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ABSTRACT

Policy makers have been striving through market reforms to ensure proper functioning of agricultural markets and marketing channels to ensure food security, realize welfare impacts from policies, bridge the gap between the affluent and deprived regions. The core of which is due to regional ecological differences among other factors. In addition, the purported ability of marketing participants to influence the conduct of the market and respond to certain price shocks more faster/slowly than others warrants examining the regional maize market linkages within the past decade. Using regional monthly wholesale price data from 2002 – 2010, the consistent threshold autoregressive model is employed for the study considering the robustness and the limitations of other approaches. Results indicate that regional maize markets are integrated. Bidirectional market interdependence was found between market pairs both in the short and long run. The long run causality was however heterogeneous with respect to positive and negative shocks. The nature of price adjustment is asymmetric and traders respond quickly when market margins are squeezed than when stretched for all market pairs except between Brong Ahafo and Greater Accra market pairings. The time path needed for adjustment ranged from 7 to 26 months. The minimum adjustment time was 7 months occurring between Brong Ahafo - Greater Accra markets linkage for positive deviations and Brong Ahafo - Ashanti market for negative deviations. The recent expansion in communication infrastructure motivates the regional market integration. This implies that resources should be allocated to transportation development; the main hindrance to trade. The suboptimal condition of asymmetry is also motivated by inventory behaviour of traders but this remains a testable hypothesis. Traders in Greater Accra are slow in passing on price increases for the fear of loss of goodwill and/or loss of customer share given the multiple sources of supply.

Keywords: Threshold Cointegration, Maize, Ghana, Price Transmission

1 INTRODUCTION

1.1 Background

Ghana like most other developing countries in Africa embarked on economic reforms in the past three decades on agricultural markets that led to the liberalization of most state controlled sectors. The events that trigger agricultural market reforms are 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). The Food and Agricultural Sector Development Policies over the past decade 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 II, 2002; FASDEP II, 2008). The improvement in the efficiency of Ghana's agricultural markets is relevant for growth given that the country is basically agrarian hence agriculture contributing the largest share to the economy.

The professed ability of trade liberalization to integrate markets through demand and supply forces and offer producers high price incentives was a major economic need that contributed to Ghana and most developing nations in Africa to adopt liberalization policies (Amikuzuno, 2010). A contentious issue of discussion for countries that embarked on market reforms is whether price transmission between spatial domestic markets have improved or not (Badiane and Shively, 1997). 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 regionally separated markets to each other.

Economic theory postulates that the proper functioning of markets and marketing channels is essential for the optimal allocation of resources (Abdulai, 2000). Spatial market integration or price transmission has become a common tool and an indicator for measuring market performance in a number of countries. According to McNew (1996), market integration is less clearly defined and often based on statistical criteria than economic phenomena and due to the imprecise definition in literature, empirical procedures have also varied. Spatial market integration measures the extent to which markets at geographically distant locations (such as between regions) share common long-run price or trade information on a homogenous commodity. Such markets are connected by arbitrage and this is reflected in the price information of the respective regional markets.

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) indicate that symmetric relationships are often assumed to be representative of competitive markets, while asymmetric responses are linked with the existence of some market imperfections (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. According to Langyintuo (2010), traders usually organize themselves into associations under the leadership of a "market queen" with the objective of influencing the conduct of the market, hence portraying the maize market as a characteristic of imperfectly competitive market.

The analysis of price transmission is captured with cointegration models where it is often assumed that the tendency for markets to move towards the long-run equilibrium is always present. This assumption however does not always hold in the presence of fixed costs of adjustment and economic agents may adjust continuously only when the benefits of adjustment exceed the cost. Thus, adjustment occur only after the deviation from equilibrium exceeds some critical threshold (Seo, 2006) often caused by transaction cost which result in nonlinear pattern of price adjustment or asymmetries. In such cases shocks above certain threshold bring about a different response than do smaller shocks (Falsafian and Moghaddasi, 2008) because transaction cost is often higher than potential earnings due to price differential. Moreover, traders may often respond quickly to shocks that squeeze their profit margins than those that stretch it. As a consequence traders may not fully or may slowly pass on cost decreases in contrast to cost increases which are passed on across markets more quickly.

Ecological conditions influence the differences in regional maize production in Ghana. This condition combined with other factors creates 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 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 questions as to whether regional markets are integrated or do they share common long-run price movement? Are the responses of regional markets to each other a/symmetric? And how long does a market take to complete adjustment when there is a price shock in the other?

1.2 Objective of the Study

Given that prices drive resource allocation and output mix decisions by economic actors, the main objective of the study is to analyze the dynamics of price transmission relationships between regional markets in Ghana. The specific objectives addressed in this work is to determine whether regional price movement of maize share a common long-run relation, to determine if the response of price shocks are a/symmetric and to determine the time path needed for shocks to be transmitted from one region to the other.

Though there have been extensive studies on the Ghanaian maize market, a continuous knowledge of the spatial performance of the markets is relevant for policy initiatives especially with the continuous efforts in the agricultural market policy development and other policy initiatives over the last decade. The study intends to contribute to the growing body of literature in price transmission modeling.

1.3 The Organization of the Study

The problem background and objectives of the study are presented in the first section while section two discusses the literature review and theoretical concepts related to the problem under study. Section three also presents the systematic empirical methodology employed in study. The results and discussion are presented as the fourth section whiles the summary, conclusion and recommendation are finally presented in section five.

2 LITERATURE REVIEW

This section presents the general overview of the maize economy in Ghana followed by the theoretical concepts and finally some empirical evidence related to this study.

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 a bulk of the Upper East Region). The cropping system and production technologies vary between the remaining four agro-ecological zones[1] 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 middle parts or the transitional zone which includes Brong Ahafo and parts of Ashanti and Eastern regions of Ghana (WABS, 2008). The maize market in Ghana comprise of the yellow maize which is mostly used in the poultry industry and the white maize used as 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 market while limited amount of yellow maize is imported for poultry feed industry with some internal cross-border trade occurring with the Sahel 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 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 when farmers generally sell their output immediately after harvest, usually between August to October to meet their cash needs. The minor season harvest occurs in January and February which is sometimes stored and sold between May and July when

[1] The agro-ecological zone is presented in Figure 3.1in the third section

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).

The 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 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 (This inventory behavior is also hampered by the uneven distribution of maize across time caused by seasonal factors and inadequate storage facilities). The local assemblers and commission agents often act individually while the wholesalers organize themselves into associations under the leadership of market queens who sometimes influence the conduct of the market (Langyintuo, 2010). This is a characteristic of imperfectly competitive market, however Alderman and Shively (1996) indicate the maize market appear 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 lasting 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, Eastern Region services Central Region while Greater Accra is supplied from Brong Ahafo, Ashanti and Eastern Regions (Langyintuo, 2010). Langyintuo characterize the maize market as imperfectly competitive since the association of the wholesalers if successful; have the power to collude to maximize joint profits and where ineffective traders make strategic moves to maximize their individual profits.

