on price transmission outside of Ghana. Loveridge (1991) employs correlation coefficient approach to test for the impact of infrastructure on marketing in Rwanda. The results of the study reveal that the pre- and post-road paving market integration is different. The construction of new roads increased the strength of linkages between major central markets; however the farm level price data still suggest high cost of moving food between rural and urban markets. Loveridge suggested investment in the transport sector as a possibility of reducing these costs. Badiane et al. (2010) analyzed the extent to which local markets would respond to liberalization of Senegal's groundnut market. The authors employ a dynamic model of price formation that uses estimates of spatial market integration across local markets to measure the response of local markets to policy changes. This model was then used to simulate the impact of liberalizing groundnut prices to allow domestic prices to reflect their international level. They found this would change prices in the central market Dakar, which determines prices in the production regions of Kaolack and Fatick. Also, groundnut prices would have been higher and passed on entirely to Kaolack and to a lesser extent to Fatick if the market had been fully liberalized in January 2007 when the groundnut parastatal agency (SONACOS) was privatized.

Muyatwa (2001) studies whether the regional markets have become spatially integrated following the liberalization of the maize market in Zambia. The study employs cointegration analysis and error correction model using monthly wholesale price data from 1993 to 1997. The outcome of the test indicates that the magnitude of market integration and the speed of price transmission between the regional markets have been very limited. Also, even with the rapid emergence of private traders, the rate of filling in the gap left by the state has been slow while private participants are constrained with inadequate finance, lack of storage facilities, lack of access to market information, old vehicles and poor transportation infrastructure. The efficient operation of the maize market would therefore need the government providing an enabling environment for trading.

Saran and Gangwar (2008) also used the Engle and Granger cointegration tests to examine the performance of six wholesale egg markets in India from the period 1982 to 2000. The study indicates that the markets under study are cointegrated apparently due to the performance of market intelligence functions by the National Egg Coordination Committee which helps in transmitting price signals through media print on day to day basis throughout India. The high degree of cointegration indicates how efficient and competitive the markets are at the wholesale level. However, whether the farmers and the traders at the grass-root level realize the price changes remains to be examined. In using the recently developed threshold cointegration approach, Van Campenhout (2007) introduces a time trend to the threshold and the adjustment parameter to examine price transmission in the Tanzania maize market using weekly prices from seven markets. The result from this study reveals that the model disregarding transaction cost and time trend has higher half-lives ranging from 3.9 to 22 weeks. Observing the nonlinearities caused by transaction cost, when the half-lives reduced to 4 to 11 weeks, and introducing the time trend to the TAR model reduced the half-lives further to 1.5 to 5 weeks. Also, transaction costs have decreased between the market pairs over time; however, integration of individual routes shows considerable heterogeneity.

Falsafian and Moghaddasi (2008) employs the threshold cointegration approach using weekly price data from 1998 to 2006 to evaluate the patterns of price adjustment in selected spatially separated chicken markets in Iran. Their results confirm different speed of adjustment in response to positive and negative shocks in every case. Thus Qom-Tehran markets suggest much faster adjustment in response to negative shocks than positive shocks while Ghazvin-Tehran markets show much faster speed of adjustment to positive shocks than negative shocks.

In evaluating daily price linkages among four corn and four soybean markets in North Carolina, Goodwin and Piggot (2001) adopts the threshold cointegration and nonlinear impulse response functions to investigate the dynamic adjustments to shocks. Results indicate strong support for market integration even though adjustments may take many days to complete after a price shock. Adjustments are, however, faster in response to deviations from equilibrium when compared to the model that ignores threshold behaviour. Tostao and Brorsen (2005) measure the efficiency of spatial maize price arbitrage in Mozambique's post-reform period using parity bound model. The results indicate that spatial arbitrage between the central and southern Mozambique is efficient in 90-100 percent of the time. However, price spreads between the north and those in central/southern Mozambique fall below transportation costs nearly all of the time. These estimates indicate that it is not worth to ship maize from the northern surplus maize regions to the southern regions. The authors indicate that food shortages and price instability are likely to continue because though market liberalization seems to have helped achieve spatial efficiency, high transfer cost seems to be limiting trade and potential benefits from freeing the markets and hence improvement in transportation networks may help alleviate the costs involved.

Using an extension of the parity bound model which allows for dynamic shift in regime probabilities in response to changes in marketing policy, Negassa and Myers (2007) studied the maize and wheat markets in Ethiopia. Evidence of dynamic adjustment path is found and grain marketing reforms are found to have improved efficiency in some markets and worsened it in others. They attribute the inefficiency to misallocation of resources in the two markets and suggest different policy responses for the two commodities to improve efficiency since maize traders made loses most of the time while wheat traders made excess profit most often.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter deals with the models and procedures employed in carrying out this study. It discusses the basic theory underlying price transmission and market integration analysis. It also presents the empirical model employed in achieving the objectives set out in the study.

3.1 Theoretical Framework

The idea behind the measurement of market integration is to understand the interaction among prices in spatially separated markets. The model of spatial integration predicts that, under competitive conditions, price differences between two markets in the same economic market for a homogeneous commodity will approximately equal the inter-market transportation costs. The study of price transmission often takes its root from what is referred to as the Law of One Price (LOP) which states that a price of a homogenous commodity in one market can differ by at most the costs π_t^{XY} of moving them from location X to location Y. This condition is termed spatial arbitrage condition or the weak form of LOP. If this relationship holds as equality then it is referred to as the strong form of the LOP that is,

$$P_t^Y - P_t^X = \pi^{XY} \qquad 3.1$$

where P_t^Y and P_t^X denotes prices of a homogenous commodity in markets X and Y in time t. In the existence of the strong form of LOP, an equilibrium condition is attained where price differences among markets evolve over time toward the transactions costs π_t^{XY} (Barrett, 2001). This notion is a long run concept; prices can deviate from equality in the short run due to various shocks. When such a disequilibrium situation occurs, price signals will elicit the movement of products between surplus and deficit markets, thus restoring the long run equilibrium.

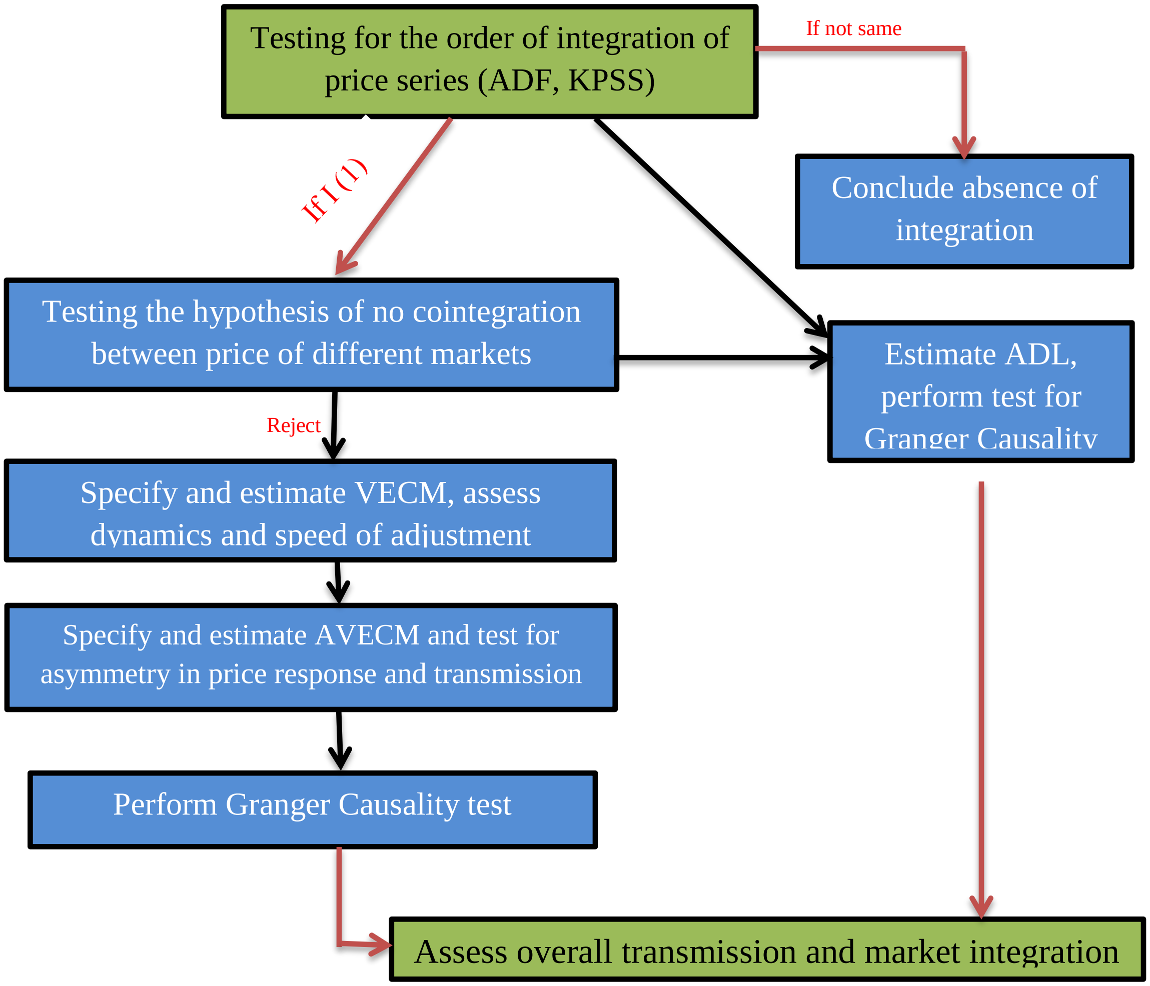
The economic notion of equilibrium can be empirically investigated in the framework of cointegration analysis, where the cointegration relationship is interpreted as long run equilibria. The existence of such a relationship implies a stationary term which is interpreted as the temporal and stochastic deviations from the equilibrium. The central characteristic of such a stationary series is that it frequently crosses its mean value. This property can also be interpreted as a long run tendency toward the mean, that is series does not drift apart from its mean value due to its stationarity (Rico Ihle, 2009). Such behavior closely corresponds to the economic understanding of equilibria, which is in itself a long run concept.

3.2 Empirical framework

The definition of price transmission provided in the chapter two earlier encompasses the case of perfect market integration, the inherent dynamic market relationships that arise due to inertia or discontinuities in trade, as well as non linearities that may arise due to policies and other distortions in arbitrage. More importantly, it implies hypotheses, through its components, that are testable within a cointegration–error correction model framework. A number of time series techniques can be used to test each of the components of price transmission and thus ultimately assess the extent of price transmission and integration between these markets. These procedures are depicted in the figure below.

The first step is to determine whether the individual price series P^S (Producer Prices) and P^C (Consumer Prices) are both non-stationary or integrated or I(1)).

Figure 3.1: Empirical framework for assessing price transmission



Source: Adopted from Rapsomanikis et al. (2003)

The test of stationarity is usually carried out using the ADF (Dickey and Fuller, 1979) and KPSS tests (Kwiatkowski et al., 1992). If the prices are not both I(1), they cannot be cointegrated. If they are both stationary or 'I(0)' they can be studied using Auto Regressive Distributed Lag (ARDL) models. If the series are both I(1), the null hypothesis that they are not cointegrated can be tested using a maximum likelihood procedure developed by Johansen (1988). If the null hypothesis of no cointegration is rejected, the VECM can be estimated, again using methods proposed by Johansen. The

AVECM can then be estimated and Granger causality test will be run based on the VECM.

3.3 Method of Analysis

This section presents the methods used to analyze the data for the study. All the price series were tested for stationarity by using Augmented Dickey-Fuller test and KPSS test as confirmatory test. Johansen Maximum likelihood test was conducted to test for cointegration among the price series pairs. Standard Vector Error Correction Model (SVECM) was used to analyse long-run inter-market response to shocks. In order to test whether price transmission is symmetric or asymmetric, Asymmetric Vector Error Correction Model (AVEM) was used and lastly Granger causality test was run to determine the extent of integration among the respective markets. These methods are discussed below.

3.3.1 Stationarity

A data series is said to be stationery if it has a constant mean and variance. That is the series fluctuates around its mean value within a finite range and does not show any distinct trend over time. In a stationary series, displacement over time does not alter the characteristics of a series in the sense that the probability distribution remains constant over time. A stationary series is thus a series in which the mean, variance and covariance remain constant over time. Hence, it can also be said that a non-stationary series is one in which the mean, variance and covariance changes over time. In a stationary series the mean always has the tendency to return to its mean value and fluctuate around it in a more or less constant range, while a non-stationary series has a changing mean at different points in time and its variance changes with the sample size (Mohammed, 2005). The condition of stationarity can be illustrated by the following

$$P_t = \phi P_{t-1} + \mu_t \tag{3.2}$$

where μ_t is a random walk with mean zero and constant variance. If ϕ <1, the series P_t is stationary and if $\phi = 1$, then the series P_t is non-stationary and is known as random walk. In other words the mean, variance and covariance of a series P_t changes with time or have infinite range. However, P_t can be made stationary by differencing. Differencing can be done multiple times on a series depending on the number of unit roots a series has. If a series becomes stationary after differencing d times, then the series contain d unit roots and hence is integrated at order d denoted as $I(d)$. In equation (3.2), where $\phi = 1$, P_t has a unit root. A stationary series could also exhibit other properties such as when there are different kinds of time trends in the variable. This can be illustrated as in equation (3.3) has a constant term (α) and a time trend (t), this can be rewritten as

$$P_t = \alpha + \beta t + \varphi P_{t-1} + \mu_t \qquad t=1\ldots\ldots\ldots\ldots T \tag{3.3}$$

Equation (3.3) has two types of trends. If $\beta = 0$ and $\phi = 0$, then;

$$P_t = \alpha + \mu_t \tag{3.4}$$

Then in this case P_t follows a stochastic trend which trend upward or downwards depending upon the sign of α. Also if $\beta \neq 0$ and $\phi = 0$ then;

$$P_t = \alpha + \beta t + \mu_t \tag{3.5}$$

And P_t follows a deterministic trend which trend upwards or downwards depending on the sign of β and is a trend stationary series, that is, it may trend but the deviation from this trend are stationary. If $\beta \neq 1$ and $\phi = 0$ then both stochastic and deterministic trends are present. If $\beta \neq 0$ and $\phi \neq 1$ but $\phi < 1$, then the series is stochastically stationary but has deterministic trend. A stochastic trend in (3.4) can only be removed by differencing, since P_t is stationary after first difference as (3.2) indicates and P_t is then referred to as difference stationary series. A deterministic trend can also be removed from the series by regressing P_t on time trend t: the residual from this regression are stationary and represent P_t as a detrended series (Mohammed, 2005).