Unlike most African countries such as Tanzania (prior to 1990), the state never played a dominant role in maize marketing in Ghana. The marketing parastatal, GFDC never accounted for greater than 15 percent of the total marketable surplus, leaving majority of the marketing activity a private commercial system (Al-Hassan et al., 1999). The involvement of the state in maize marketing in Ghana however depressed maize prices while reducing price variability (Badiane and Shively, 1997) but ceased operation in the mid 1990s due to bad management. The introduction of the Economic Recovery Program in the 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 (surfaced with asphalt) 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 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) indicates a mobile phone penetration rate in Ghana is about 73 percent and was expected to be 80 percent by the end of the year 2011. It has become a substitute for travel and a quicker and easier means of accessing market information for commerce. Egyir et al. (2011) report the significant contribution of mobile phones as the single most important ICT tool driving price transmission in the food commodity market 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 Spatial Arbitrage, 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. 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), but the growing body of literature recognize these terms to be related and 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). Spatial market integration however 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 location. In Barrett and Li (2002), market integration is defined 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 which assumes that price relationships between spatially separated competitive markets depend on the size of the transaction costs (Barrett, 2005). 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 by the transport cost T_t, thus $P_{1t} = P_{2t} + T_t$. Trade between the two regions occurs only if $|P_{1t} - P_{2t} > T_t|$. Earlier studies on spatial market integration tested this formulation in the concept of the "Law of One Price" using regression analysis.

The study of Goletti et al. (1995) indicates 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 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 diversity in their respective self-sufficiency position. 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.

2.3 Techniques for Measuring 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 are discussed in the subsections below.

2.3.1 Static Price Correlation Methods

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 a homogeneous good 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. The regression coefficient measure follows the "Law of One Price" (LOP) which is based on the formulation;

$$P_{1t} = \beta_0 + \beta_1 P_{2t} + \varepsilon_t \tag{2.1}$$

The ε_t is the error term and β_0 and β_1 are parameters to be estimated. The strong version of the LOP states that prices of a given good on spatially separated markets are equal and move perfectly together in time and the necessary condition is to test $\beta_0 = 0$ and $\beta_1 = 1$. A weak version of the LOP was also defined since the strong version rarely occurs in reality and hence the necessary restriction for equation (2.1) is to test $\beta_0 \neq 0$ and $\beta_1 = 1$. Recent developments in time series econometrics allow 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 weaknesses 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 above. 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. Letting P_{1t} and P_{2t} represent local and central markets respectively, the model can be expressed as:

$$P_{1t} = \sum_{j=1}^{n} \alpha_j P_{1t-j} + \sum_{j=0}^{n} \beta_j P_{2t-j} + \gamma X_t + \varepsilon_t \tag{2.2}$$

j is the lag lengths and X represents the constant, seasonal, time and policy variables. From the above model, the restriction $\beta_j = 0$ 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 $j = (1,...n)$ and failing to reject this hypothesis implies 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 $\sum \alpha_j + \sum \beta_j = 1$, 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 the 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 whiles the 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 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 co-movement as indicated by the concept of market integration. The magnitude of the co-integration 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 the threshold autoregressive and the parity bound models in recent analysis of market integration.

2.3.5 Parity Bound Models

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; 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; trade will not occur and spatial arbitrage conditions are not fulfilled whiles 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; Sonogo, 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.

2.3.6 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) or 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 (Abduali, 2006).

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) or 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), and 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 (see von Cramon-Taubadel and Fahbusch, 1994; von Cramon-Taubadel and Loy, 1996). Other studies (Engle and Granger, 1998; Enders and Siklos, 2001; Abdulai, 2000 etc) 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 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 due mention 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 behavior 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 FIFO accounting criteria does not allow firms to adjust output rapidly to cost changes until inventory is depleted whiles the 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 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. They argue from Ward (1982) perspective 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 goodwill.

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 received extensive study on price behaviour and their response to each other most especially in the maize market. Earlier studies began with researchers such as Alderman (1992), 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 (1992) employs the Ravallion dynamic model and the standard cointegration technique to find out if price movements for maize (the main cereal consumed in Ghana) are fully transmitted to other regions. However, he notes imperfections in how market information is processed. 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 indicate in their findings that, markets in Ghana appear to function reasonably well with the exception of rice. Markets integrate in the long-run though markets 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) investigate 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 show that 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 and Bolgatanga in the Upper East regions).

In a similar study as those discussed above, Abdualai (2000) utilizes the threshold cointegration 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. In Cudjoe et al. (2007), a pair-wise correlation analysis reveals high correlation between the price of imported rice (the main imported food product in Ghana) and local staples (local rice, maize, cassava and yam) in the markets located in the poorest regions, thus Wa and Tamale located in the northern part of the country. Correlation coefficient is also relatively high between world prices of rice and maize. A more robust test using the Johansen cointegration test reveals heterogeneity of price transmission in Ghana. Price transmission is high for grain products both in the short and long run while for root crops such as cassava and yam, no evidence of price transmission is found across different regional markets. Asuming-Brempong and Osei-Asare (2007) however use 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 investigate the gains from ICT based market information services in the Ghanaian food commodity markets using the Ravallion-Timmer model in 11 selected markets. The study reveals 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) indicate 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, i.e. 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) find 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.

Zooming out of the corridors 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. He therefore suggests investment in the transport sector as a possibility of reducing these costs. Badiane et al. (2010) analyze 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 whole 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 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 use 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 a higher half-lives ranging from 3.9 to 22 weeks. Observing the nonlinearities caused by transaction cost, the half-lives reduces 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 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) study 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.

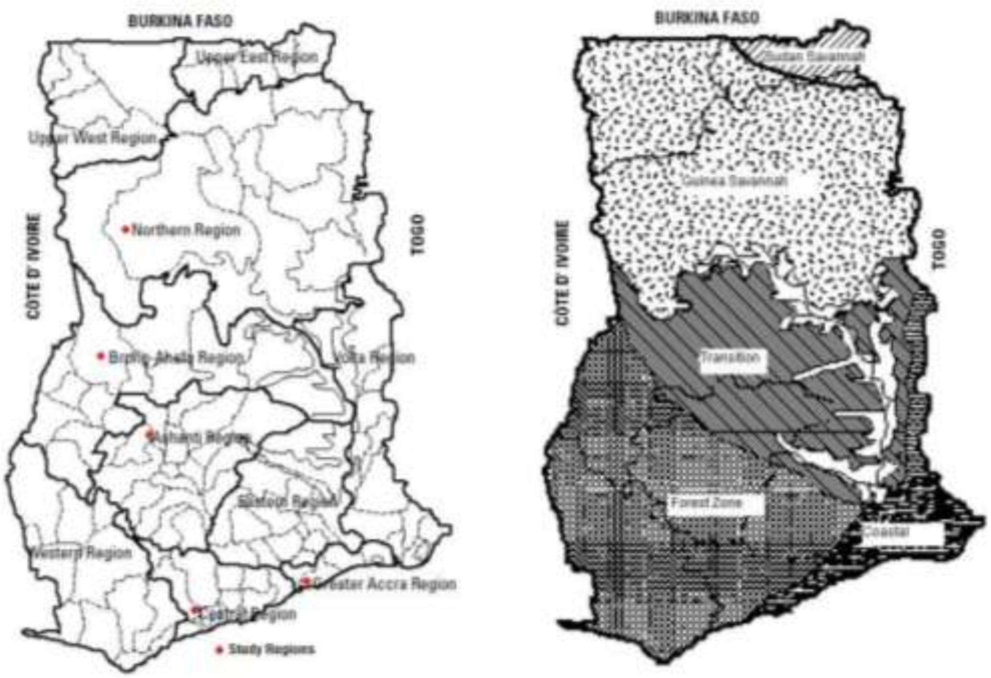
3 METHODOLOGY

This section presents the study areas under consideration followed by the data collection and handling and finally discusses the empirical approach used for the study.

3.1 The Study Area

The study focuses on Ghana located in West Africa and surrounded by Burkina Faso in the north, Togo in the east, Cote d'Ivoire in the west and the Gulf of Guinea in the south. There are ten administrative regions in the country (refer to Figure 3.1) comprising of Upper West, Upper East, Northern, Brong-Ahafo, Ashanti, Volta, Central, Eastern, Western and Greater Accra. However, the markets under study are Brong-Ahafo (BA), Ashanti (AS), Northern (NR), Central (CR) and Greater Accra (GA) regions. These locations are selected based on the availability of data. 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, Brong-Ahafo is taken as the central/reference market along which other markets are compared.

Figure 3.1 Regional Boundaries and Agro-ecological Zones in Ghana



Source: adopted from Morris et al. (1999)

3.2 Data Collection and Treatment

Secondary data of wholesale white maize price series from the regions under consideration were used in the study. The data was obtained from the Ministry of Agriculture Statistical Research and Information Directorate (MoFA-SRID). The data used were monthly averages of rural and urban wholesale prices of maize from the various regions but due to lots of missing values prior to 2002; the study considered price data from January 2002 to December 2010 making a total of 108 observations. Within this period, regions with more than two consecutive and recurring missing values were dropped. Hence one or two consecutive missing values were interpolated with the average of the previous four months. The total numbers of observations missing for the selected series were 2, 3, 1 and 6 for GA, AS, BA and NR respectively. The price units of the data collected from MoFA-SRID were for per 100kg of white maize. Prices prior to July 2007 were in old Ghana 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 Ghanaian 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. It is often more interesting to know how price of a commodity change relative to other prices in the economy, but since comparison of prices in the study was at the same level of the market and for the same homogenous commodity, nominal values were used in the analysis without deflating.

3.3 Analytical Approach

The modern view of market integration is mostly analyzed with cointegration models which evolved due to the behavior of economic series being nonstationary, thus series increase or decrease over time. Hence, the use of cointegration models begin with univariate analysis of each price series called unit root test which reveals the underlying data generating process. A variable y_{it} is said to have unit root or integrated of order one (represented as $y_{it} \sim I(1)$) if the first difference (Δ^1) is stationary (i.e. $\Delta^1 y_{it} \sim I(0)$). Granger and Newbold (1974) indicate that estimating ordinary least square regression from time series that exhibit random walk often lead to spurious regression and hence hypothesis test of parameters become invalid. Studies of spatial market integration exhibit similar approach to the study of statistical properties of variables. However, failure to study the properties properly results in inconsistent results (Alemu and Van Schalkwyk 2009). In analyzing the underlying data generating process, factors that can affect inference on unit root are considered, which include seasonality and structural breaks.

3.3.1 Seasonality in Time Series

While most studies on market integration relied on readily available seasonally adjusted data, majority rely on seasonally unadjusted price data. For modeling purposes price data collected for several periods in a year must be adjusted for seasonality to avoid inconsistent and inaccurate results (Alemu and Van Schalkwyk 2009). The seasonal fluctuations in price data can be a stable one resulting from weather or natural conditions or can be variable resulting from the behavior of economic agents. According to Hylleberg et al. (1990), seasonality can be deterministic (i.e. repetitive year after year and hence capable of prediction without error from previous months), stochastic (evolves over time) or both. A deterministic process can be modeled by regression models with seasonal dummy variables. A stochastic process also be stationary over time or seasonally integrated i.e. non-stationary integrated process (Schulze, 2009) and will have to be modeled with the appropriate filtering approach (e.g. $1-L^s$ where s is the number of observations per year) to render the series stationary. In most studies of agricultural market integration, researchers assume deterministic process which can lead to spurious regressions, model misspecification and affects model performance if the seasonal process changed over time (Schulze, 2009, Shen et al., 2009). This is because the seasonal dummies do not reflect the dynamic nature of the seasonality inherent in the actual data. The dummy coefficients only reflect initial conditions plus the accumulation of random shocks (Shen et al., 2009).

In determining how to model seasonality in this study, the seasonal unit root test developed by Hylleberg et al. (1990) often called HEGY for quarterly data and later extended by Franses (1991) and Beaulieu and Miron (1993) for monthly data was used. This model allows examining both the seasonal and non-seasonal unit root process of the data. The null hypothesis of unit roots at zero and monthly seasonal frequencies against the alternative of stationarity was tested. The model below was considered:

$$\Delta_{12} y_{it} = \beta_0 + \gamma t + \sum_{i=1}^{11} \beta_i D_{it} + \sum_{k=1}^{12} \pi_k z_{k,t-1} + \sum_{j=1}^{p} \delta_j \Delta_{12} y_{it-j} + \varepsilon_{it,1} \tag{3.1}$$

Where the parameters β_0, β_i, π_k and δ_j are estimated with OLS. In model (3.11), β_0 is the constant, D_{it} represents seasonal monthly dummies with $D_{it} = 1$ for month i and 0 otherwise, t is the trend variable, $z_{k,t-1}$ are nonsingular linear transformations[2] of lagged values of y_{it} , $\varepsilon_{it,1}$ is the error term and the value of p is automatically selected with BIC. In order to test for unit root at zero and π frequency, the null $H_{k0} : \pi_k = 0$ for $k = 1,2$ were tested against the alternative $H_{k1} : \pi_k < 0$ using t-statistics. The complex unit roots were tested with the joint null hypotheses $H_{k0} : \pi_{k-1} = \pi_k = 0$ for $k = 4,6,8,10,12$ against the alternative H_{k1} : at least one of π_{k-1} and π_k is different from zero using F-statistics[3]. The statistics were then compared to the

[2] Refer to Appendix A of Beaulieu and Miron (1993) for the transformation expression excluded from this study for the sake of brevity.
[3] A t-statistic can also be used to test for unit root at the individual frequencies for k=3, 4... 12.

critical values generated by Beaulieu and Miron (1993). Hylleberg (1995) recommends it is best to complement the HEGY type of test with the seasonal unit root approach by Canova and Hansen (1995). The Canova and Hansen approach is a Lagrangian Multiplier type based that test the null of stationarity (seasonal pattern is deterministic) against the alternative of seasonal unit root for the individual or joint frequencies from the equation:

$$y_t = \alpha y_{t-1} + \sum_{i=1}^{s-1} D_{it}\beta_{it} + \varepsilon_t \qquad (3.2)$$

The notion behind the Canova-Hansen approach is to the instability of the parameter β_{it} similar to that of KPSS test. From equation (3.2) $\beta_{it} = \beta_{it-1} + u_t$ was estimated and $Var(u_t) = 0$ was tested. The null hypothesis is rejected in case the seasonality in a series is not constant. This means the null should not be rejected after seasonally adjusting the data or having no seasonal pattern at all implies that seasonality is constant. The LM-statistic from the test was then compared with the appropriate critical values for the specific frequency or joint frequencies. The seasonal frequencies in monthly data are represented by $\pi, \pi/2, 2\pi/3, \pi/3, 5\pi/6$ and $\pi/6$ which are equivalent to 6, 3, 4, 2, 5 and 1 cycles per year respectively (Canova and Hansen, 1995 and Beaulieu and Miron, 1993).