3.3.2 Testing For Unit Roots

The first step in cointegration analysis is to test the order of integration of the variables. The order of integration is given by the number of times a series needs to be differenced so as to make it stationary. If series are integrated of the same order, a linear relationship between these variables can be estimated and co-integration can be tested by examining the order of integration of this linear relationship. Formally, variables are said to be cointegrated (m, n) if they are integrated of the same order, n and if a linear combination exists between them with an order of integration, $m - n$, which is strictly lower than that of either of the variables (Mackay et al, 1997). The Dickey–Fuller (DF) test (Dickey and Fuller,1981) is the method most widely used for testing the stationarity of time series data. The DF test is based on the estimation of equation (3.2) using OLS where μ_t is assumed to be a random process with mean zero and a constant variance. The process tests the null hypothesis of unit root, that is, $H_O : \phi = 1$ against the alternate hypothesis of stationary, that is, $H_a : \phi < 1$. If H_O is rejected, then P_{t-1} is stationary. There are, however some problems with this method. Firstly, the presence of lagged dependent variable P_{t-1} in the equation makes the OLS estimator ϕ, biased downward to wrong results, that is, accept a hypothesis when it is to be rejected. The second problem is that if $\phi = 1$ (P_t is non stationary), OLS cannot be applied to equation (3.2) because OLS is applicable only to stationary data. When OLS is applied to non-stationary data the property of consistency is violated and the test statistics are not normally distributed, even in large samples. The solutions to these problems are presented by Dickey and Fuller (1981) involved differencing. P_{t-1} is subtracted from both sides of equation (3.2), thus

$$\Delta P_t = \gamma P_{t-1} + \mu_t \qquad 3.6$$

where $\gamma = \phi_{t-1}$, Equation(3.6) is the differenced form of (3.2). Differencing renders the equation stationary hence equation (3.6) can now be estimated using OLS and test the null against the alternative hypothesis, that is $H_O : \gamma = 0$, against $H_a : \phi < 1$. If the null hypothesis is rejected, then P_t is stationary and if the null is not rejected then P_t is non-stationary (Gujarati, 2003). The t-statistic is usually used to test such hypothesis, however, under the unit root hypothesis the distribution of γ is not standard and does not follow the t-distribution, hence the critical values from the t-statistic are not used. Equation (3.6) assumes that P_t is a simple first order autoregressive with mean zero and no deterministic component (constant and trends) and that $t = 0, P_0 = 0$. Under the hypothesis of non-stationarity using a model with no deterministic trends the mean of the series is determined by the initial value, this implies that equation (3.6) is only valid when the overall mean is zero. However, since it is not known whether $P_0 = 0$, a drift or constant is included in the equation, thus

$$\Delta P_t = \alpha_2 + (\varphi_{2-1})P_{t-1} + \mu_t \qquad 3.7$$

The t_μ –statistic is used to test the null hypothesis $Ho: \phi_{2-1} = 0$. The t_μ –statistics are the tabulated estimates of the stationary regression which includes a trend as constant. If the calculated t_μ values (t-value of the coefficient ϕ_{2-1}) is greater than the critical t_μ –value, the unit root hypothesis is accepted and P_t is non-stationary and if the null hypotheses is rejected then P_t is stationary. P_t follows a stochastic trend and drift upwards and downwards depending upon the sign of the constant term if the null hypothesis of unit root is true. Under the alternative hypothesis $Ha: \phi_{2-1} < 0$, P_t is stationary with a constant term and has no trend. It is therefore not appropriate to use equation (3.4) to test for unit root since it does not nest both the null and alternative hypothesis. The form in which the null hypothesis is most practically used is one in which the series both have a stochastic trend against the alternative of trend stationary. A trend is therefore included in equation (3.4) which then becomes

$$P_t = \alpha_3 + \beta_3 t + (\varphi_{3-1})P_{t-1} + \mu_t \qquad 3.7$$

This indicates that the series P_t now has both stochastic and deterministic trends and can be used as a DF–equation to test the unit root hypothesis of $Ho: \phi_{3-1} = 0$. The t–statistics is a descriptive characteristic of a sample and is used with critical values from Dickey & Fuller (1981). The equation (3.7) can be used to test the hypothesis of unit root and no trend, $Ho: \phi_{3-1} = \beta_3 = 0$ against the alternative hypothesis and trend stationary $Ha: \phi_{3-1} = \beta_3 \neq 0$ by using the Ø3 – statistic with critical values from Dickey and Fuler. The DF– statistic is based on the assumption that μ_t is a white noise. If this assumption does not hold, it leads to autocorrelation in the residuals of the OLS regressions and this can make invalid the use of the DF–statistic for testing unit root. There are two approaches to solve this problem (Towsend, 2001). In the first instance the equations to be tested, that are (3.3)–(3.7) can be generalized. Secondly the DF –statistic can be adjusted. The most commonly used in the first approach which is the Augmented Dickey–Fuller (ADF) test. μ_t is made white noise by adding lagged values of the dependent variable to the equations being tested, thus

$$\Delta P_t = (\varphi_{1-1})P_{t-1} + \sum_{i=1}^{k} \varphi_1 P_{t-1} + \mu_t \qquad 3.8$$

$$\Delta P_t = \alpha_2 + (\varphi_{2-1})P_{t-1} + \sum_{i=1}^{k} \varphi_1 \Delta P_{t-1} + \mu_t \qquad 3.9$$

$$\Delta P_t = \alpha_3 + \beta t(\varphi_{3-1})P_{t-1} + \sum_{i=1}^{k} \varphi \Delta P_{t-1} + \mu_t \qquad 3.10$$

The ADF test uses the same critical value with DF. In this study, Augmented Dickey–Fuller (ADF) test was used. JMulti and Eviews softwares were used in the analysis, all the price series were tested for stationarity.

3.3 Cointegration

Cointegration is founded on the principle of identifying a long run relationship between variables. If two data series have a long run equilibrium relationship it implies that divergence from the equilibrium are bounded, that is they move together and are co integrated. Generally for two or more series to be integrated two conditions have to be met. One is that the series must all be integrated to the same order and secondly a linear combination of the variables exist which is integrated to an order lower than that of the individual series. If in a regression the variables become stationary after first differencing, that is I(1), then the error term from the cointegration regression is stationary, I(0) (Hansen and Juselius 1995). If the cointegration regression is presented as

$$\alpha + P_{1t} - \beta P_{2t} = v_t \qquad 3.11$$

where P_{1t} and P_{2t} are both I(1) and the error term is I(0), then the series are cointegrated of order I(1,0) and β measures the equilibrium relationship between the series P_{1t} and P_{2t} and v_t is the deviation from the long-run equilibrium path. An equilibrium relationship between the variables implies that even though P_{1t} and P_{2t} series may have trends or cyclical seasonal variations the movement in one that is matched by movements in the other. The economic interpretation that is accepted is that in the long-run two or more series P_{1t} and P_{2t} themselves are non-stationary, they will move together closely over time and the difference between them is constant , that is stationary (Mohammed, 2005).

3.3.1 Testing for Cointegration

There are two main commonly used methods for testing co integration. The Augmented Dickey – Fuller residual based test by Engle and Granger (1987), and the Johansen Full Information Maximum Likelihood (FIML) test by Johansen and Juselius (1990). This study adopted the Johansen Full Information Maximum Likelihood test due to its advantage. The major disadvantage of the residual based test is that it assumed a single co integrating vector. But if the regression has more than one cointegrating vector this method becomes inappropriate (Johansen and Juselius, 1990). The Johansen method allows all possible cointegrating relationships and allows the number of cointegrating vectors to be determined empirically.

3.3.2 Johansen Approach for Cointegration

The Johansen cointegration test is based on the following vector autoregressive.

$$P_t = A_t P_{t-1} + \ldots\ldots\ldots\ldots + A_k P_{t-k} + \mu_t \qquad 3.12$$

where P_t is an $(nx1)$ vector of I(1) variables (containing both endogenous and exogenous variables), A_t is $((nxn))$ matrix of parameters and μ_t is (n x 1) vector of white noise errors. P_t is assumed to be non-stationary hence equation (3.12) can be rewritten in first difference or error correction form as:

$$\Delta P_t = \pi P_{t-1} + \Gamma_1 \Delta P_{t-1} + \ldots\ldots\ldots\ldots\ldots + \Gamma_{k-1} \Delta P_{t-k+1} + \mu_t \qquad 3.13$$

where $\Gamma_1 = -(1 - A_1 - A_2 \ldots\ldots. A_i), (i = 1, \ldots\ldots\ldots k-1)$ and $\pi = -(1 - A_1 - A_2 - \ldots.. - A_k)$. Γ_1 gives the short run estimates while π gives the long run estimates. Information on the number of cointegrating relationships among variables in P_t is given by the rank of the matrix π. If the rank of the π matrix r, is 0 <r > n, there are r linear combinations of the variables 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. If there variables which are 1(0) and are significant in the long-run cointegrating space but affect the short run model then equation (3.12) can be rewritten as:

$$\Delta P_t = \Gamma_1 \Delta P_{t-1} + \pi P_{t-k} + v D_t + \mu_t \qquad 3.14$$

where D_t represent the I(0) variables. To test for cointegrating vector two Likelihood Ratio (LR) tests are used. The first is the trace test statistic;

$$\Lambda_{trace} = -2 \ln Q = -T \sum_{ir+1}^{p} \ln(1 - \lambda_i) \qquad 3.15$$

This tests the null hypothesis of r cointegrating vectors against the alternative that it is greater than r. The second test is known as the maximal–eigen value test.

$$\Lambda_{\max} = -2\ln(Q : r+1) = -T\ln(1-\lambda_{r+1}) \quad 3.16$$

Which test the null hypothesis of r cointegrating vectors against the alternate that r+1. The trace test shows more robustness to both skewness and excess kurtosis in the residuals than the maximal eigen-value test (Haris, 1995). The error correction formulation in (3.13) includes both the difference and level of the series hence there is no loss of long run relationship between variables which is a characteristic feature of error correction modeling. 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), the Scharz Bayesian Criterion (SBC) and the Hannan-Quin Information Criterion (HQ) was used for the selection. Hall (1991) suggests that the process might be sensitive to lag length, different lag orders should be used starting from an arbitrary high order. The correct order is where a restriction on the lag length is rejected and the results are consistent with theory.

3.4 Vector Error Correction Model (VECM)

The equilibrium relationship between the local (producer) market price series P_t^S and central(consumer) market prices series P_t^C are denoted as $P_t^C - \beta_0 - \beta P_t^S = V_t$. If V_t, the error term is assumed to follow an autoregressive (AR) process, then $V_t = \alpha V_{t-1} + e_t$.Then the above equation can be represented as

$$P_t^C - \beta P_t^S - \beta_0 = \alpha V_{t-1} + e_t \quad 3.17$$

The equation (3.17) implies that the long run relationship or cointegration between P_t^C and P_t^S is a function of the autoregressive process of V_t. In the above linear representation, V_{t-1} represents deviations from equilibrium and is called the error correction term ECT, while α measures the response of P_t^C and P_t^S to deviation from equilibrium following shocks to market equilibrium. The VECM for equation (3.17) was estimated. This form specifies changes in each of the contemporaneous prices, ΔP_t^C and ΔP_t^S as a function of the lagged short-term reaction of both prices, ΔP_{t-k}^C and their deviations from the equilibrium at period V_{t-1} (that is ECT_{t-1}) as follows

$$\Delta P_t^S = \delta_2 + \alpha^S[ECT_{t-1}] + \sum \beta_k^{SC} \Delta P_{t-k}^C + \sum \beta_k^S \Delta P_{t-1}^S + \varepsilon_t^S \qquad 3.18$$

$$\Delta P_t^C = \delta_1 + \alpha^C[ECT_{t-1}] + \sum \beta_k^C \Delta P_{t-k}^C + \sum \beta_k^{CS} \Delta P_{t-1}^C + \varepsilon_t^C \qquad 3.19$$

This can be formulated in vector form as

$$\Delta P_t = \alpha_0 + \alpha_1 ECT_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta P_{t-1} + \varepsilon_t \qquad 3.29$$

where $\Delta P_t = [\Delta P^S \Delta P^C]$ is a vector of first difference of prices in the local (producer) and central (consumer) market respectively. $\varphi_i = 1,....K$, is a KxK matrix of short-run co-efficient which quantify the short-run response of the contemporaneous price differences to their lagged values. They express the short-run reactions of the matrix of prices P_t to random shocks.

The error correction term, ECT_{t-1}, depicts deviations from the long run relationship or 'errors' that are 'corrected' by the price transmission process, is a continuous and linear function of the deviation of P_t from the long-run equilibrium relationship following a shock on P_t^S or P_t^C ; the δ_1 and δ_2 denote long-run inter-market price margins. The coefficient $\alpha_1 = (\alpha^S \alpha^C)$ called the loading or adjustment parameters, are the elasticity of price transmission or the speeds of price adjustment by the net producer and net consumer markets respectively to deviations from long-run equilibrium.

The closer the value of α_1 approaches one; the faster the deviation from equilibrium becomes corrected. The ε_t is assumed to be a white noise process. If P^S and P^C are cointegrated, then α^S and α^C must be negative and positive respectively. If this is the case, then if for example P^S becomes too large relative to P^C then the error correction term must be positive, a decrease in P^S in equation (3.18) of the VECM and an increase P^C in equation(3.18) will drive the prices back towards their long run equilibrium.

The speed of adjustment parameters can be more easily expressed as a half-life, T_{half}, which indicates how long it takes for half of the deviation from long-run equilibrium to be corrected. The half-lifes are computed using the following formular: $T_{half} = In(0.5)/In(1+\alpha)$, where α is the adjustment parameter estimate from the VECM. In all the estimates, since the time of observations are monthly, T_{half} are in months and can be multiplied by 30days to convert the half-life into units of days.

3.5 Asymmetric Vector Error Correction Model (AVECM)

Early empirical analysis of asymmetric price transmission involved the use of variation of a variable splitting technique introduced by Wolffram (1971) and later refined by Houck (1977) and Ward (1982). This technique splits a variable X_t into its positive and negative components such that $X_t^+ = X_t$ for all $X_t > 0$ and 0 otherwise and $X_t^- = X_t$ for all $X_t < 0$ and 0 otherwise. Houck (1977) model has been employed in spatial price transmission analysis in an attempt to account for asymmetric adjustments. In this framework, the response of a price P_1 and to another P_2 is estimated with the following equation:

$$\sum_{t=1}^{T}\Delta P_{1t} = \beta_0 + \beta^{+}\sum_{t=1}^{\tau}\Delta P_{2t}^{+} + \beta^{-}\sum_{t=1}^{\tau}\Delta P_{2t}^{-} + \varepsilon_t \qquad 3.20$$

where ΔP^{-} and ΔP^{+} represent the positive and negative changes in P respectively, $\beta_{0,}\beta^{+} and \beta^{-}$ are co-efficients and T is the current time period. Asymmetry is tested in the model by determining whether $\beta^{-} = \beta^{+}$. Some analyst introduce long-run term in $\sum \Delta P_{2t}^{+}$ and $\sum \Delta P_{2t}^{-}$ to differentiate between short-run and long-run asymmetry. Long run symmetry is tested by determining whether the sum of the co-efficient in these polynomials are equal, while short-run symmetry is tested by establishing whether the polynomials are identical.

Von Cramon–Taubadel and Loy (1996) demonstrated the model is fundamentally incompatible with cointegration between two price series. Granger and Lee(1989) extended the Error Correction Model specification to allow for asymmetric adjustments by applying the split technique described above to the ECT. The resulting Asymmetric Vector Error Correction Model (AVECM) is:

$$\Delta P_{1t} = \alpha_0 + \sum_{i=1}^{n}\phi_1 \Delta P_{1,t-1} + \sum_{i=1}^{n}\phi_2 \Delta P_{2,t-1} + \beta_2^{+} ECT_{t-1}^{+} + \beta_2^{-} ECT_{t-1}^{-} + \varepsilon_t \qquad 3.21$$

$$\Delta P_{2t} = \alpha_1 + \sum_{i=1}^{n}\phi_1 \Delta P_{1,t-1} + \sum_{i=1}^{n}\phi_2 \Delta P_{2,t-1} + \beta_2^{+} ECT_{t-1}^{+} + \beta_2^{-} ECT_{t-1}^{-} + \varepsilon_t \qquad 3.22$$

Where $\varepsilon_t ....N(0,\sigma^2)$. Since $ECT_t^{+} + ECT_t^{-} = ECT_t$, the standard symmetric VECM is nested in the AVECM and the F-test to test the null hypothesis of symmetry

$Ho:\beta_2^+ = \beta_2^-$. If this is rejected then price transmission process among the market is asymmetric.

This extended model of AVECM was used for this study and in this case the variables being modelled are prices at different markets that are spatially related which imply that a positive (negative) ECT indicates that the marketing margin is above (below) its long run equilibrium. The suspicion expressed by farmers that producer price increases are passed on faster than producer price decreases would then be equivalent to the testable hypothesis that positive ECT values are corrected more rapidly than negative ECT values.

3.6 Granger Causality Test

Granger (1969) causality test provides evidence of whether price transmission is occurring between markets and in which direction. The existence of cointegration between P_t^S and P_t^C implies Granger causality. Furthermore, since cointegration between variables does not automatically imply causality between them, the evidence of causality between the variables must be provided by Granger causality analysis. P_t^S is said to granger–causes P_t^C, if both current and lagged values of P_t^S improves the accuracy of forecasting P_t^C (Judge et al 1998). The Granger causality models applied in this study are specified in the equations below.

$$P_t^s = \sum_{k=1}^{n} a_k P_{t-1}^C + \sum_{k=1}^{n} b_k P_{t-1}^S + \varepsilon_{1t} \qquad 3.23$$

$$P_t^c = \sum_{k=1}^{n} c_k P_{t-1}^s + \sum_{k=1}^{m} d_k P_{t-1}^c + \varepsilon_{2t} \qquad 3.24$$

where P_t^S refers Local/producer/supplier markets in this case Techiman in the Brong Ahafo Region while P_t^C refers to the central(consumer) markets in this case Accra, Tamale and Bolga. The equations (3.23-3.24) postulate that P_t^S is dependent on P_{t-1}^S and P_{t-1}^C; while P_t^C is also dependent on P_{t-1}^S and P_{t-1}^C. The ε_{1t} and ε_{2t} are uncorrelated error terms. Rejection of the null hypothesis by a suitable F-test indicates that prices in market P_t^S Granger-cause prices in market P_t^C which implies that past values of the series on the right hand side are adding information on the actual values of the series on the left hand side, in addition to what is provided by its own past values. If prices in P_t^C also Granger-cause prices in P_t^S, then, prices are said to be determined by a Simultaneous Feed Back Mechanism (SFM). This is the phenomenon of bi-directional causality. If the Granger-causality runs one way, it is called unidirectional Granger-causality and the market which Granger-causes the other is tagged the exogenous market. Exogeneity can be weak or strong. Weak exogeneity occurs when the marginal distribution of P_{t-1}^S is independent of the joint distribution of both P_{t-1}^S and P_{t-1}^C. Strong exogeneity occurs when there is no significant Granger-causality from the other variable (Hendry, 1986; Juselius, 2006).

This test is significant in the sense that it is used as a confirmation of the test for the long run equilibrium between two price series as well as to understand which of the two prices acts as a source of information for the other. In addition, it enables us gain qualitative elements to understand the results, in terms of the causality direction and the extent of market integration. The variant of the Granger causality tests run in this study is based on the Vector Error Correction Model (VECM). In this study, there was a test of the evidence of Granger-causality between pairs of maize markets that are co-integrated.

3.7 Study Area and Data Source

Four maize markets namely Accra, Bolga, Tamale and Techiman were selected for the study. The locations are selected based on the availability of data, geographical location of markets, levels of production and consumption of the produce. These markets are located in Greater Accra Region, Upper East Region, Northern Region and Brong Ahafo Region, respectively. Among the Regions, production of maize is concentrated in the Brong-Ahafo region which has Techiman as the most important market in Ghana for the assembly of food commodities while consumption is concentrated in the Greater Accra region. Hence, Techiman is taken as the central/reference market along which other markets are compared.

Figure 3.2: Map of Ghana Showing the Four Analysed Market Locations

Source: Nations Online Project (http://www.nationsonline.org/).

The study employed monthly real wholesale prices of maize constituting 225 observations from January 1995 to September 2013. The price data was obtained from the Statistics, Research and Information Directorate of the Ministry of Food and Agriculture (SRID-MOFA).

The price units of the data collected from MoFA-SRID were per 100kg of white maize. Prices prior to July 2007 were in old Cedi (₵) currency values which were converted to the New Ghana Cedi (GH₵) by dividing by 10,000. Prices at this level can be interpreted as GH₵/100kg or pesewas/kg (pesewa is the smallest unit of the Ghana currency). Empirical econometric analysis of the data was based on logarithmic transformation of prices for ease of interpretation of parameters (in terms of percentages or as elasticities) and the possibility of reducing the problem of heteroscedasticity. Ghana experienced high rates of inflation during the 1990s and first half of the 2000s, hence the price series were deflated, with 2012 as the base year, using consumer price indices for food (CPIs) published by the Ghana Statistical Services(GSS).

CHARPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

Discussion of the results emanating from the study is presented in this chapter. The discussion on the variability and movement of wholesale maize prices is presented in section 4.1. The stationarity analysis of the time series wholesale price data and the test of cointegration are discussed in section 4.2. Section 4.3 present discussions on the short-run and long-run dynamic interrelationship between the maize market pairs. The results of asymmetry in price transmission between the maize market pairs are discussed in section 4.4. In section 4.5 is discussions on results of Granger causality test.

4.1 Descriptive Analysis Of maize Markets

Agricultural prices in different markets are often influenced by fluctuations in yield, production, seasonality, condition of infrastructure and government policy coherence. In addition the behaviour of consumers and other market participants affect other agents and the resulting dynamic process leads to determination of prices at different point in time. Hence, it is relevant to understand the nature of variability in prices over time and space and factors leading to these prior to analyzing the price linkages. Table 4.1 shows summary statistics of real wholesale maize prices in the study areas.

4.1.1 Average Wholesale Price

Across the markets, the highest real wholesale price was observed in **Accra** market with a maximum of GH₵118/100Kg while the minimum was observed in **Techiman** market with GH10.8 /100Kg. The highest average wholesale price was, however. observed in

Accra at GH₵ 31.90 /100Kg while the lowest average wholesale price was GH₵22.86/ 100kg observed in the **Bolgatanga** market.

Table 4.1 Descriptive statistics of monthly real wholesale maize prices (1995-2013)

	Accra	Techiman	Tamale	Bolgatanga
Mean	31.901	25.776	23.394	22.860
Standard Deviation	28.951	23.546	20.598	19.101
Minimum	21.00	10.80	15.00	18.00
Maximum	118.500	90.500	75.750	73.750
Coefficient of Variation	90.75	91.35	88.05	83.56
Observations	225	225	225	225

Source: Own computation from price data

Notes: Coefficient of Variation (CV) is computed as $CV = \sigma / \bar{X} * 100$ where σ is the standard deviation: and $\bar{x}$, the mean.

It seems that there are other factors that are equally important in comparison to the volume of production in price determination. Whenever high production quantity does not exert a depressing effect on price of a given product, as established in traditional economic theory, then one can suspect that arbitrage in that commodity between product-surplus and product-deficient areas of the country continuously take place (Mafimisebi, 2012). This is the situation in Ghana where maize distributors from Southern Ghana especially traders from Makola in Accra go to the high production centres in the middle belt mostly Techiman and to some extent Tamale in the North to purchase and assemble maize for onward transportation to sell in the Southern markets. Such continuous arbitraging even-out supplies between high-production and low-production areas of the country thereby preventing glut in the high production areas which could occasion a price fall and preventing deficits in the low production-high consumption areas resulting in price hikes. This however may not necessarily lead to law of one price to hold or otherwise.

4.1.2 Variability in Average Wholesale Prices

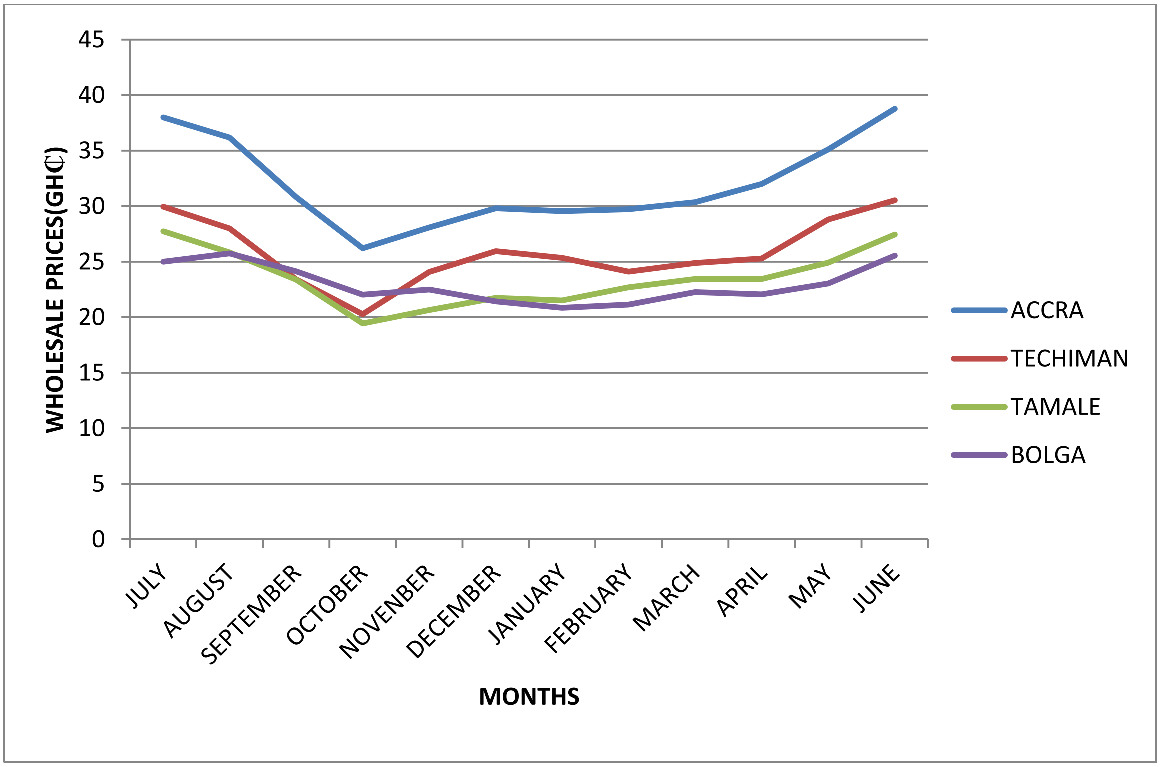
Variability in Average Wholesale Prices (VAWP) was quite high for the period (1995-2013) covered by the study. It fluctuated between 83.4% for Bolgatanga to 91.35% for Techiman. The average variability was 88.42% (Table 4.1). The variations in prices were, however, close to each other. The implication of the high variability index is that the price of maize fluctuates widely across seasons in all markets analyzed. High price variability translates into unstable producer incomes which is capable of exerting a deleterious effect on production and production planning (Olayemi, 1973; Mafimisebi, 2001). The impact of poor production planning is expected to be harmful on consumers' welfare especially in a country such as Ghana where poverty is very pervasive currently about 28.5% (Ghana Statistical Service, 2006) and food expenditures constitute a large proportion of households' disposable income.

4.1.3 Monthly Trend and Seasonal Variation among Maize Markets

The wholesale prices vary periodically and portray trends and cycles or seasonal patterns depicted graphically in Figure 4.1. As observed in Figure 4.1 these prices generally followed the same pattern (i.e., move in the same direction) and increases over time. It shows monthly wholesale prices, starting from July to June of the following year. This shows that prices generally decline rapidly in the four months after the new crop harvest which comes in July for the southern sector of the Ghana. That these declines occur at the end of the major crop season is indicative of the need for effective storage system. Such storage facilities would help farmers to control the release of their harvest and in so doing moderate the price decline which in the long run helps manage producer incomes.

As depicted in Figure 4.1, once the excess output occurring at harvest has been taken off, the market prices begin to rise steadily throughout the rest of the year. Between September and October each year maize prices experience a drastic decrease in price with respect to the markets under study.

Figure 4.1: Seasonal Trends in Maize Prices



Source: Own computation from price data

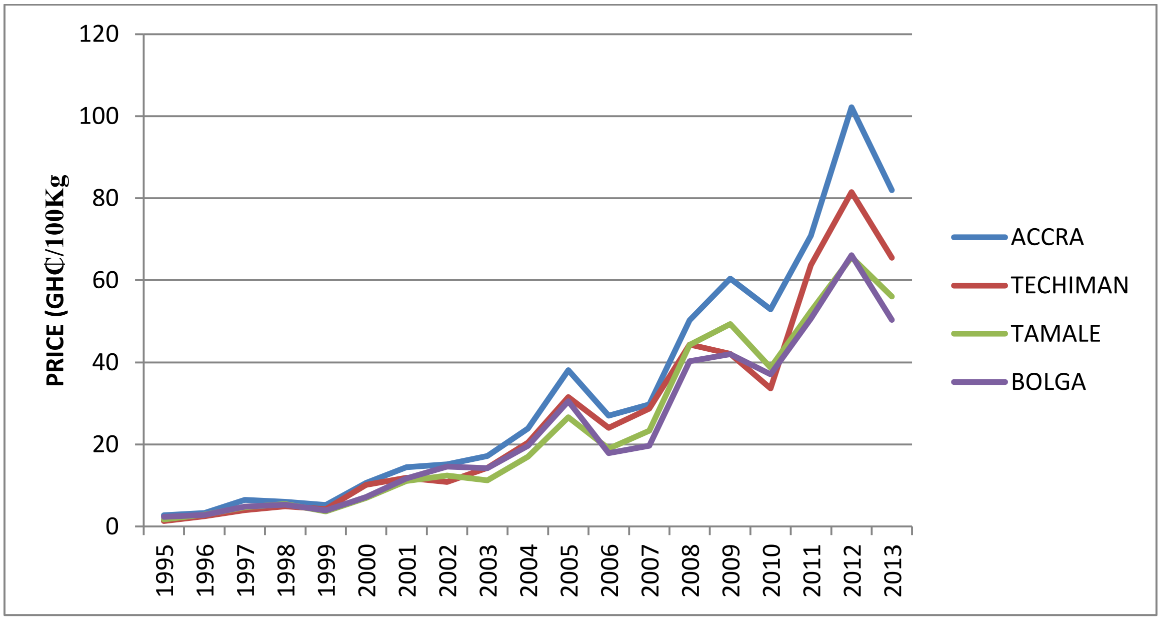
Accra records 17.4% and 17.5% decline in maize price in September and October respectively, 19.6% and 15.5% for Techiman, 10.5% and 20.23% for Tamale and 6.7% and 9.5% for Bolgatanga. Also shown in the figure 4.1, a good minor crop harvest in the northern sector which comes in November and December could lead to some price depression in the subsequent month January as seen in 0.8%, 2.4%, 1.0% and 2.7%

decline in Accra, Techiman, Tamale and Bolgatanga prices respectively. If these price changes are indicative of major and minor season crop output situation, then the results are consistent with the major and minor cropping season in the country.