The appropriate filter was applied to the time series data depending on the conclusions from the seasonality test. In the case of deterministic seasonality, the OLS estimator is the same irrespective of whether the seasonal dummies are introduced into the regression model, or whether both the regressand and regressor or only the regressor is seasonally adjusted by regressing them on the seasonal dummies and a constant before running a regression using the seasonally adjusted data (Brendstrup et al., 2001).

3.3.2 Unit Roots in the Presence of Structural Breaks

Using the seasonally adjusted data following the result above, further analysis of unit root was conducted. The Augmented Dickey Fuller formulation was used to determine the presence of unit root in the deseasonalized series denoted as P_{it} hereafter. Thus, the regression

$$\Delta P_{it} = \alpha_o + \gamma t + \psi P_{it-1} + \alpha_j \sum_{j=1}^{m} \Delta P_{it-j} + u_{it} \qquad (3.3)$$

was estimated where α_o, γ, ψ and α_j are parameters to be estimated, $P_{it}(i = 1, 2, ...)$ is the price series, t is trend variable, $j = 1, 2, ...m$ is the lag length determined by AIC or BIC and

u_{it} is the disturbance or error term. The null hypothesis tested was P_{it} has unit root ($Ho:\psi=0$) against the alternative P_{it} is stationary ($H_1:\psi<0$). The t-statistic of the parameters were compared to Dickey and Fuller (1981) critical values to make inference as to whether the series is a random walk (if $\psi=0$) with drift (if $\alpha_o\neq0$) and deterministic trend (if $\gamma\neq0$) using the t-statistic or alternatively F-statistic. If $\gamma=0$, the model is estimated without trend and subsequently if $\alpha_o=0$, the model without the drift term is estimated. Failing to reject the null hypothesis of unit root implies taking the first difference and testing again until the d^{th} difference (Δ^d) is stationary. For certainty and imperfection of the ADF test, the PP test was also applied hoping that the verdict of one will confirm the other. The estimation and testing procedure of the PP test was not discussed for the sake of brevity[4].

A known weakness of the Dickey-Fuller type test is its potential confusion of structural breaks in the series as evidence of nonstationarity (Baum, 2001) and in the presence of structural break; the ADF is biased towards the non-rejection of the null hypothesis. Perron (1989) proposed allowing for a known or exogenous structural break in the test which was later criticized as an approach which invalidates the distribution theory underlying the conventional testing. Following this several researchers developed approaches that allow determining single and multiple break points endogenously (Zivot and Andrews, 1992; Perron, 1997; Lumsdaine and Papell, 1998; Clemente, Montañés and Reyes, 1998). In this study the Zivot and Andrews (1992) test which allows for a single structural break in the intercept and/or the trend of the series determined by a grid search over possible break points was used to verify the behavior of the series. The break date is selected where the t-statistic from the ADF test of unit root is at a minimum or most negative (Glynn et al., 2007). The Zivot and Andrews's model allowing for both break in trend and intercept is expressed as:

$$\Delta P_{it}=\alpha_o+\gamma t+\psi P_{it-1}+\theta_1 DT_t+\theta_2 DU_t+\alpha_j\sum_{j=1}^{m}\Delta P_{it-j}+u_{it} \qquad (3.4)$$

where θ_1 and θ_2 are parameters to be estimated in addition to the ADF equation. ($DU_t=1$ if $t>TB$ and 0 otherwise) is a dummy variable indicator for a shift in mean at each possible break date (TB) while ($DT_t=t-TB$ if $t>TB$ and 0 otherwise) is the corresponding trend shift variable. Restricting $\theta_1=0$ is a model with only shift in intercept while $\theta_2=0$ is a model representing only shift in trend. The null hypothesis tested was P_{it} contains unit root with a

[4] Eviews 7 manual provides a comprehensive application of the PP test.

drift that excludes a structural break while the alternative hypothesis was that the series is trend stationary process with a one-time break occurring at an unknown point in time.

3.3.3 Cointegration Analysis

The concept of cointegration is based on the fact that if price series P_{it} (denoted P_t^i hereafter) are integrated of the same order, say order one, then a linear combination of the series produces a stationary series which is used as an indication of market integration. Consider the long-run relationship between the prices in a given local market P_t^1 and the central market P_t^2 such that:

$$P_t^1 = \alpha_0 + \alpha_1 P_t^2 + \mu_t \qquad (3.5)$$

Where P_t^1 and P_t^2 are nonstationary series, μ_t is the random error term with constant variance that can be contemporaneously correlated, α_0 (an arbitrary constant that accounts for price differential, i.e., transportation costs and quality differences) and α_1 (slope) is the parameter of the cointegration regression. Then according to Engle and Granger (1987), long-run market integration within this framework involves testing whether the marketing margin (μ_t) was stationary by estimating the following relationship:

$$\Delta\mu_t = \rho\mu_{t-1} + \varepsilon_t \qquad (3.6)$$

where the lags of the dependant variable can be included by relying on information criterions to ensure that the error term (ε_t) is a white noise process. Stationarity of the residuals (i.e., $-2 < \rho < 0$) with mean zero indicates rejection of the null hypothesis of no cointegration ($\rho = 0$) where the t-statistic is compared to the Dickey-Fuller critical values for unit root test. The study of co-movement of variables in the long-run according to Enders and Siklos (2001) can alternatively be captured with the Johansen procedure which involves the specification of the functional form:

$$\Delta x_t = \pi x_{t-1} + v_t \qquad (3.7)$$

where x_t is an (nx1) vector of random variables all integrated of degree 1, π is an (nxn) matrix, v_t is an (nx1) vector of normally distributed disturbances. Equation (3.7) can be augmented with deterministic regressors, lags of Δx_t and also allowing the components of x_t to be integrated of various orders. The underlying mechanism of the above formulation is the estimation of π and determining its rank (r). The implicit assumption is that if $\pi \neq 0$, then the system exhibits symmetric adjustment around $x_t = 0$ in that for any $x_t \neq 0$, Δx_{t+1} is always πx_t . The Johansen approach makes use of the Trace Eigen value and Maximum Eigen value statistics. Johansen and Juselius (1990) indicate that the decision should be based on the Maximum Eigen value statistic should both test statistics result in different inferences. Unlike the Engle and Granger approach, the Johansen procedure allows for more than one cointegrating relationships. Also, it is well known that conclusion from the Engle and Granger procedure depends on the choice of dependant variable which is resolved with the Johansen procedure (Goodwin and Schroeder, 1990).