4.1.4 Annual Trend and Variation in Maize Markets

Figure 4.2 shows annual price trend for maize with respect to markets under study. It shows an upward shift in the mean crop year price over time. Prices peaked in 2005, 2008 and 2012 periods with highest price generally occurring in the **Accra** market which was not surprising given the fact that demand is highest in this location. According to National Population and Housing Census (2010), Greater Accra Region has a population of 4,010,054 people and yet produces only 4,681Mt of maize which is 0.24% of the total maize produced in Ghana. Given that maize is a staple food in Ghana, clearly demand for the commodity will outweigh supply leading to high prices in the Region. **Techiman** and **Tamale** wholesale market prices were generally the lowest over time compared to the other markets under study. This is possibly due to high production of the crop in the two Regions; Brong Ahafo and Northern Region produces 29.7% and 10.3% constituting 40% of total maize produce in Ghana (SRID, 2012). While this producing areas are net exporters of maize.

Figure 4.2: Annual Trend in Nominal Maize Prices (1995-2013)



Source: own computation from price data

In 2005, Accra, Techiman, Tamale and Bolgatanga records 37%, 35%, 36% and 36% growth rate in prices respectively. While prices decreased gain in between 2006 and 2007, in 2008 prices increased again by 41%, 35% ,47% and 51% for Accra, Techiman, Tamale and Bolga respectively. The high prices were due to combination of factors that changes supply and demand. Supply factors are adverse weather conditions, higher fuel prices and high cost of fertilizer prompting the Government of Ghana to reintroduce fertilizer subsidy programme in 2008. The demand factors include continuous population growth, income growth, increasing demand for maize for bio-fuel use in the world market and other speculative factors that drive prices more than basic supply and demand factors would have dictated.

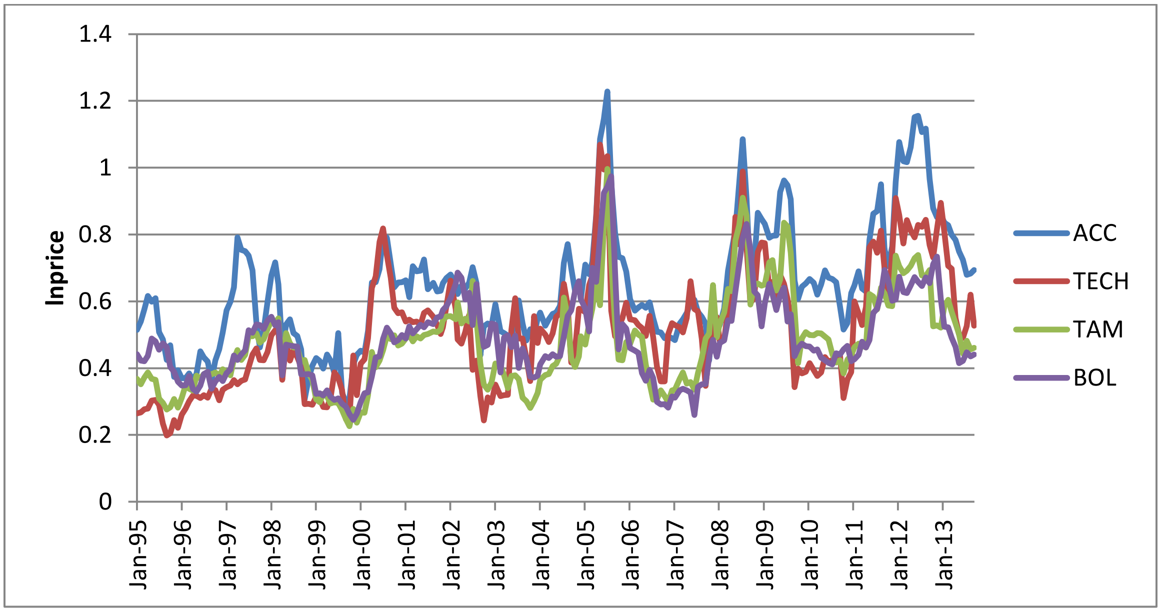
Maize prices generally decrease again between 2009 to 2010 and began to rise in 2011 until it reached its highest in 2012 with growth rates of 31%, 22%, 20% and 23% for

Accra, Techiman, Tamale and Bolgatanga respectively. After such astronomical price increases in 2012, it began to drop again in 2013. The price volatility, due mainly to rapid changes in supply and demand levels, irratic rainfall and high cost of transportation, implies a major source of price and income risks, and uncertainty for maize farmers and traders. Instability in food prices is a serious problem affecting food security. Food price fluctuations directly affect the well being of the poor who spend a high proportion of their income on food. In general, lower food prices benefit consumers and stimulate economic growth but can lower producer (farmers) income and reduce the employment of landless workers, if such low prices do not reflect lower cost of production and or improved productivity.

4.2 Unit Root Test Results

The hypothesis of unit roots in the levels and first differences of each price series was tested using the ADF and KPSS tests. Visually examining the graphical plot of the series in Figure 4.3 reveals the unlikelihood of a non-zero expected mean in the levels of the series and justifies the inclusion of a constant in the equations used for the unit root tests.
No obvious, persistent trending behaviour is, however, observed in the graphical plot, prompting the omission of a deterministic trend in both tests for unit root and in the Johansen's cointegration model.

Figure 4.3 Monthly Wholesale Real Prices of Maize in Ghana (2012 as Base)



Source: Own computation from price data from Ghanaian Ministry of Food and Agriculture. Notes: *Natural logarithms of deflated wholesale maize prices in GH₵/100Kg (deflated using the national consumer price index, with 2012 =100).

The chosen lag lengths in both tests are based on the Hannan-Quinn criterion (HIC), Akaike Information Criteria (AIC) and Schwarz Bayesian Criterion (SBC). The JMulti software was used for both the cointegration and unit root analysis. The results of the unit root tests are presented in Table 4.2. The results of the ADF test, considering the suggested lag lengths, show that at the 1%, 5% and 10% critical values of -2.56 and -1.94 and -1.62, the null hypothesis of unit root, $H_o : \rho = 0$ that is the price series is non-stationary, cannot be rejected for all four price series. As expected, the null hypothesis is rejected after taking a first difference of all series and testing for stationarity.

The KPSS results confirm those of the ADF test; by these, the null hypothesis of no unit roots (that is the series is stationary) in the level of the price series at the 1% and 5% significance levels is strongly rejected, but cannot reject the null hypothesis at the first difference of the price series. Therefore, the price series under study are a first-difference stationary process which implies that they have unit root or are I(1).

Table 4.2: Results of ADF and KPSS Unit Root Tests on the Monthly Price Series

Price Series	ADF		KPSS		Lags	Observation
	Levels	First Diff.	Levels	First Diff.		
Accra	-1.5522	-9.725***	2.9678***	0.0188	2	225
Techiman	-1.6568	-10.514***	3.1257***	0.0299	2	225
Tamale	-1.1149	-9.718***	2.3446***	0.0262	2	225
Bolga	-0.8892	-7.986***	1.0804***	0.0340	2	225

Source: Own computation from maize wholesale price data for 1995-2013

The implication of this finding is that all the price series were generated by similar stochastic processes and can exhibit the tendency toward long-run equilibrium. This result is well supported by earlier findings that food commodity price series are mostly stationary after first-differencing in Ghana and elsewhere (Alexander & Wyeth, 1994; Ogundare, 1999) perhaps owing to the possession by such series of trends arising from price inflation and cyclical variations from season leading to mean non-stationarity.

4.3 Cointegration Test Results

With the proof that the price series is non-stationary, the next step in the process of analysis is to determine the existence or otherwise of cointegration between net producer/net consumer markets pairs using Johansen's maximum likelihood VAR approach (Johansen and Juselius, 1990). The results of the cointegration test between the market pairs are presented in Table 4.3. The results provide evidence in favour of cointegration between the five maize market pairs under study. The null hypothesis of r = 0, implying an absence of a cointegration relation is rejected for all the market pairs at both the 1% and 5% significance levels. However, the null hypothesis of one cointegration relation, that is r = 1 between pairs of net producer/net consumer markets cannot be rejected. Therefore, there exists at least one stationary cointegration relation (r = 1) between the pairs of net producer and net consumer price series measured monthly, and by implication among the system of markets considered.

Table 4.3 Johansen's Cointegration Test Statistics

Market Pairs	Test Statistic		Lags	Observ.	Conclusion
	Ho: r =0	Ho: r = 1			
Techiman-Accra	37.71**	14.03	2	225	Cointegrated
Techiman-Tamale	33.75**	12.06	2	225	Cointegrated
Techiman-Bolga	31.84**	8.91	2	225	Cointegrated
Tamale-Bolga	37.39**	8.61	2	225	Cointegrated
Tamale-Accra	36.14**	10.45	2	225	Cointegrated

Source: Own computation from maize wholesale price data for 1995-2013.

The asterisks ***, ** and * denote rejection of the null hypothesis of no cointegration vector at the1%, 5% and 10% levels respectively. The critical values for r = 0 and r = 1 at the 1%, 5% and 10% significance levels are 24.69, 20.16 and 17.98 and 12.53, 9.14 and 7.60 respectively.

The findings imply that similar stochastic processes, possibly induced by efficient information flow, drive the dynamics of prices in the system of markets (Motamed et al. 2008). In this way, maize prices in the producer and consumer markets do not drift apart in the long run. The proof of cointegration is also evidence for a common domestic maize market in Ghana, where inter-market prices adjust to achieve long-run, market equilibrium.

Since a good quality, trunk road connects the system of markets under study, concluding that a common domestic maize marketing system exists in Ghana as a whole may be delusive for all cases. It is likely that cointegration may be lacking between net producer and consumer markets that are poorly connected by road, rail or water transport. The evidence of at least one cointegrating relation between the market pairs however provides an ideal setting for use of Vector Error Correction Model techniques to analyze the nature of price transmission and market integration between the markets.

4.4 Vector Error Correction Model Estimates

The evidence of significant cointegrating vectors between the net producer and net consumer maize market pairs is a necessary condition for using the VECM to determine the effects of price shocks on price adjustment.

4.4.1 Price Transmission between Maize Markets in Ghana

The results of the econometric estimation of the VECM for the net producer and consumer market pairs are presented in Table 4.4. The speeds or magnitudes of price transmission, which measures the response of price shock by producer markets show varying degrees of price relationships. Both the coefficient of net producer and net consumer markets are significant and show the expected signs of negative and positive respectively. In Techiman-Accra market pair, following a shock that creates disequilibrium, Techiman adjusts by 5.8% and Accra by 13.3% to ensure equilibrium while it will take 12 months for such shocks in Techiman to be corrected and it will take Accra 5 months. Also in Techiman-Tamale pair the speed of adjustment are 4.1% and 12% for any shock that cause disequilibrium to Techiman and Tamale markets respectively. While it will take 17 months for Techiman to correct such shocks, Tamale will take 6 months to ensure equilibrium. In Techiman-Bolgatanga market pairs, following a shock that creates disequilibrium, Techiman adjust by 7.4% and Bolgatanga by 9.1% to ensure equilibrium. The half life for the adjustment is 9 months for Techiman and 7 months for Bolgatanga. In Tamale-Bolgatanga pairs there seems to be rather faster speed of adjustment that will correct any shock that will cause disequilibrium and this might be due to shorter distance between these markets. The speed of adjustment are 12.9% and 15% respectively while it will take just 5months for Tamale to return to equilibrium Bolgatanga will take 4 months. Lastly in Tamale-Accra pair following a shock, Tamale will adjust by 11% and Accra by 13% to ensure equilibrium while it will take 6 months for Tamale to correct such disequilibrium, it will take Accra 5 months.

Averagely, 8.2% of any disequilibrium will be corrected within a month by the net producer markets, while 12.4% of such shocks will be corrected within a month by Consumer markets. This signifies a 4.2% difference in the rate of price transmission between the producer and consumer markets and hence in the level of spatial integration of the maize markets. The net producer markets will return to equilibrium in 10 months' time while net consumer markets will return to equilibrium by 5 months after a shock. This however means that shocks are more quickly corrected by consumer market than those of producer markets.

Table 4.4: Results of the Standard Vector Error Correction Model (VECM)

Market Pairs	α^s	λ^s	α^c	λ^c
Techiman-Accra	-0.066**	10.2	0.140**	4.5
Techiman-Tamale	-0.041**	15.1	0.117**	5.5
Techiman-Bolga	-0.076**	8.8	0.091**	7.2
Tamale-Bolga	-0.129**	5.0	0.150**	4.3
Tamale-Accra	-0.110**	5.9	0.132**	4.9
Average	**-0.082**	**9.61**	**0.124**	**5.4**

The half-lives λ^s and λ^c of the adjustment parameters α^s and α^c measure in months, the time taken for one-half of the deviation from equilibrium to be eliminated. A month equals 30 days. Significant adjustments at the 5% is denoted by **.

The above findings also imply that, despite the significant improvement in road and transport infrastructure, market infrastructure as well as information technology, leading to decline in transaction costs in the distribution level of maize supply chain especially between the specific markets under study. Other opportunities for efficient transmission of maize price signals between producer and consumer markets deteriorated over time or may not have improved alongside those factors. The near-oligopolistic behaviour of wholesalers, seasonality, bad road network from producer communities to market centers, unstable macroeconomic environment such as inflation, high interest rates and currency depreciation, restricted access to commercial finance and risks to trade may jointly undermine the potential of the improved infrastructure in boosting price transmission and the market competitiveness of maize produced. According to Barret (2005), without good access to distant markets that can absorb excess local supply, firms' adoption of improved production technologies will tend to cause producer prices to drop, erasing the gains from technological change and thereby dampening incentives for farmers to adopt new technologies that can stimulate economic growth. Clearly, poorly integrated markets can choke off the prospective gains from technological change such as adoption of new high yielding maize varieties.

4.5 Asymmetry Vector Error Correction Model Estimates

The evidence of asymmetry in price transmission between the producer markets and consumer markets in maize markets under study are estimated using the Asymmetry Vector Error Correction Model and the results are presented in Table 4.5. Positive shocks are events that suddenly increase the price of maize in the local/ central markets while negative shocks are events that decreases the price of maize in the markets (both local and central markets). The results show that in all the markets studied there is a faster adjustment to positive shock than negative shocks implying positive asymmetry.

In Techiman-Accra market pair, following a positive shock that creates disequilibrium, 25.7% of such shocks will be eliminated within a month and it will take only 2.3 months for the system to return to equilibrium while in the events of negative shock (price decreases) that leads to disequilibrium, only 0.9% of such deviations will be corrected within a month leaving 91.1% of the deviation to be corrected in subsequent months which means that it will take 77 months for such deviations to be eliminated.

Similarly, in Techiman-Tamale market pair, positive shocks(price increase) that leads to disequilibrium 16% of such deviation will be eliminated within a months and it will take 4 months to reestablish equilibrium while in the events of negative shock, 0.9% of such deviation will be corrected within a month and it will take 77 months to return to equilibrium.

Table 4.5 Results of Asymmetry Vector Error Correction Model

TECHIMAN- ACCRA			**TECHIMAN-TAMALE**			**TECHIMAN-BOLGA**			**TAMALE- BOLGA**			**TAMALE-ACCRA**		
Var.	Coef.	t-stat	Var.	Coef	t-stat.	Vari	Coef.	t-stat	Var	Coef.	t-stat	Var	Coef.	t-stat
C	0.012	1.21	C	0.009	0.85	C	0.014	1.55	C	0.013	2.14	C	0.4	1.24
$\Delta Tech_{t-1}$	0.027	0.29	$\Delta Tech_{t-1}$	0.085	1.03	$\Delta Tech_{t-1}$	0.118	1.57	ΔTam_{t-1}	0.099	1.28	ΔTam_{t-1}	-0.12	-1.33
$\Delta Tech_{t-2}$	0.059	0.66	$\Delta Tech_{t-2}$	0.094	1.15	$\Delta Tech_{t-2}$	0.016	0.21	ΔTam_{t-2}	-0.106	-1.39	ΔTam_{t-1}	-0.15	-1.81
ΔACC_{t-1}	0.125	1.30	ΔTam_{t-1}	-0.137	-1.34	ΔBol_{t-1}	-0.198	-1.84	ΔBol_{t-1}	0.148	1.67	ΔACC_{t-1}	0.42	5.56*
ΔACC_{t-2}	-0.23	-2.62	ΔTam_{t-2}	-0.265	-2.73	ΔBol_{t-2}	-0.103	-0.99	ΔBol_{t-2}	-0.080	-0.99	ΔACC_{t-1}	-0.09	-1.26
ECT^{+}_{t-1}	-0.26	**-1.87***	ECT^{+}_{t-1}	-0.160	-1.73*	ECT^{+}_{t-1}	-0.245	**-2.93****	ECT^{+}_{t-1}	-0.37	**-3.9****	ECT^{+}_{t-1}	-0.15	**-1.66****
ECT^{-}_{t-1}	-0.01	0.08	ECT^{-}_{t-1}	-0.01	-0.10	ECT^{-}_{t-1}	0.004	0.05	ECT^{-}_{t-1}	-0.047	0.47	ECT^{-}_{t-1}	0.012	0.104
Tests for asymmetry			**Tests for asymmetry**			**Tests for asymmetry**			**Tests for asymmetry**			**Tests for asymmetry**		
F-test	Prob.		F-test	Prob.		F-test	Prob.		F-test	Prob.		F-test	Prob.	
1.674	0.197		0.782	0.378		3.11**	0.079		7.43**	0.00		0.929	0.336	
Wald t			Wald t			Wald t			Wald t			Wald t		
-0.265	0.205		-0.151	0.170		-0.249	0.141		-0.42	0.154		-0.157	0.163	

Source: Own computation from maize wholesale price data (1995-2013)

ECT^{+}_{t-1} and ECT^{-}_{t-1} measures adjustment to positive shocks and negative shocks respectively. Positive shocks are events that increase price of maize in the local and central markets while negative shocks are events that decrease the price of maize in the central and local markets. Wald test was conducted to test the existence of asymmetry.

Also Techiman-Bolgatanga market pairs exhibited the same correction mechanism with respect to positive and negative shock. In events of positive shock, 24.5% of such deviation will be corrected within a month while it will take 2.5months to return to equilibrium. On the other hand only 0.4% of deviation due to negative shock will be eliminated within a 174 months. This is an obvious case that in events of maize price reduction it takes several months or years for such signal to be transmitted to consumer markets while maize prices increases are transmitted faster to consumers.

The result shown in Table 4.5, revealed the same pattern of adjustment to shock by the remaining market pairs. In Tamale-Accra market price pairs, following a deviation due to positive shock, 37.3% of such disequilibrium will be corrected within a month and it will take just 1.5 months for the deviation to return to equilibrium. While only 4.7% of deviation due to negative shock will be eliminated within a month and will take 14 months for the deviation to return to equilibrium. For the remaining pair, a positive shock to Tamale-Accra markets, 15% of deviation will be corrected within a month and the remaining 85% will be corrected in subsequent months and it takes 4.3 months for the deviation to return to equilibrium, while only 1.2% of deviation due to negative shocks will be corrected in a month and it will take almost 57 months for such shocks to return to equilibrium.

However, a statistical test of asymmetry indicates that only two out of the five market pairs exhibit asymmetry in price transmission between the producer and consumer markets pairs, these are Tamale-Bolgatanga and Techiman-Bolgatanga. The implication of the findings are that price increases in the producer markets are transmitted faster to consumer markets and not vice versa. This observation from the analysis confirmed the assertion of farmers that producer price increases are passed on faster to consumers than producer price decreases. The results also show that most of the short run coefficients are not significant at conventional levels.

The causes of asymmetry in price transmission between the producer and the consumer market pairs depend on the characteristics of the maize market. However, considering the abilities of traders and their associations to influence the conduct of the market by determining how much to release into the market (Langyintuo, 2010), inventory management and stock behaviour potentially stands as a motivating cause of asymmetry. Moreover, Abdulai (2000) rules out menu cost since price determination is through private negotiation between traders and consumers. Also, the government has not been involved in trading and pricing maize. Even though the recent establishment of National Food Buffer Stock Company (NAFCO) was meant to stabilize food grain supply and price by buying excess maize in the market and stored for onward release into the market, one wonders to what extent this function has been performed given the recent rising trend in the price of maize in the market. Hence government intervention might not be a major factor causing asymmetry in price transmission.

In recent years there has been influx of telecommunication companies in Ghana. Because of this there is high penetration rate of mobile communication in most parts of the country, information flow is easier and quicker making search cost and information asymmetry a minimal option in causing asymmetry in price transmission in Ghana.

4.6 Causality and Exogeneity in Maize Market Price Series

Having identified markets that are linked within a network of markets, it is also useful for policy purposes to isolate the market(s) that play(s) leadership position(s) in the formation and transmission of prices. It has been established in the literature that such leader markets exists in any network of market for a homogeneous commodity integrated of the same order and having no tendency to diverge in the long-run. In this study, ten (10) markets pairs were investigated for evidence of price causation and exogeneity, and the result of the test is shown in Table 4.6.

Table 4.6: Result of Granger-causality Test for Maize Markets (1995-2013)

Null hypothesis	Granger causality		Instantaneous causality		Results
	F-stat	P-val	F-stat	P-val	
Techiman-Accra	5.611	0.0009	43.00	0.000	
Accra-Techiman	4.1729	0.0063	43.00	0.000	Bidirectional
Techiman-Tamale	8.2687	0.0003	38.57	0.000	
Tamale-Techiman	0.2910	0.7477	38.57	0.000	Unidirectional
Techiman-Bolga	8.044	0.004	16.20	0.001	
Bolga-Techiman	1.7481	0.1754	16.20	0.0001	Unidirectional
Tamale-Bolga	11.988	0.000	28.99	0.000	
Bolga-Tamale	1.7698	0.1716	28.99	0.000	Unidirectional
Tamale-Accra	4.08	0.0175	44.87	0.000	
Accra-Tamale	3.003	0.00507	44.87	0.000	Bidirectional

Source: Compiled from Result of Granger-Causality Test

As shown in Table 4.6, Four (4) markets are linked, Techiman-Accra, Accra-Techiman, Tamale-Accra, Accra-Tamale and exhibited bi-directional (two-way) causality. While Techiman Granger-caused Accra at 1% in the first market link, Accra Granger-caused Techiman at 5% in the second market link. Thus, Techiman proved stronger than Accra in the first two market links. In the third and fourth market links, Tamale and Accra also exhibited exogeneity at the same level of significance (5%). The bidirectional causality between these markets means that the markets are strongly integrated with each other, experiencing physical arbitrage to settle any disequilibrium between the markets.

The remaining six (6) market links showed uni-directional (one way) Granger-causality in which there is no significant causality from the other market (Hendry, 1986). As reported in Fackler (1996), Gupa and Mueller (1982) argue that the failure of one price to be predictive of another when the second is predictive of the first (unidirectional causality) is an indication that the second price is not incorporating the price information from the first region. Unidirectional causality is therefore taken to indicate that a market is informationally inefficient. Also according to Borsen et al. (1985), Supply and demand fluctuations in a location with large volume of commodity represent a large shift in aggregate demand and supply. Thus these locations are expected to have a large influence on prices in other locations. Considering the market pairs that exhibit unidirectional causality, Techiman-Tamale, Techiman-Bolgatanga and Tamale-Bolgatanga, it is expected that the trade volumes in Techiman should be larger than that of Tamale and Bolgatanga in terms of demand and supply of maize. Hence leading to Techiman prices Granger causing Tamale and Bolgatanga prices and not vice versa. The same is the reasons explains why Tamale prices also Granger caused Bolgatanga prices but not the other way round.

Thus, the markets occupying leadership position in maize pricing are Techiman, Accra and Tamale. Techiman showed very strong exogeneity, Tamale exhibited strong exogeneity, while Accra is only weakly exogenous in price formation and transmission. The implication of exogeneity from these markets is that the lagged or historical prices in these leader markets yield a better prediction of changes in contemporaneous prices in the others, provided the lagged prices in the follower markets have been accounted for. In other words, it means that the error variance of forecasting prices in the follower markets will reduce by using past values of prices in the leader markets. The fact that Techiman and Tamale markets are in the central and northern part of Ghana are strong sources of stochastic trends influencing the market for maize in Ghana. This indicates that these markets play dominant roles in marketing of maize and this is probably in consonance with the high maize production capacities of their respective Regions. Brong Ahafo Region and Northen Region produce 30% and 10.4% of total maize produce in Ghana. Hence they constitute a huge market that influences the price of maize in Ghana.

Accra is located in southern part of Ghana, which is mainly maize consuming areas and are sources of causation in maize prices. This is an indication that supply forces far exceed demand in driving the market (Mafimisebi, 2007). The maize market in Ghana thus exhibit near oligopolistic structure with the tendency of exhibiting characteristics of an imperfect market where the cross-sectional aggregation of demand and supply loses its foundation.

CHAPTER FIVE

SUMMARY, CONCLUSSIONS AND RECOMMENDATIONS

5.0 Introduction

The study is summarised in this chapter. Conclusions based on the research results are also presented in this chapter. The chapter ends with policy recommendations based on the findings and conclusions of the study.

5.1 Summary

The fact that an understanding of agricultural price behaviour is fundamental to the evolvement of workable agricultural development plan and sustainable food secuirity policy is incontrovertible. It is the case, that several governments over the years through the implementation of various agricultural sector policies and programmes strive to achieve market efficiency with the ultimate goal of ensuring food availability from surplus to deficit areas, realizing welfare impacts of policy initiatives and attempts to bridge the gap between the deprived and affluent regions that result from ecological differences and other factors. Despite such efforts, agricultural development policies in Ghana have concentrated much attention on increasing agricultural productivity while research on market price analysis has been relegated to the background. The purported ability of the market participants to influence the conduct of the market resulting in a full and faster transmission of cost increases to consumers than the contrary cost decreases makes it necessary to study the nature of market price linkages in Ghana. The study sought to acquire knowledge about the state of maize markets in Ghana in the last decade.

Using monthly wholesale maize prices data between 1995 to 2013 the study examined: the variation and trends within wholesale maize prices in four markets under study, price linkages among local and central maize markets in Ghana between 1995 to 2013, whether price transmission between local and central markets are symmetric or asymmetric and the extent to which maize markets in Ghana are spatially integrated.

A descriptive analysis of the data shows that the market with the highest average values for monthly wholesale prices was Accra while the lowest value was Bolgatanga. The variability in wholesale maize market prices as determined by the coefficient of variation was on the average approximately 88 percent. The high fluctuations in mean wholesale prices indicate that maize prices were unstable. Also, the seasonal variation indicates that prices generally decline rapidly in the four months after the new crop harvest which comes in July for the southern sector of the Ghana. A trend analysis in all the four markets show that prices were lowest in September and highest in June. The annual trend also shows a general increase in price of maize over the years with a cyclical pattern in every four years that is 1996, 2000, 2004, 2008 and 2012.

All the price series showed econometric integration of the order I (1) meaning that similar stochastic processes generated these series. The test for cointegration using the Johansen Maximum Likelihood tests reveals that all the five market parings were cointegrated. The market pairs examined showed that their prices series do not diverge at equilibrium thus exhibiting spatial price linkage. The results complement earlier studies of market integration in the Ghanaian market, which potentially can be attributed to the non-interventionist role of the government, improvement in communication infrastructure and the different degrees of self-sufficiency that create arbitrage between the maize markets.

Considering the various methods for analyzing market linkages and their limitation, Vector Error Correction Model (VECM) was selected to best model the adjustment of maize prices. The results indicate that the speed of adjustment was higher for consumer markets (Accra and Bolgatanga) than the producer markets (Techiman and Tamale). It ranges between 8.2% and

12.4% for producer and consumer markets respectively. While price linkages indicate that equilibrium was established within 9.6 months for producer markets and 5.4 months for consumer markets. Also the adjustment mechanism between the maize markets after a shock was characterized by asymmetry where traders responded faster to shocks that squeezed their marketing margin than those that stretched them. Two out of the five markets pairs, Accra-Bolgatanga and Tamale-Bolgatanga, exhibited positive asymmetry in price transmission even though the remaining markets show faster adjustment to price increases compared to price decreases, they are not statistically significant.

The results of granger causality revealed that Ghanaian maize markets are well integrated. The markets exhibit both bidirectional and unidirectional causality. Evidence of price causality and leadership exists in the Ghanaian maize market in favour of Techiman, Accra and Tamale.

5.2 Conclusion and Policy Recommendations

High variability implies that price of maize fluctuates widely across seasons in all markets analyzed. This translates into unstable producer incomes which has deleterious effect on production and production planning. The high variability in prices demands an improvement in basic marketing information especially in relation to prices. Collection, collation and dissemination of maize price information need to be provided by Ministry of Food and Agriculture (MOFA). There is a need for re-organization and re-equipping of the Statistics, Research and Information Division of Ministry of Food and Agriculture in terms of finance, facilities and personnel to be able to effectively perform these functions. A regular and wide dissemination of price and market supply information will lead to effectiveness of arbitrage among markets, it will reduce uncertainties in market supplies in different locations and lead to a reduction in the risks associated with inter-market trade. Doing this will lead to an efficiently functioning market network where very few markets are segmented and where maize is delivered to consumers at competitive cost. Also, such a market network with very high proportion of the markets linked in the long-run disallows exploitative tendencies by market agents and actors.

Price transmission between maize markets have improved over time due to improvement in road, transport and market infrastructure as well as information technology leading to decline in transaction costs in the distribution level of maize supply chain but this may not be the case for all maize producing communities throughout the country. There is still evident that several roads linking the producer and consumer markets are in a bad condition which hampers the rate of price transmission and for that matter trade flow between the consumer and the producer markets. It is therefore recommended that policy initiatives be directed towards ensuring efficient transportation of agricultural commodities across markets. These include investment in new transporting vehicles, rail/road construction and maintenance. These may contribute to reducing transaction costs and subsequently improving market integration and the imperfection observed in the maize market in Ghana.

The adjustment mechanism after a shock was characterised by asymmetry which are signals of market failure, redistribution and net welfare losses to producers and consumers. The observed asymmetry is often used to indicate a suboptimal condition. Given the challenge in explaining the underlying causes of asymmetry through the model, inventory and stock management behaviour of traders in the maize market suitably serves as the potential source of asymmetry. Traders were slow in passing on price decrease from Techiman to Accra but are quick to pass on price increases to consumers due to stock holding behavior of traders. It is recommended that inventory and stock behaviour of traders be improved through investment in storage facilities by the government given the seasonal nature of the commodity. This can ensure even flow of maize throughout the season and enhance traders' response to both positive and negative shocks.