The cointegration approach of Johansen and Engle and Granger implicitly assume a linear and symmetric adjustment mechanism. The point here is that the cointegration tests and their extensions are mispecified and have low power in the presence of asymmetric adjustment (Enders and Siklos, 2001; Enders and Granger, 1998; Balke and Fomby, 1997). This led to the application of new models such as threshold autoregressive models which recognize transaction cost in spatial price linkages. To allow for the recognition of transaction costs and the test for asymmetry, the threshold models of Ender and Granger (1998) and Enders and Siklos (2001) were applied in this study. The threshold autoregressive model can be expressed using the residuals from equation (3.5) as:

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1-I_t)\rho_2\mu_{t-1} + \sum_{i=1}^{p}\gamma_i\Delta\mu_{t-i} + \omega_t \qquad (3.8)$$

Where I_t is the Heaviside indicator function such that

$$I_t = \begin{Bmatrix} 1 & if\,\mu_{t-1} \geq \tau \\ 0 & if\,\mu_{t-1} < \tau \end{Bmatrix} \qquad (3.9)$$

and τ is the value of the threshold, ω_t is a sequence of zero-mean, constant variance iid random variables, such that ω_t is independent of $\mu_j, j < t$. The adjustment is symmetric if the speed of adjustment coefficients $\rho_1 = \rho_2$, and hence become a special case of Engle-Granger approach in equation (3.6). The lagged dependent variable was included to ensure the residuals were white noise and the lag length was selected using AIC or BIC. If the system is convergent then the long-run equilibrium value of the sequence is given by $\mu_t = \tau$. In such cases, adjustment is $\rho_1\mu_{t-1}$ if μ_{t-1} is above its long-run equilibrium value and $\rho_2\mu_{t-1}$ if μ_{t-1} is below long-run equilibrium. If for instance $-1 < \rho_1 < \rho_2 < 0$, then the negative phase of the μ_t series will tend to be more persistent than the positive phase. If the Heaviside indicator function depends on μ_{t-1} as in equation (3.9), then equation (3.8) is termed Threshold autoregressive model (TAR). However, when the Heaviside indicator depends on the previous period's change in μ_{t-1}, i.e. Momentum Heaviside Indicator:

$$I_t = \begin{cases} 1 & if\,\Delta\mu_{t-1} \geq \tau \\ 0 & if\,\Delta\mu_{t-1} < \tau \end{cases} \qquad (3.10)$$

then equation (3.8) is called Momentum-threshold autoregressive (M-TAR) model in that the μ_t series exhibit more "momentum" in one direction than the other. For M-TAR, if $|\rho_1| < |\rho_2|$, then the model exhibits little adjustment for positive but substantial decay for negative, thus, increases tend to persist but decreases tend to revert quickly to the attractor irrespective of where disequilibrium is relative to the attractor. According to Enders and Granger (1998), MTAR representation may capture sharp movements in a sequence while TAR is used to capture a deep-cycle process if, e.g. positive deviations are more prolonged than negative deviations. There is generally no presumption as whether to use TAR or MTAR model, the recommendation is to select the adjustment process by a model selection criterion such as AIC or BIC.

The null hypothesis tested in the threshold model was no cointegration which is based on a nonstandard joint F-test of $\rho_1 = \rho_2 = 0$. The test statistic Φ_i ($i = TAR, MTAR$) was compared to critical values provided by Enders and Siklos (2001) when the point estimates of ρ_1 and ρ_2 imply convergence ($\rho_1 < 0, \rho_2 < 0$), alternatively the maximum t-statistic ($t - Max_i$ where $i = TAR, MTAR$) can be used. When the null hypothesis of no cointegration is rejected, then a standard F-test of symmetric adjustment can be performed by testing if $\rho_1 = \rho_2$. Rejection of both null hypotheses $\rho_1 = \rho_2 = 0$ and $\rho_1 = \rho_2$ imply the existence of threshold cointegration and asymmetric adjustment (thus price pairs exhibit nonlinear adjustment). The distribution of the test of the null of no cointegration is nonstandard and depends on the number of regressors included in equation (3.1) and the deterministic components.

According to Enders and Siklos (2001), τ is set to zero in most economic applications so that the cointegrating vector coincides with the attractor. However, in many applications, there is no a priori reason to expect the threshold to coincide with the attractor and therefore it becomes necessary to estimate the value of τ along with the values of ρ_1 and ρ_2. Omitting the presence of threshold effects in the long-run equilibrium relationships will lead to misleading interpretations of equilibrium relationships because the cointegrating vector will not be consistently estimated (Gonzalo and Pitarakis, 2006). Chan's (1993) methodology allowing a grid search over potential thresholds that minimize the sum of squared errors from the fitted model to yield a superconsistent estimate of the threshold was adopted. Thus, the estimated residuals were sorted in ascending order, i.e., $\mu_1 < \mu_2 < ... < \mu_T$ for TAR and $\Delta\mu_1 < \Delta\mu_2 < ... < \Delta\mu_T$ for MTAR where T denotes the number of usable observations. The largest and smallest 15 percent of the values were eliminated and each of the remaining 70 percent of the series μ_t was considered as potential threshold. For each of the potential thresholds, the models were estimated using equations (3.8) and (3.9) for TAR and (3.8) and (3.10) for MTAR and this is termed Consistent Threshold Autoregressive Models. The analog of the F-test and t-test statistics for consistent-threshold model specification in Enders and Siklos (2001) critical values are represented as Φ_i^* and $t - MAx_i^*$ respectively. Model diagnostics was performed on each model with Ljung-Box statistics to ensure the residuals were white noise. Considering the TAR and MTAR model, when $|\rho_1| < |\rho_2|$ then positive asymmetry exists and when $|\rho_1| > |\rho_2|$ the negative asymmetry exists.

3.3.4 Short-Run Dynamics of Price Linkages

When the price series are integrated or cointegrated, then an error correction model can be used to examine the short-run dynamics (Engle and Granger, 1987). Enders and Granger (1998) indicate that if threshold cointegration is satisfied, the estimate of symmetric error correction model would be an incorrect representation since positive and negative deviations would not reveal differential adjustments. Given that adjustment is asymmetric, the following asymmetric (equivalently "threshold") error correction models were estimated:

$$\Delta P_t^1 = \psi_0 + \sum_{h=1}^{r} \psi_h \Delta P_{t-h}^1 + \sum_{h=0}^{m} \alpha_h \Delta P_{t-h}^2 + \lambda_1 I_t \mu_{t-1} + \lambda_2 (1 - I_t) \mu_{t-1} + \in_{1t} \quad (3.11)$$

$$\Delta P_t^2 = \psi_0 + \sum_{h=1}^{r} \psi_h \Delta P_{t-h}^2 + \sum_{h=0}^{m} \alpha_h \Delta P_{t-h}^1 + \lambda_1 I_t \mu_{t-1} + \lambda_2 (1 - I_t) \mu_{t-1} + \in_{2t} \quad (3.12)$$

where $\in_{it}$ is the innovation with zero mean and constant variance. I_t is the corresponding Heaviside indicator from the threshold autoregression, $\psi_0, \psi_h, \alpha_h, \lambda_1 \, and \lambda_2$ are parameters to be estimated. For the sake of exposition and given that the direction of causality was unknown prior to estimation; the variable used as the dependent variable was treated as the local market. For instance, P_t^1 was treated as the local market variable in equation (3.11) but in equation (3.12), P_t^2 was treated as the local market variable. Theoretically, cointegration implies the existence of causality between variables but the direction of causality cannot be determined from the cointegration test in the (M)-TAR model. The vector error correction model is therefore a remedy for determining the direction of causality; hence equations (3.11) and (3.12) were both estimated for all market pairs. In this case the parameters of interest were the short-run parameter (α_h) for the explanatory variable and the adjustment parameter (λ_j). Granger causality tests were examined by testing whether the joint significance of all α_h statistically differs from zero ($\alpha_0 = ... = \alpha_m = 0$ imply short-run causality) based on Wald-test and/or whether the λ_j coefficients of the error correction model were also significant (long-run causality).The results of direction of causality from the estimation of the two models could be unidirectional causality or there could be feedback from both price series. From the error correction models, impulse-responses were calculated to determine the length of time needed to complete transmission of a price shock; often represented graphically. This length of time may vary depending on the direction of the shock in the case of asymmetric relationship between market pairs.