Maize market links exhibit both bidirectional and unidirectional causality which means that the markets are strongly integrated. Techiman was revealed as a market leader whose price changes influence all other markets. The price causality and leadership exists in the Ghanaian maize market in favour of Techiman and Tamale, requires that these markets are to be targeted for pricing policy directed at reducing maize price and boosting maize production and consumption. By exercising exogeneity over other markets, prices formed in them will be efficiently transmitted to the follower markets with little or no distortions.

5.3 Limitations of the study and Suggestions for Future Research

A limiting concern of the study is that, producer prices are currently difficult to come by and so wholesale price transmission could be an approximation of examining producer price transmission which has not been explored yet. The process of generating price data need to be taken serious by appropriate bodies in charge of collecting agricultural price data, that is well trained and qualified personnel's should be used in collecting such information since it has several policy implications on both consumers and producers. Also the approach does not examine the underlying causes of the findings linked to asymmetry. The causes of asymmetry in price transmission are only based on understanding of the maize marketing operations. It would therefore be worthwhile if future studies employ methodologies that examine the potential causes of asymmetry. Also, a better understanding of the market would be observed if future studies explore the transmission mechanics from rural (producer villages) to urban (Techiman, Wenchi etc.) areas because most traders also purchase their supplies from the rural(producer villages) areas.

REFERENCES

Abdulai, A. (2000). Spatial price transmission and asymmetry in the Ghanaian maize market. *Journal of Development Economics,* 63(2), 327-349.

Abdulai, A. (2007). 'Spatial and vertical price transmission in food staples market chains in eastern and southern Africa: What is the evidence?' *Paper presented at the FAO trade and markets division workshop on staple food trade and market policy options for promoting development in eastern and southern Africa*. Rome, March 1-2.

Abunyuwah, I. (2007). '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, 2007).

Akiyama, T., Baffes, J., Larson, D. F. and Varangis, P. (2003). 'Commodity market reform in Africa: Some recent experience'. *World Bank Policy Research Working Paper 2995*. March 2003.

Alderman, H. (1993). 'Intercommunity price transmittal: analysis of food markets in Ghana'. *Policy Research Working Paper Series 884*. The World Bank, W. DC.

Alderman, H. and Shively, G. E. (1991). 'Prices and markets in Ghana'. *Cornell Food and Nutrition Policy Program Working Paper,* No. 10, Ithaca, NY.

Alderman, H., Shively, G. E. (1996). Economic reform and food prices: evidence from markets in Ghana. *World Development*, 24 (3), 521–534.

Alexander, C. and Wyeth, J. (1994). Co-integration and market integration: an application to the Indonesian rice market. *Journal of Development Studies*, 30 (4), 303-328

Al-hassan, R., Poulton, C. and Dorward, A. (1999). 'Improving access to maize marketing opportunities in remote areas of Ghana'. *Paper presented at the workshop on 'improving smallholder market access in remote areas of Sub-saharan Africa'.* Workshop at Wye College, Kent, UK, 42.

Amikuzuno, J. (2009). 'Spatial price transmission and market integration between fresh tomato markets in Ghana: Any benefits from trade liberalisation?' (A PhD dissertation, Faculty of Agricultural Sciences, Georg-August-University of Göttingen, Germany 2009).

Amikuzuno, J. (2010). Spatial price transmission and market integration between fresh tomato markets in Ghana: Any benefits from trade liberalization? *Paper Presented To Department of Agricultural Economics and Extension, University for Development Studies,* Tamale, Ghana.

Amonde, T., Mcdonald, L. and Barrett, K. (2009). *An economic enquiry into the causes of the perceived asymmetric price transmission in markets for specific consumer goods in Jamaica.* Paper presented to the fair trading commission (FTC) of Jamaica, April, 2009.

Armah, P. W. and Asante, F. (2004). *Ensuring food security in Ghana-the role of maize storage systems.* Seminar paper presented at the institute of statistical, social and economic research, Accra, August. 22.

Asuming-Brempong, S. and Osei-Asare, Y. (2007). *Has imported rice crowded-out domestic rice production in Ghana? What has been the role of policy?* AAAE conference proceedings, Accra, Ghana.

Badiane, O. and Shively, G. E. (1997). 'The response of local maize prices to the 1983 currency devaluation in Ghana'. *MTID discussion papers 12*, International Food Policy Research Institute (IFPRI).

Badiane, O., Ulimwengu, J. M. and Wouterse, F. (2010). Spatial price transmission and market integration in Senegal's groundnut market, *International Food Policy Research Institute Series Number 1014*.

Balke, N.S. and Fomby, T. B. (1997). Threshold cointegration. *Int. Econ. Rev,* 38, 627-645.

Ball, L. and Mankiw, N. G. (1994). Asymmetric price adjustment and economic fluctuations. *The Economic Journal*, 104 (423), 247–261.

Barrett, C. (1996). Market analysis methods: are our enriched toolkits well suited to enlivened markets? *American Journal of Agricultural Economics, 78*, 825–9.

Barrett, C. B. (2005). *Spatial market integration.* The new Palgrave dictionary of economics (2^{nd} ed.), London, Palgrave Macmillan.

Barrett, C. B. and Li, J. R. (2002). Distinguishing between equilibrium and integration in spatial price analysis. *American Journal of Agricultural Economics*, 84, 292-307.

Baulch, B. (1997). Transfer costs, spatial arbitrage, and testing for food market integration. *American Journal of Agricultural Economics*, *79*,477-487.

Ben-Kaabia, M., Gil, J. M. and Boshnjaku, L. (2002). Price transmission asymmetries in the Spanish lamb sector. *International congress*, August, 28-31, Zaragoza, European Association of Agricultural Economists.

Borsen, B. Wade, J-P. C, Warren, R. Grant, A and Ngenge, W. (1985). Spatial and temporal relationships among selected U.S grain markets. *North Central Journal of Agricultural Economics,* 7, 1-10.

Cirera, X. and Arndt, C. (2006). 'Measuring the impact of road rehabilitation on spatial market efficiency in maize markets in Mozambique'. *DNEAP discussion paper 30*, Ministry of Planning and Development, Mozambique.

Clemente, J., Montañés, A. and Reyes, M. (1998). Testing for a unit root in variables with a double change in the mean. *Economics Letters*, 59, 175-182.

Cudjoe, G., Breisinger, C. and Diao, X. (2008). 'Local impacts of a global crisis: Food price transmission and poverty impacts in Ghana'. *Discussion paper*. International Food Policy Research Institute.

Cutts, M. and Kirsten, J. F. (2006). Asymmetric price transmission and market concentration: an investigation into four South African agro-food industries. *South African Journal of Economics*, 74(2), 323-333.

Dercon, S., 1995. On market integration and liberalization: method and application to Ethiopia. *Journal of Development Studies*, 32(4), 112–143.

de Janvry, A., Fafchamps, M. and Sadoulet, E. (1991). Peasant household behavior with missing markets: some paradoxes explained. *Economic Journal*, 101, 1400-17.

Delgado, C. (1986). A variance components approach to food grain market integration in northern Nigeria. *American Journal Of Agricultural Economics*, 68 (4), 970-979.

Dickey, D. and Fuller, W. **(**1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427-431.

Egyir, I. S., Al-Hassan, R. and Abakah, J. K. (2011). The effect of ICT-based market information services on the performance of agricultural markets: experiences from Ghana, *International Journal of ICT. Res. Dev*., 2, 1-13.

Enders, W. and Granger, C. W. J. (1998). Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates. *Journal of Business and Economic Statistics*, 16, 304 - 11.

Enders, W. and Siklos, P. L. (2001). Cointegration and threshold adjustment. *Journal of Business and Economic Statistics* 19, 166-176.

Engle, R. F. and Granger C. W. J. (1987). Cointegration and error correction: representation, estimation and testing. *Econometrica*, 55, 251-276.

Engle, R. F. and Yoo, B. S. (1987). Forecasting and testing in co-integrated systems. *Journal of Econometrics*, *Elsevier*, 35(1), 143-159.

Fackler, P. L. (1996). 'Spatial price analysis: A methodological review'. *Proceedings of the ncr-134 conference on applied commodity price analysis, forecasting, and market risk management*. Chicago, II.

Fackler, P. And Goodwin, B. (2001). *Spatial price analysis, in handbook of agricultural economics* (2nd ed.). Gardner and G. Rausser, Amsterdam: Elsevier.

Fafchamps, M. (1992). Cash crop production, food price volatility, and rural market integration in the third world. *American Journal of Agricultural Economics*, 74 (1), 90–99.

Falsafian, A. and Moghaddasi, R. (2008). *Spatial integration and asymmetric price transmissionin selected Iranian chicken markets*. Paper prepared for presentation at the 12th EAAE Congress 'People, Food and Environments: Global Trends and European Strategies', Gent (Belgium), 26-29 August.

FAO (1997). 'Market information services: theory and practice'. Agricultural Services Bulletin 125, Rome.

FAO (2008**)**. FAOSTAT: Agriculture Data. Available online: http://faostat.fao.org

FASDEP I (2002). *Food and agriculture sector development policy, ministry of agriculture, Ghana.* MOFA, Accra

FASDEP II (2008). Food and agriculture sector development policy, ministry of agriculture. MOFA, Accra Ghana.

Frey, G. and Manera, M. (2005). 'Econometric models of asymmetric price transmission'. Department of statistics, University of Milan-Bicocca and Fondazione Eni Enrico Mattei

Gage, D., Bangnikon, J., Abeka-Afari, H., Hanif, C., Addaquay, J., Antwi, V. and Hale, A. (2012). 'The market for maize, rice, soy and warehousing on northern Ghana'. The enabling agricultural trade (EAT) project.

Goletti, F., Ahmed, R. and Farid, N. (1995). Structural determinant of market integration: the case study of rice in Bangladesh. *The Development Economics*, 32, 245-264.

Goodwin, B. K. and Piggott, N. E. (1999). 'Spatial market integration in the presence of threshold effects'. *American Agricultural Economics Association*.

Goodwin, B. K. and Holt, M. T. (1999). Asymmetric adjustment and price transmission in the US beef sector. *American Journal of Agricultural Economics,* 81, 630-637.

Goodwin, B. K. and Piggott, N. (2001). Spatial market integration in the presence of threshold effects. *American Journal of Agricultural Economics*, 83,302-17.

Goodwin, B. K. and Schroeder, T. C. (1990). Testing perfect spatial market integration: An application to regional United States cattle markets. *N. Cent. J. Agr. Econ*. 12,173-85.

Granger, C. W. J. and Lee, T. H. (1989). Investigation of production, sales and inventory relationships using multicointegration and non-symmetric error correction models. *Journal of Applied Econometrics*, 4, 135- 159.

Gujarati, D. N. (2003). *Basic Econometrics* (3rd ed.). McGraw Hill Publishing Company.

Gupa, S. and Mueller R. A. E. (1982). Analysing the pricing efficiency in spatial markets: concepts and applications. *European Review of Agricultural Economics*, 9, 301-312.

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.

Hansen, S. and Juselius, K. (1995). *Cats in rats*: *cointegration analysis of the time series estimates*. Evanston , Illinois.

Hansen, 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, 170-209.

Harris, R. (1995). *Using cointegration analysis in econometric modelling*. Prentice hall, Harvester Wheatsheaf.

Hassouneh, I., Von Cramon-Taubadel, S., Serra, T. and Gil, J. M. (2012). Recent developments in the econometric analysis of price transmission *Working Paper 2*. Transparency of Food Pricing Transfop, January.

Heien, D. M. (1980). Markup pricing in a dynamic model of the food industry. *American Journal of Agricultural Economics*, 62, 10-18.

Hendry, A. (1986). Econometric modelling with co-integrated variables: an overview. *Oxford Bulletin of Economics and Statistics*, 25 (2), 15-35.

Hossain, M. I. and Verbeke, W. (2010) Evaluation of rice markets integration in Bangladesh. *The Lahore Journal of Economics*, 15 (2), 77-96.

Houck, J. P. (1977). An approach to specifying and estimating nonreversible functions. *American Journal of Agricultural Economics*, 59, 570-572.

Isard, P. (1977). How far can we push the law of one price? *The American Economic Review*, 67 (5), 942-948.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic*

Dynamics and Control, 12, (2), 231–254.

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.

Katengeza, S. P. (2009). 'Malawi agricultural commodity exchange and spatial rice market integration'. (Masters thesis in agricultural and applied economics, University of Malawi, 2007).

Key, N., Sadoulet, E. and de Janvry, A. (2000). Transactions costs and agricultural household supply response. *American Journal of Agricultural Economics*, 82 (2), 245- 259.

Kinnucan, H. W. and Forker, O. D. (1987). Asymmetry in farm-retail price transmission for major dairy products. *American Journal of Agricultural Economics*, 69, 285–292.

Kovenock, D. and Widdows, K. (1998). Price leadership and asymmetric price rigidity. *European Journal of Political Economy*, 14 (1), 167-187.

Kwiatkowski, D., Phillips, C. B., Schmidt, P., and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? *J. Econometrics* 54, 159-178.

Langyintuo, A. S. (2010). 'Grain distribution in ghana under imperfectly competitive market conditions'. AAAE third conference/aeasa 48th conference, september 19-23, Cape Town, South Africa.

Loveridge, S. (1991). Marketing in Rwanda-imports and infrastructure. *Food Policy*, 16, 95-104.

Madhusudan, G. (2011). Agricultural policy reforms and spatial integration of food grain markets in India. *Journal of Economic Development*, 36(2), 15-37.

Manera and Frey (2005). 'Econometric models of asymmetric price transmission'. Nota di Lavoro, Fondazione Eni Enrico Mattei, No.100.2005

Mafimisebi, T. E. (2012). Spatial equilibrium, market integration and price exogeneity in dry fish marketing in Nigeria: a vector auto-regressive approach. *Journal of Economics, Finance and Administrative Science*, 17 (33), 31-37,

Mafimisebi, T.E. (2001). Spatial price equilibrium and fish market integration in Nigeria. (PhD thesis, university of Ibadan, Nigeria. 2001.)

Mackey, A., Morrisey, O. and Vailant, C. (1997). Trade liberazation and agricultural supply response, issues and some lessons. *Journal of development research*, 9-2, 129-147.

McNew, K. And Fackler, P. L. (1997). Testing market equilibrium: is cointegration informative? *Journal of Agricultural and Resource Economics*, 22, 191-207.

Mensah-Bonsu, A., Agyeiwaa-Afran, A. and Kuwornu, J. K. M. (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. and Von Cramon-Taubadel, S. (2004): Asymmetric price transmission: a survey, *Journal of Agricultural Economics*, 55(3), 581-611.

Mockshell, J. And Egyir, I. S. (2010). Assessing the market integration of locally produced groundnut in Ghana, *tropentag*, september 14-16, Zurich.

MOFA (2005). 'Facts and Figures.' Accra, Ghana.

MOFA (2012). 'Agriculture in Ghana: Facts and Figures'. Accra, Ghana

Morris, M. L., Tripp, R. and Dankyi, A. A. (1999): Adoption and impacts of improved maize production technology: a case study of the Ghana grains development project. *Economics Program Paper 99-01*. Mexico, d.f.: cimmyt.

Mohammmed S. (2005). Supply response analysis of major crops in Pakistan. *Pakistan Journal of Agricultural Research*, 15, 124(54).

Motamed M., K. Foster, A and Tyner, W. E. (2008). Applying cointegration and error correction to measure trade linkages: maize prices in the United States and Mexico. *Agricultural Economics*, 39, 29-39.

Muyatwa, V. P. (2001). The liberalization and integration of regional maize markets in Zambia, (Ph.D. thesis, University of Manitoba 2001).