4 RESULTS AND DISCUSSION

The variability and movement of regional maize wholesale prices, the univariate analysis of the series, the test for cointegration and the short-run dynamic interrelationship between pairs of markets are presented in this section.

4.1 Price Variability, Trend and Seasonal Variation among Regional Markets

Agricultural prices in different markets are often influenced by fluctuations in production, seasonality and the general economic environment. 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 variability in prices over time and space prior to analyzing the price linkages. Table 4.1 shows the seasonally unadjusted nominal regional maize prices across the regions under consideration.

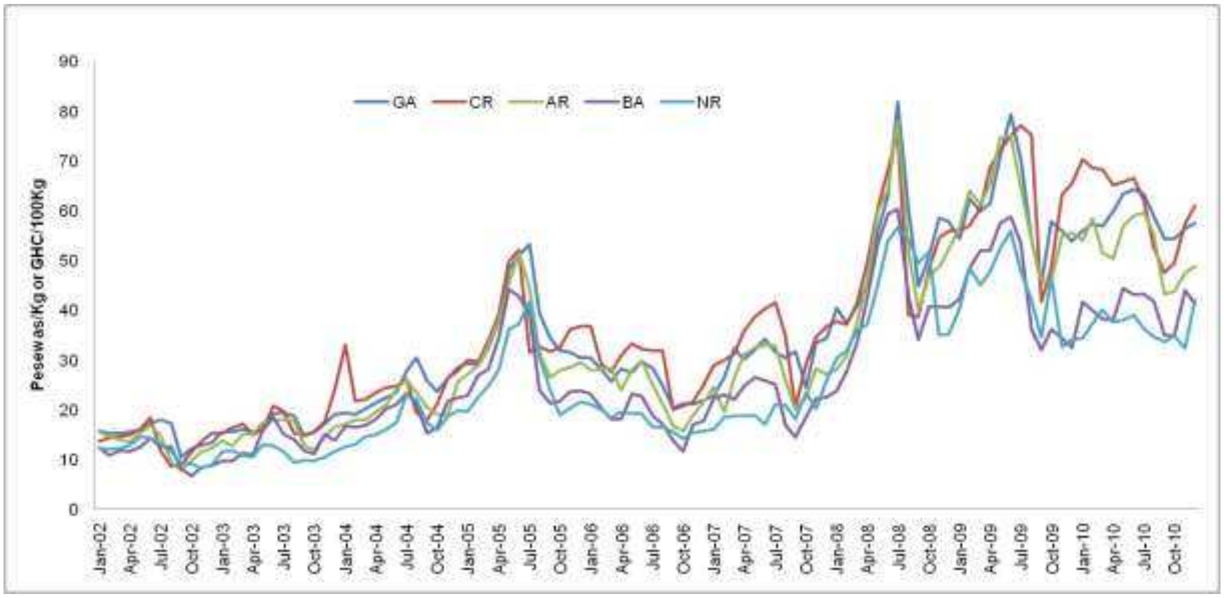
Table 4.1 Descriptive Statistics of Nominal Regional Maize Prices

	GA	CR	AS	BA	NR
Mean	35.80	36.54	32.93	26.68	25.46
Median	30.60	32.37	28.12	22.80	20.21
Maximum	82.00	77.25	78.16	60.39	56.67
Minimum	10.59	8.65	7.96	6.75	8.40
Std. Dev.	17.87	18.71	17.54	13.63	13.26
Coef. Variation	49.92	51.20	53.27	51.09	52.08
Observations	108	108	108	108	108

Across regions, the highest nominal wholesale price was observed in GA market with a maximum of 82 GHC/100Kg (i.e., 82 pesewas/kg) while the minimum was observed in BA market with 6.75 GHC/100Kg. The highest average wholesale price was however observed in CR market with 36.54 GHC/100Kg while the lowest average wholesale price was 25.46 GHC/100kg observed in NR market. The highest variability in price was 53.27 percent observed in the AS market as indicated by the coefficient of variation while the lowest was 49.92 percent observed in the GA market. The variations in prices were however approximately close to each other.

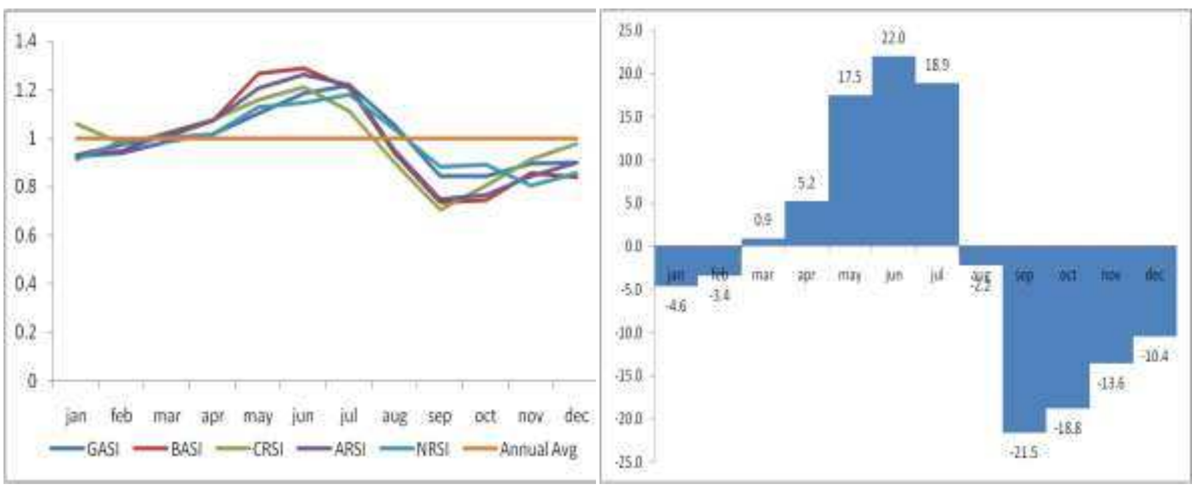
The regional wholesale prices vary periodically and portray trends and cycles or seasonal patterns which can be depicted graphically. As observed in Figure 4.1, regional prices generally followed the same pattern (i.e., move in the same direction) and increases over time. Prices were at their highest level in 2008 and 2009 periods with highest generally occurring in the GA market which was not surprising given the fact that consumption is concentrated in this region. BA and NR wholesale market prices were generally the lowest over time compared to the other regions under study.

Figure 4.1 Nominal Price Levels across Time by Regions from 2002 to 2010



Source: Authors computation from price data

Figure 4.2 Regional Seasonal Indexes and Average Seasonal Variation in Price



Source: Authors own computation from data a) b)

Agricultural prices have often exhibited seasonal variation tied to the annual nature of the crop cycle. Thus prices are often lowest in the harvest periods and high when they are out of season. In Figure 4.2 a), the seasonal variation is presented for all the regions and they appear to follow similar pattern. Prices generally start to rise above the annual average from April to July and gets to its peak in June while falling below the annual average price from August to February with the lowest price occurring in September. Figure 4.2 b) shows the percentage of the average seasonal variation. The highest price observed in June was on the average 22 percent above the annual average price whiles the lowest price occurring in September was on the average 21.5 percent below the annual average price.

4.2 The Univariate Analysis: Unit Root and Seasonality Tests

The HEGY type auxiliary regression in equation (3.1) was estimated with intercept and monthly seasonal dummies for which the results are presented in Table 4.2. The lags needed to remove serial correlation in the residuals were automatically selected with BIC.

Table 4.2 HEGY Test for Seasonal Unit Root

Frequencies	BA	GA	CR	NR	AS	Freq
π_1	-0.027	0.584	-1.471	-0.112	-0.567	0
π_2	-2.902**	-2.631*	-3.734***	-1.836	-2.882**	pi
$\pi_3 = \pi_4$	7.048**	4.455	6.395**	5.291*	11.817***	pi/2
$\pi_5 = \pi_6$	8.815***	11.864***	9.757***	6.959**	2.253	2pi/3
$\pi_7 = \pi_8$	4.756	16.690***	12.945***	8.674***	5.625*	pi/3
$\pi_9 = \pi_{10}$	7.930**	18.005***	7.458**	7.292**	15.502***	5pi/6
$\pi_{11} = \pi_{12}$	8.747***	8.633***	4.449	8.675***	13.290***	pi/6
T (Lags)	76(20)	76(20)	76(20)	82(14)	79(17)	
Canova Hansen Test						
$L_{\omega-joint} - Stat$	1.238	1.258	1.328	1.462	1.078	

*, ** and *** are rejected at 10, 5 and 1% respectively for HEGY. The joint critical values for Canova-Hansen test are 10%, 5%, and 1% are 2.49, 2.75 and 3.27 respectively.

The results failed to reject the null hypothesis at the zero frequency for all variables in the corresponding regions. The t-statistic for the bi-monthly seasonal frequencies also indicates rejection of the null of seasonal unit root for all regions except price series for NR. In each region, there was an indication of unit root for one joint seasonal frequency, thus at frequencies of pi/3 for BA, pi/2 for GA, pi/6 for CR, and 2pi/3 for AS. This is because the F-statistics failed to reject the null at all conventional significance levels. Because most of the unit roots at the seasonal frequencies were rejected, price series can possibly be modeled with deterministic seasonality. To confirm this assertion, the joint test of stationarity for all frequencies using the Canova and Hansen Lagrangian Multiplier statistic reported in the lower part of Table 4.2 was compared with the appropriate critical values. As observed, none of the null hypothesis in the various series was rejected at the conventional significance levels. In general there was an indication of unit root at zero frequency (non-seasonal components) while the seasonal components were constant over time. Hence it was best to treat seasonality as a deterministic component in the subsequent regressions. To control for seasonal factors in this study, all variables were regressed on the seasonal dummies and a constant as it makes no difference to the OLS estimates if the seasonal dummies were included in each regression. The residuals were then used as the seasonally filtered/adjusted series for further analysis.

4.3 Unit Root and Structural Breaks

The Philip Peron unit root test was estimated to complement the Augmented Dickey Fuller test in Table 4.3. With the exception of GA which had both drift and trend deterministic components, all the other regions can be characterized as a random walk process without drift and deterministic trend in the ADF tests. Though CR was represented as just a random walk in the ADF test, it was best described as a random walk with drift and trend in the PP test. The test statistic failed to reject the null hypothesis of a unit root in level data for all regions. However, the null hypothesis was rejected at 1 percent significance level after the first difference for both the ADF and PP tests.

Table 4.3 ADF and PP Unit Root Test

ADF Test			PP Test	
Variables	Level	First-Difference	Level	First-Difference
BA^{0}	-1.423	-5.265***	-1.060	-10.961***
GA^{11}	-2.647	-11.822***	-2.327	-11.832***
CR^{0}	-1.190	-10.446***	-3.000^{11}	-12.035***
NR^{0}	-1.016	-10.945***	-1.016	-10.945***
AS^{0}	-1.004	-10.464***	-1.004	-10.464***

^{0}, ^{10}, and ^{11} represent models without drift and trend, with only drift and with drift and trend respectively for ADF test. *** rejects the null at 1% level

The issue of structural break was considered using the Zivot-Andrews unit root test allowing for a single break point. In Table 4.4, break in intercept, trend and both were considered, where t-Min is the minimum ADF test statistic with the potential break date in parentheses.

Table 4.4 Zivot-Andrews Unit Root under Single Structural Break

Variables	Intercept t-Min (Break Point)	Trend t-Min (Break Point)	Both t-Min (Break Point)
BA	-3.113 (2006m2)	-2.681 (2004m8)	-3.455 (2005m8)
GA	-3.527 (2006m2)	-2.873 (2004m10)	-3.876 (2005m10)
CR	-3.285 (2006m2)	-2.976 (2004m2)	-3.897 (2006m2)
NR	-2.916 (2007m10)	-2.590 (2009m2)	-3.278 (2007m12)
AS	-3.113 (2006m3)	-2.697 (2009m10)	-3.499 (2005m11)

Series trimmed at 10%. Critical values for intercept: 1%: -5.43 5%: -4.80; trend: 1%: -4.93 5%: -4.42 and both: 1%: -5.57 5%: -5.08

The test statistic presented in each column failed to reject the null hypothesis of unit root process when compared with the critical values[5]. In summary, the HEGY, Canova-Hansen, ADF, PP and Zivot-Andrews tests show evidence that all variables have unit root at the zero frequency and hence can be concluded that price series in the various regions were integrated of order one. It was therefore appropriate to continue further with cointegration analysis.

4.4 Cointegration Analysis

The result of the cointegration regression (or the long-run relation) representing the first step of the Engle-Granger procedure is presented in Table 4.5 using BA as the reference/central market. The intercepts α_0 represent the constant absolute margin between the local markets and the central market, but these values were negligible. The slopes α_1 were close to one which provides support for spatial market integration (Falsafian and Moghaddasi, 2008). Since price series were nonstationary, formal hypothesis test on the parameters as a static representation of the law of one price would not be valid. This is because the estimated standard errors indicate inconsistency though the estimated parameters are consistent.

[5] The test rejects the null in first difference but this is not reported in the table for the sake of brevity

Table 4.5 The Long-Run Relationship Estimation Results

Local Markets	α_0	α_1	Adj. R^2
GA	-1.02E-15(-9.08E-14)	0.972(43.620)	0.947
CR	-1.07E-15(-6.30E-14)	0.984(29.011)	0.887
NR	-3.33E-16(-2.47E-14)	0.983(36.613)	0.926
AS	1.05E-15(9.04E-14)	1.017(43.786)	0.947

The values in parentheses are the t-statistics

The second stage of the analysis of market integration with the Engle and Granger approach was to examine the stationarity of the residuals generated from the cointegrating regression. Using the Dickey-Fuller approach in equation (3.6) but without the drift term, it was observed that for all market pairs $\rho < 0$ with t-statistics compared to Dickey-Fuller critical value of -2.587 at 1 percent significant level. The results indicate that the null hypothesis of no cointegration between the central market and local markets was rejected, which imply the corresponding markets were integrated. This result is presented in Table 4.6 below:

Table 4.6 Stationarity Test of the Long-Run relation residuals

Markets	ρ	Q (4)	Q (8)	Lags
GA-BA	-0.547 (-6.321)	1.975 (0.740)	13.212 (0.105)	0
CR-BA	-0.350 (-3.523)	0.013 (1.000)	1.506 (0.993)	2
NR-BA	-0.334 (-4.604)	0.080 (0.999)	1.687 (0.989)	0
AS-BA	-0.384 (-3.553)	0.476 (0.976)	1.733 (0.988)	2

Dickey-fuller critical value at 1 percent significance level is -2.587. Values in parentheses under ρ are the t-statistics and those under Q(4/8) are the probability values of the Ljung-Box statistics.