Negassa, A. and Myers, R. (2007). Estimating policy effects on spatial market efficiency: an extension to the parity bounds model. *American Journal of Agricultural Economics*, 89(2), 46-64.

Negassa, A., Meyers, R. and Gabre-Maldhin, E. (2003). Analyzing the grain market efficiency in developing countries: review of existing methods and extensions to the parity bound model. *Discussion Paper, 63*. Market Trade and Institutions Division

Nyanteng, V. K. and Asuming-Brempong, S. (2003). *The role of agriculture in the food security of Ghana 2003*. Paper presented at the "Roles of Agriculture Project, International Conference, 20-23 October, Accra.

Ogundare, G. O. (1999). The determinants of the traditional export crops in Nigeria using co-integration approach. (M.Sc. thesis University of Ibadan, Nigeria, 1999).

Olayemi, J. K. (1973). Rice marketing and prices: a case study of Kwara state, Nigeria. *Bulletin of Rural Economics and Sociology,* 8(2), 211-242.

Pillar, C. and Wood, R. O. (1988). Transaction costs in arbitrage models. *Journal of Econometrics*, 39(2), 309-326.

Rapsomanikis, G. and Karfakis, P. (2007). 'Margins across time and space: threshold cointegration and spatial pricing applications to commodity markets in Tanzania'. *Paper presented in the workshop on staple food trade and market policy options for promoting development in eastern and southern Africa,* Rome.

Rapsomanikis, G., Hallam, D. and Conforti, P. (2004). 'Market integration and price transmission in selected food and cash crop markets of developing countries: Review and applications. *Commodity Market Review* FAO, Rome.

Ravallion, M. (1986). Testing market integration. *American Journals for Agriculture Economics*, 1, 102-108.

Reagan, P. B. and Weitzman, M. L. (1982). Asymmetries in price and quantity adjustments by the competitive firm. *Journal of Economic Theory, 27*, 410-420.

Rico, I. (2009). 'Models for analyzing nonlinearities in price transmission'. (A PhD dissertation, Faculty of Agricultural Sciences, Georg-August-university, Göttingen, Germany, 2009).

Roberts, J. M., Stockton, D. J., Struckmeyer, C. S. (1994). Evidence on the flexibility of prices. *Review of Economics and Statistics,* 76(1), 142–150.

Sankaran, G., Naillon, J., Nguyen, J., Chang, H. H., Hilde, P. and Chadwick, B. (2011). Telecommunications industry in Ghana: A study tour analysis. University of Washington-bothel.

Sanogo, I. (2008). Spatial integration of the rice market: empirical evidence from mid- west and far-west Nepal and the Nepalese-Indian border. *Asian Journal of Agriculture and Development, 4(1),* 139-156.

Scherer, F. M. and Ross, D. (1990). *Industrial market structure and economic performance.* (3rd ed.). Houghton Mifflin, Boston.

Saran, S. and Gangwar, L. S. (2008). Analysis of spatial cointegration amongst major wholesale egg markets in India. *Agricultural Economics Research Review, Agricultural Economics Research Association (India), 21(2), 56-76.*

Sexton, R. J., King, C. L. and Carman, H. F. (1991). Market integration, efficiency of arbitrage, and imperfect competition: methodology and application to U.S celery. *American Journal of Agricultural Economics*, 73(3), 568-80.

Shively, G. E. (1996). Food price variability and economic reform: an arch approach for Ghana. *American Journal of Agricultural Economics,* 78 (1), 126–136.

Spiller, P. and Huang, C. J. (1986). On the extent of the market: wholesale gasoline in the north-eastern United States. *Journal of Industrial Economics, 35(2)* 131-145.

Timmer, P. C. (1974). A model of rice marketing margins in Indonesia. *Food Research Institute Studies,* 12(2), 145-167.

Tomek, W. G. and Robinson, K. L. (2003). *Agricultural product prices*. Ithaca, NY: Cornell University Press.

Tong, H. (1978). On a threshold model in pattern recognition and signal processing. (ed.). c. Chena. Amsterdam: Sijhoff and Noonhoff.

Tostão, E. and Brorsen, B. W. (2005). Spatial price efficiency in Mozambique's post-reform markets. *Agricultural Economics, 33*.

Townsend, T. P. (2001). 'World cotton market conditions'. *Belt cotton conference proceedings, cotton economics and marketing conference,* National Cotton Council, Memphis, TN.

Tsay, R. (1989). Testing and modelling threshold autoregressive processes. *Journal of American Statistics Association, 84*, 231-240.

Tweenten, L. G. and Quance, C. L. (1969). Positivistic measures of aggregate supply elasticities: some new approaches. *American Journal of Agricultural Economics, 51*, 342-352.

Uchezuba, I. D., Jooste, A. and Willemse, J. (2010). 'Measuring asymmetric price and volatility spillover in the South African broiler market'. AAAE third conference/aeasa 48th conference, september 19-23, 2010, cape town, south africa.

Van Campenhout, B. (2007). Modeling trends in food market integration: method and an application to Tanzanian maize markets. *Food Policy, Elsevier,* 32(1), 112-127.

Von Cramon-Taubadel, S. (1998). Estimating asymmetric price transmission with the error correction representation: an application to the German pork market. *European Review of Agricultural Economics*, *25*, 1-18.

Von Cramon-Taubadel, S. and Fahlbusch, S. (1994). Identifying asymmetric price transmission with error correction models. Poster session EAAE European seminar in reading.

Von Cramon-Taubadel, S. and Loy, J. P. (1996). Price asymmetry in the international wheat market: comment. *Canadian Journal of Agricultural Economics*, *44*, 311-317.

WABS (2008). 'Maize value chain study in Ghana: Enhancing efficiency and competitiveness'. WABS consulting ltd.

Ward, R. W. (1982). Asymmetry in retail, wholesale and shipping point pricing for fresh vegetables. *American Journal of Agricultural Economics 62*, 205-212.

Winters, B. Alan, L., Mcculloch, N. and Mckay, A. (2004): Trade liberalization and poverty: the evidence so far. *Journal of Economic Literatur*e, 42, 72–115

Wlazlowski, S., Giulietti, M., Binner, J. and Milas, C. (2009). Price dynamics in European petroleum markets. *Energy Economics*, 31(1), 99-108.

Wolffram, R. (1971). Positivistic measures of aggregate supply elasticities-some new approaches: some critical notes. *American Journal Of Agricultural Economics 53*,356-356.

SARI (1996). Savanna Agricultural Research Institute. *Annual Report.*

Yeboah, A. (2012): Spatial price transmission in the regional maize markets in Ghana. Erasmus Mundus Program in Agricultural, Food and Environmental Policy Analysis (AFEPA):Food and Resource Economics, Rheinische Friedrich University of Bonn, Germany Department of Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Zivot, E. and Andrews, K. (1992). Further evidence on the great crash, the oil price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics*, 10 (10), 251–70.

APPENDICES

APPENDIX 1: NOMINAL WHOLESALE MAIZE PRICE DATA (1995-2013) FROM SRID-MOFA

YEARS	ACCRA	TECHIMAN	TAMALE	BOLGA
1. 1995	2.10	1.08	1.50	1.80
2. 1995	2.30	1.14	1.50	1.80
3. 1995	2.60	1.25	1.68	1.90
4. 1995	2.96	1.34	1.86	2.10
5. 1995	3.06	1.55	1.88	2.50
6. 1995	3.30	1.65	1.98	2.60
7. 1995	2.90	1.66	1.76	2.60
8. 1995	2.87	1.38	1.75	2.80
9. 1995	2.57	1.20	1.67	2.80
10. 1995	2.90	1.27	1.75	2.50
11. 1995	2.40	1.57	1.98	2.50
12. 1995	2.63	1.48	1.88	2.40
1. 1996	2.55	1.80	2.15	2.40
2. 1996	2.65	2.00	2.50	2.50
3. 1996	2.86	2.24	2.52	2.80
4. 1996	2.80	2.45	2.56	2.60
5. 1996	3.02	2.50	2.98	2.60
6. 1996	3.62	2.50	2.97	2.80
7. 1996	3.52	2.60	3.11	3.11
8. 1996	3.45	2.56	3.15	3.20
9. 1996	3.02	2.80	3.15	2.80
10. 1996	3.52	2.78	3.22	3.00
11. 1996	3.90	2.60	3.22	3.20
12. 1996	4.49	2.97	3.51	3.20
1. 1997	5.20	3.11	3.52	3.50
2. 1997	5.60	3.25	3.54	3.70
3. 1997	6.17	3.50	4.11	4.21
4. 1997	7.87	3.50	4.52	4.22
5. 1997	7.70	3.70	4.34	4.50
6. 1997	7.78	3.80	4.56	4.70
7. 1997	7.75	4.23	5.22	5.40
8. 1997	7.30	4.65	5.22	5.34
9. 1997	5.68	4.85	5.32	5.60
10. 1997	4.89	4.50	5.05	5.60
11. 1997	5.47	4.50	5.17	5.50
12. 1997	6.40	4.80	5.52	5.80

1. 1998	7.10	5.22	5.67	5.80
2. 1998	7.73	5.54	5.78	5.70
3. 1998	7.26	5.66	6.12	6.00
4. 1998	7.21	5.80	6.12	6.00
5. 1998	6.43	5.76	6.12	5.70
6. 1998	6.65	5.15	5.78	5.70
7. 1998	6.07	5.45	5.55	5.60
8. 1998	5.98	5.22	5.55	5.60
9. 1998	5.45	4.82	5.00	4.56
10. 1998	3.61	3.45	5.00	4.50
11. 1998	4.32	3.45	4.53	4.50
12. 1998	4.85	3.46	4.33	4.50
1. 1999	5.20	3.80	3.70	3.90
2. 1999	5.23	3.84	3.70	4.03
3. 1999	5.06	3.60	4.10	4.03
4. 1999	5.73	3.68	4.10	4.34
5. 1999	5.60	4.13	3.90	4.16
6. 1999	5.17	5.20	4.00	4.10
7. 1999	6.84	5.03	4.00	4.20
8. 1999	4.40	4.50	3.70	3.96
9. 1999	3.98	3.30	3.30	3.80
10. 1999	4.10	3.35	3.00	3.49
11. 1999	5.48	5.83	3.70	3.27
12. 1999	5.95	4.32	3.20	3.57
1. 2000	6.25	5.70	3.70	4.12
2. 2000	6.37	6.08	3.80	4.63
3. 2000	7.50	7.18	4.68	4.81
4. 2000	10.03	9.78	6.85	5.73
5. 2000	10.33	10.60	6.33	6.80
6. 2000	11.21	12.53	6.80	7.00
7. 2000	13.20	13.53	7.50	8.07
8. 2000	13.50	12.60	8.50	8.90
9. 2000	12.60	11.85	8.60	8.90
10. 2000	11.70	10.58	9.08	8.70
11. 2000	12.20	10.50	8.70	9.00
12. 2000	12.50	10.80	9.00	9.50
1. 2001	12.90	10.50	9.50	9.50
2. 2001	12.24	10.90	10.00	10.50
3. 2001	14.68	11.20	10.00	10.50
4. 2001	14.70	11.50	10.55	11.00
5. 2001	15.00	11.50	10.60	11.50

6. 2001	15.98	12.45	11.00	11.50
7. 2001	14.20	12.80	11.20	12.00
8. 2001	14.78	12.50	11.50	12.00
9. 2001	14.27	12.00	11.50	12.50
10. 2001	14.45	11.50	11.80	12.70
11. 2001	15.06	12.00	12.50	13.20
12. 2001	15.45	13.50	12.80	13.50
1. 2002	15.87	15.45	12.96	14.22
2. 2002	15.43	13.64	12.90	15.43
3. 2002	15.01	11.73	14.40	16.56
4. 2002	15.83	11.60	13.06	16.43
5. 2002	15.83	12.62	13.60	15.01
6. 2002	16.42	14.00	13.50	15.66
7. 2002	17.80	10.00	16.76	13.40
8. 2002	16.70	10.78	13.90	16.62
9. 2002	11.21	8.12	10.60	13.73
10. 2002	13.60	6.30	9.10	12.02
11. 2002	14.00	8.20	8.80	12.31
12. 2002	14.00	7.90	9.50	14.19
1. 2003	16.20	9.60	11.33	14.51
2. 2003	15.50	9.60	12.40	11.76
3. 2003	16.00	10.10	12.02	15.58
4. 2003	15.83	10.20	10.84	15.86
5. 2003	15.83	16.85	12.33	15.15
6. 2003	19.00	20.24	12.58	16.52
7. 2003	20.00	16.23	12.20	13.30
8. 2003	18.00	16.50	10.50	15.49
9. 2003	16.00	14.25	9.97	14.24
10. 2003	17.50	12.25	9.54	12.71
11. 2003	17.10	19.07	10.36	12.76
12. 2003	19.00	16.48	11.30	13.11
1. 2004	20.00	18.31	12.90	14.53
2. 2004	19.00	18.02	13.68	15.71
3. 2004	20.00	17.52	14.00	15.75
4. 2004	21.00	18.81	15.17	16.48
5. 2004	21.80	21.31	15.90	16.70
6. 2004	23.00	22.11	17.17	17.10
7. 2004	27.30	24.91	23.33	18.90
8. 2004	30.60	23.30	22.10	22.10
9. 2004	27.70	16.50	17.00	22.70
10. 2004	25.00	18.00	16.00	25.00

11. 2004	26.40	23.10	17.40	26.40
12. 2004	24.50	23.30	20.00	24.50
1. 2005	29.30	23.40	19.40	23.86
2. 2005	28.70	27.35	22.45	21.50
3. 2005	31.00	29.20	24.95	30.21
4. 2005	37.50	37.19	29.00	28.80
5. 2005	48.00	47.27	26.00	35.12
6. 2005	51.20	44.44	36.80	41.33
7. 2005	53.80	45.33	43.66	41.33
8. 2005	43.00	25.71	32.33	43.78
9. 2005	36.50	22.42	24.25	31.21
10. 2005	33.40	23.87	19.40	20.80
11. 2005	33.40	25.20	19.40	24.39
12. 2005	31.70	27.40	22.00	23.83
1. 2006	28.20	25.41	22.00	21.40
2. 2006	27.05	25.68	24.25	21.40
3. 2006	27.90	25.40	24.00	21.40
4. 2006	28.65	25.30	24.00	18.74
5. 2006	28.58	24.43	20.25	17.85
6. 2006	29.73	27.70	17.67	19.65
7. 2006	27.85	25.00	15.50	18.75
8. 2006	25.75	20.45	15.50	15.15
9. 2006	25.65	18.20	16.88	14.73
10. 2006	24.75	18.20	16.00	14.75
11. 2006	25.08	25.45	15.13	14.30
12. 2006	25.00	27.30	17.00	16.10
1. 2007	25.00	27.30	17.33	16.10
2. 2007	27.90	27.30	19.25	17.43
3. 2007	28.90	26.80	20.50	17.90
4. 2007	30.38	29.55	19.00	17.90
5. 2007	32.50	36.10	19.63	17.90
6. 2007	33.30	31.80	18.50	14.30
7. 2007	31.70	31.80	21.50	19.20
8. 2007	30.95	27.25	24.00	19.65
9. 2007	29.75	19.33	27.25	19.64
10. 2007	23.50	24.69	28.00	24.11
11. 2007	32.00	30.93	36.67	27.38
12. 2007	31.50	31.82	28.33	25.00
1. 2008	30.75	28.00	31.00	27.68
2. 2008	34.25	28.70	33.50	28.57
3. 2008	41.67	34.60	38.33	32.73

4. 2008	46.50	39.50	39.04	33.55
5. 2008	52.00	54.50	50.00	40.20
6. 2008	62.25	50.25	54.00	46.43
7. 2008	71.60	65.20	60.00	52.14
8. 2008	59.75	50.25	56.50	54.86
9. 2008	43.50	39.00	38.75	49.50
10. 2008	46.50	40.00	42.25	41.08
11. 2008	57.40	49.60	43.40	41.00
12. 2008	57.50	52.75	44.00	35.70
1. 2009	58.00	54.00	45.40	41.42
2. 2009	56.25	45.19	51.00	46.43
3. 2009	57.75	47.79	52.50	45.09
4. 2009	59.50	45.00	47.25	42.86
5. 2009	71.20	52.15	51.00	47.50
6. 2009	75.80	51.40	65.80	50.50
7. 2009	75.25	48.27	65.50	42.86
8. 2009	71.40	43.29	58.80	44.30
9. 2009	51.50	26.65	44.75	33.93
10. 2009	46.80	30.70	32.00	35.40
11. 2009	50.00	29.83	38.00	36.75
12. 2009	51.50	30.70	40.00	36.75
1. 2010	53.40	33.20	40.00	37.20
2. 2010	53.25	32.00	40.50	36.75
3. 2010	51.00	31.00	41.50	37.50
4. 2010	54.25	32.25	42.00	36.00
5. 2010	58.80	36.80	42.00	36.00
6. 2010	58.00	36.25	42.00	36.00
7. 2010	58.00	36.90	38.40	35.74
8. 2010	56.75	37.13	36.00	38.43
9. 2010	49.75	37.38	36.00	37.50
10. 2010	43.40	26.20	32.40	38.40
11. 2010	45.25	31.00	36.00	39.50
12. 2010	53.50	33.25	37.50	36.00
1. 2011	56.60	52.40	40.40	37.26
2. 2011	61.25	50.00	42.00	39.00
3. 2011	57.25	47.50	42.00	43.00
4. 2011	57.25	53.00	42.00	42.00
5. 2011	72.50	70.50	57.50	44.75
6. 2011	80.75	73.00	57.50	53.00
7. 2011	82.00	70.25	54.25	54.50
8. 2011	89.00	76.00	60.00	58.25

9. 2011	69.75	64.50	57.50	64.00
10. 2011	64.50	54.00	53.75	60.50
11. 2011	70.25	68.50	53.75	55.25
12. 2011	89.00	84.50	68.50	56.25
1. 2012	102.25	81.50	67.00	64.00
2. 2012	98.25	74.50	66.00	60.50
3. 2012	99.25	82.25	67.50	61.00
4. 2012	105.25	80.50	70.00	64.25
5. 2012	116.50	80.00	73.75	68.00
6. 2012	118.50	85.00	75.75	67.50
7. 2012	114.25	85.00	70.00	66.75
8. 2012	114.50	86.50	69.25	68.85
9. 2012	97.50	77.50	70.00	66.00
10. 2012	87.75	73.00	52.50	71.00
11. 2012	85.50	82.00	53.00	73.75
12. 2012	87.00	90.50	52.75	61.50
1. 2013	84.50	81.75	59.25	53.00
2. 2013	85.50	73.00	62.50	54.00
3. 2013	84.75	74.00	60.25	52.00
4. 2013	84.50	59.25	57.50	50.00
5. 2013	82.25	55.00	55.00	45.50
6. 2013	81.25	55.00	49.75	47.25
7. 2013	77.50	60.00	55.00	51.00
8. 2013	78.50	71.25	52.50	50.00
9. 2013	79.00	60.00	52.50	50.25
10. 2013				
11. 2013				
12. 2013				

APPENDIX 2 (A) MONTHLY GROWTH RATES OF MAIZE PRICES(1995-2013)

MONTH	ACCRA	GR (%)	TECHIMAN	GR (%)	TAMALE	GR (%)	BOLGA	GR (%)
JULY	37.98	-2.057	29.96	-1.87	27.72	0.97	25.01	-2.09
AUGUST	36.17	-5.018	27.99	-7.02	25.83	-7.32	25.75	2.89
SEPTEMBER	30.81	-17.39	23.4	-19.6	23.37	-10.53	24.13	-6.73
OCTOBER	26.22	-17.526	20.26	-15.53	19.44	-20.23	22.01	-9.59
NOVENBER	28.07	6.599	24.07	15.85	20.65	5.88	22.5	2.14
DECEMBER	29.8	5.827	25.96	7.26	21.73	4.96	21.41	-5.07
JANUARY	29.55	-0.874	25.34	-2.42	21.51	-1.01	20.85	-2.67
FEBRUARY	29.71	0.546	24.09	-5.2	22.7	5.23	21.12	1.28
MARCH	30.35	2.109	24.87	3.13	23.43	3.12	22.26	5.11
APRIL	31.99	5.122	25.27	1.6	23.44	0.06	22.05	-0.98
MAY	35.1	8.875	28.8	12.26	24.9	5.85	23.02	4.24
JUNE	38.76	9.446	30.52	5.61	27.45	9.29	25.53	9.81
AVERAGE	**32.04**	**-0.36**	**25.88**	**-0.49**	**23.51**	**-0.31**	**22.97**	**-0.14**

(B) ANNUAL GROTH RATE IN WHOLESALE MAIZE PRICES(1995-2013)

YEAR	ACCRA	GR (%)	TECHIMAN	GR (%)	TAMALE	GR (%)	BOLGA	GR (%)
1995	2.72	-	1.38	-	1.77	-	2.36	-
1996	3.28	17.28	2.48	44.4	2.92	39.53	2.85	17.28
1997	6.48	49.36	4.03	38.42	4.67	37.53	4.84	41.09
1998	6.06	-7.09	4.92	17.96	5.46	14.43	5.35	9.49
1999	5.23	-15.81	4.22	-16.61	3.7	-47.64	3.9	-36.95
2000	10.62	50.75	10.14	58.45	6.96	46.85	7.18	45.62
2001	14.48	26.67	11.86	14.49	11.08	37.16	11.7	38.63
2002	15.14	4.4	10.86	-9.21	12.42	10.82	14.63	20.04
2003	17.16	11.78	14.28	23.94	11.28	-10.13	14.25	-2.68
2004	23.86	28.06	20.43	30.11	17.05	33.85	19.66	27.51
2005	38.13	37.42	31.57	35.27	26.64	35.97	30.51	35.58
2006	27.02	-41.12	24.04	-31.28	19.02	-40.08	17.85	-70.93
2007	29.78	9.29	28.72	16.29	23.33	18.5	19.71	9.42
2008	50.31	40.8	44.36	35.26	44.23	47.25	40.29	51.08
2009	60.41	16.73	42.08	-5.42	49.33	10.34	41.98	4.04
2010	52.95	-14.1	33.61	-25.19	38.69	-27.5	37.08	-13.21
2011	70.84	25.26	63.68	47.22	52.43	26.2	50.65	26.78
2012	102.21	30.69	81.52	21.89	65.63	20.11	66.09	23.37
2013	81.97	-24.69	65.47	-24.51	56.03	-17.13	50.33	-31.31
AVERAGE	**32.56**	**13.65**	**26.30**	**15.08**	**23.82**	**13.11**	**23.22**	**10.83**

APPENDIX 3. Descriptive Statistics of real wholesale Maize Market Prices(100kg/Bag)

ACCRA		TECHIMAN		TAMALE		BOLGA	
Mean	31.9	Mean	25.7	Mean	23.3	Mean	22.860
Standard Dev.	28.9	Standard Dev.	23.5	Standard Dev.	20.5	Stand.Dev	19.101
Sample Var.	838.1	Sample Var.	554.4	Sample Var.	424.2	Sample Var.	364.852
Kurtosis	0.2	Kurtosis	0.17	Kurtosis	-0.5	Kurtosis	-0.422
Skewness	1.0	Skewness	1.0	Skewness	0.8	Skewness	0.830
Range	116.4	Range	89.4	Range	74.25	Range	71.950
Minimum	21.0	Minimum	10.0	Minimum	15.0	Minimum	18.00
Maximum	118.5	Maximum	90.5	Maximum	75.7	Maximum	73.750
Sum	7177.6	Sum	5799.5	Sum	5263.6	Sum	5143.585
COE. VAR	90.75	COE. VAR	91.3	COE. VAR	88.05	COE. VAR	83.56
Count	225.0	Count	225.0	Count	225.0	Count	225.000

APPENDIX 4: RESULTS OF VECTOR ASYMMETRIC ERROR CORRECTION MODEL

1. Techiman– Accra Market Pairs

Dependent Variable: DTECH
Method: Least Squares
Date: 04/13/14 Time: 23:29
Sample (adjusted): 4 225
Included observations: 222 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011776	0.009713	1.212480	0.2267
DTECH(-1)	0.027441	0.094557	0.290212	0.7719
DTECH(-2)	0.058934	0.088268	0.667671	0.5051
DACC(-1)	0.125449	0.096328	1.302314	0.1942
DACC(-2)	-0.234423	0.089425	-2.621459	0.0094
ECT_1_POS	-0.256619	0.137581	-1.865220	0.0635
ECT_1_NEG	0.008843	0.105137	0.084109	0.9330

R-squared	0.065295	Mean dependent var	0.001126
Adjusted R-squared	0.039210	S.D. dependent var	0.081825
S.E. of regression	0.080204	Akaike info criterion	-2.177451
Sum squared resid	1.383043	Schwarz criterion	-2.070159
Log likelihood	248.6970	Hannan-Quinn criter.	-2.134133
Prob(F-statistic)	0.023146		

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-1.293893	215	0.1971
F-statistic	1.674160	(1, 215)	0.1971

Chi-square	1.674160	1	0.1957

Null Hypothesis: C(6)=C(7)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6) - C(7)	-0.265462	0.205165

Restrictions are linear in coefficients.

2. Techiman-Tamale Market Pair

Dependent Variable: DTECH
Method: Least Squares
Date: 04/13/14 Time: 23:42
Sample (adjusted): 4 225
Included observations: 222 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008412	0.009792	0.859018	0.3913
DTECH(-1)	0.084666	0.082467	1.026669	0.3057
DTECH(-2)	0.094492	0.082543	1.144759	0.2536
DTAM(-1)	-0.137029	0.102282	-1.339718	0.1818
DTAM(-2)	-0.265190	0.096896	-2.736845	0.0067
ECT_1_POS	-0.160408	0.092490	-1.734332	0.0843
ECT_1_NEG	-0.009428	0.108783	-0.086665	0.9310

R-squared	0.054113	Mean dependent var	0.001126
Adjusted R-squared	0.027716	S.D. dependent var	0.081825
S.E. of regression	0.080683	Akaike info criterion	-2.165558
Sum squared resid	1.399590	Schwarz criterion	-2.058267
Log likelihood	247.3770	Hannan-Quinn criter.	-2.122240
F-statistic	2.049971		
Prob(F-statistic)	0.060398		

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-0.884381	215	0.3775
F-statistic	0.782130	(1, 215)	0.3775
Chi-square	0.782130	1	0.3765

Null Hypothesis: C(6)=C(7)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6) - C(7)	-0.150980	0.170719

Restrictions are linear in coefficients.

3. Techiman-Bolgatanga Market Pairs

Dependent Variable: DTECH
Method: Least Squares
Date: 04/13/14 Time: 23:50
Sample (adjusted): 4 225
Included observations: 222 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.014345	0.009229	1.554356	0.1216
DTECH(-1)	0.117539	0.074881	1.569680	0.1180
DTECH(-2)	0.016022	0.074570	0.214856	0.8301
DBOL(-1)	-0.197773	0.107659	-1.837030	0.0676
DBOL(-2)	0.102605	0.103735	0.989110	0.3237
ECT_1_POS	-0.244934	0.083355	-2.938451	0.0037
ECT_1_NEG	0.004424	0.086621	0.051072	0.9593

R-squared	0.062446	Mean dependent var	0.001126
Adjusted R-squared	0.036281	S.D. dependent var	0.081825
S.E. of regression	0.080327	Akaike info criterion	-2.174407
Sum squared resid	1.387260	Schwarz criterion	-2.067115
Log likelihood	248.3592	Hannan-Quinn criter.	-2.131089
Prob(F-statistic)	0.029735		

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-1.764295	215	0.0791
F-statistic	3.112736	(1, 215)	0.0791
Chi-square	3.112736	1	0.0777

Null Hypothesis: C(6)=C(7)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6) - C(7)	-0.249358	0.141336

Restrictions are linear in coefficients.

4. Tamale–Bolgatanga Market Pairs

Dependent Variable: DTAM
Method: Least Squares
Date: 04/14/14 Time: 07:42

Sample (adjusted): 4 225
Included observations: 222 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.013129	0.006136	2.139739	0.0335
DTAM(-1)	0.099587	0.077876	1.278793	0.2023
DTAM(-2)	-0.106464	0.076562	-1.390566	0.1658
DBOL(-1)	0.148087	0.088719	1.669173	0.0965
DBOL(-2)	-0.080258	0.081470	-0.985125	0.3257
ECT_1_POS	-0.373320	0.094665	-3.943574	0.0001
ECT_1_NEG	0.046781	0.100200	0.466871	0.6411

R-squared	0.119632	Mean dependent var	0.000400
Adjusted R-squared	0.095063	S.D. dependent var	0.062915
S.E. of regression	0.059850	Akaike info criterion	-2.762933
Sum squared resid	0.770130	Schwarz criterion	-2.655641
Log likelihood	313.6855	Hannan-Quinn criter.	-2.719615
F-statistic	4.869321		
Prob(F-statistic)	0.000110		

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-2.726186	215	0.0069
F-statistic	7.432090	(1, 215)	0.0069
Chi-square	7.432090	1	0.0064

Null Hypothesis: C(6)=C(7)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6) - C(7)	-0.420101	0.154098

Restrictions are linear in coefficients.

5. Tamale-Accra Market Pairs

Dependent Variable: DTAMALE
Method: Least Squares
Date: 04/14/14 Time: 08:24
Sample (adjusted): 4 225
Included observations: 222 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.397840	0.319919	1.243565	0.2150
DTAMALE(-1)	-0.120876	0.090693	-1.332814	0.1840
DTAMALE(-2)	-0.152693	0.084117	-1.815247	0.0709
DACCRA(-1)	0.419809	0.071665	5.857960	0.0000

DACCRA(-2)	-0.093549	0.072859	-1.283959	0.2005
ECT_1_POS	-0.144596	0.086937	-1.663224	0.0977
ECT_1_NEG	0.012940	0.124036	0.104327	0.9170

R-squared	0.208459	Mean dependent var	0.228919
Adjusted R-squared	0.186370	S.D. dependent var	3.780361
S.E. of regression	3.409941	Akaike info criterion	5.322291
Sum squared resid	2499.955	Schwarz criterion	5.429583
Log likelihood	-583.7743	Hannan-Quinn criter.	5.365609
F-statistic	9.437015	Durbin-Watson stat	2.003275
Prob(F-statistic)	0.000000		

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-0.964026	215	0.3361
F-statistic	0.929346	(1, 215)	0.3361
Chi-square	0.929346	1	0.3350

Null Hypothesis: C(6)=C(7)
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6) - C(7)	-0.157536	0.163414

Restrictions are linear in coefficients.