Evidence of long-run equilibria among the pairs of price series was strong, but since the Engle-Granger test has lower power than the Johansen test, Table 4.7 presents results of the latter to examine the long-run relationship. The null of no cointegration between all markets pairs were rejected at all conventional levels for both the Trace and Max-Eingen statistics while the test statistic failed to reject the null of one or fewer cointegrating vector between all market pairs. There was no conflict between the Trace and Max-Eingen statistics, so the Johansen approach indicates cointegration between variables. The AIC, HQIC, SBC selected lag length of 1 for all price pairs for the Johansen test.

Table 4.7 Johansen Cointegration Test

Markets	Trace Ho	Trace Statistic	Max Ho	Max-Eingen Statistic
GA-BA	$r=0$	28.433***	$r=0$	27.279***
	$r\leq 1$	1.154	$r=1$	1.154
CR-BA	$r=0$	23.291***	$r=0$	21.931***
	$r\leq 1$	1.360	$r=1$	1.360
NR-BA	$r=0$	18.476**	$r=0$	17.437**
	$r\leq 1$	1.040	$r=1$	1.040
AS-BA	$r=0$	30.818***	$r=0$	29.600***
	$r\leq 1$	1.218	$r=1$	1.218

Trend assumption: linear deterministic trend, indicates1 cointegrating equations at 0.05. ** and *** represent rejection of the null hypothesis at 5% and 1% significance level.

In concluding from both the Engle-Granger and Johansen tests; the linear combinations of regional markets price results in a stationary series. This indicates that markets were integrated and move together in the long-run.

4.5 Threshold Autoregressive Modeling Results

The threshold autoregressive models are presented in this section in order to test for possibilities of asymmetric adjustments other than assuming symmetric and linear relations as in the case of Engle-Granger and Johansen tests. Table 4.8 to Table 4.11 show TAR and MTAR estimations using the residuals from equation (3.5). Table 4.8 and Table 4.9 present models that assume that the threshold value is zero. AIC and BIC were used to select lag lengths of the dependent variable to ensure the residuals of the respective models were white noise. Where AIC and BIC selects different lag lengths, both models were estimated and the model with the best performance was presented. In both TAR and MTAR models with threshold value of zero, the null hypotheses of no cointegration ($\rho_1 = \rho_2 = 0$) was rejected at 5 percent significance level for all price pairs. This implies testing for the null of symmetric adjustment ($\rho_1 = \rho_2$); the test statistics failed to reject at all significance levels for all variable pairs except for NR-BA relationship in the MTAR estimation. This was rejected at 10 percent significance level.

Table 4.8 TAR Specification with ($\tau = 0$)

Parameters	GA-BA	CR-BA	NR-BA	AS-BA
ρ_1	-0.573 (-4.88)	-0.284 (-2.26)	-0.383 (-3.61)	-0.310(-2.22)
ρ_2	-0.515 (-3.99)	-0.423 (-3.24)	-0.291 (-2.90)	-0.449(-3.35)
$\rho_1 = \rho_2 = 0$	19.868***	6.560**	10.742***	6.634**
$\rho_1 = \rho_2$	0.112	0.738	0.407	0.682
Q (4)	0.755	1.000	0.999	0.963
Q (8)	0.102	0.996	0.988	0.989
AIC	-176.79	-102.15	-174.90	-172.84
Lags	0	2	0	2

t-statistics are in parentheses and Q (4/8) is probability values for Ljung Box statistics. ***, **, * are rejected at 1%, 5% and 10% respectively.

Table 4.9 M-TAR Specification with ($\tau = 0$)

Parameters	GA-BA	CR-BA	NR-BA	AS-BA
ρ_1	-0.554 (-3.37)	-0.400 (-3.44)	-0.218 (-2.22)	-0.383(-2.53)
ρ_2	-0.433 (-2.65)	-0.475 (-4.21)	-0.476 (-4.49)	-0.383(-3.01)
$\rho_1 = \rho_2 = 0$	6.524**	14.744***	12.538***	6.251***
$\rho_1 = \rho_2$	0.487	0.213	3.198*	0.000
Q (4)	0.961	0.397	0.993	0.976
Q (8)	0.987	0.756	0.995	0.988
AIC	-162.66	-103.40	-175.86	-172.13
Lags	6	0	0	2

T-statistics are in parentheses and Q (4, 8) is probability values for Ljung Box statistics. ***, **, * are rejected at 1%, 5% and 10% respectively.

Comparing the TAR and MTAR model specifications for NR-BA, MTAR shows better performance than the TAR based on the AIC values. This means the specification for the remaining price pairs exhibited symmetric adjustment and were equivalent to the Engle and Granger specification. Thus, GA-BA, CR-BA and AS-BA are cointegrated and exhibit symmetric adjustment such that deviations from the price pairs are not different for increases or decreases in shocks. The NR-BA market prices however exhibited threshold cointegration with asymmetric adjustment. The point estimate of $\rho_1 = -0.218$ and $\rho_2 = -0.476$ for NR-BA indicates that approximately 22 percent of positive deviation and 48 percent of negative deviation from the equilibrium were eliminated within one month.

Since there was no a priori knowledge of the true values of the critical thresholds, the consistent TAR and MTAR were estimated using Chan's (1993) methodology. Table 4.10

presents consistent TAR while Table 4.11 shows the consistent MTAR specifications. In the consistent TAR and MTAR, the null hypothesis of no cointegration was as well rejected at all significance level since the test statistics were greater than the critical values presented in Enders and Siklos (2001) at the respective lag lengths. Moving on further with the test for symmetric adjustment ($\rho_1 = \rho_2$) in the consistent TAR, the results indicate that GA-BA and NR-BA exhibited symmetric adjustment while CR-BA and AS-BA exhibited asymmetry in price adjustment.

Table 4.10 Consistent – TAR Specification

Parameters	GA-BA	CR-BA®	NR-BA	AS-BA®
τ	0.08317	-0.13427	0.07456	-0.10664
ρ_1	-0.614(-4.95)	-0.300(-2.94)	-0.422(-3.92)	-0.234(-1.82)
ρ_2	-0.483(-3.98)	-0.659(-5.45)	-0.262(-2.67)	-0.581(-4.10)
$\rho_1 = \rho_2 = 0$	20.186***	19.152***	11.226***	8.745***
$\rho_1 = \rho_2$	0.573	5.135**	1.214	4.438**
Q (4)	0.757	0.338	0.999	0.914
Q (8)	0.101	0.763	0.991	0.987
AIC	-177.26	-109.61	-175.72	-176.65
Lags	0	0	0	2

® indicate selected models based on AIC. T-statistics are in parentheses and Q (4, 8) is probability values for Ljung Box statistics. ***, **, * are rejected at 1%, 5% and 10% respectively.

Considering the results in Table 4.11, the symmetry tests ($\rho_1 = \rho_2$) in the consistent MTAR show the reverse of the consistent TAR. Thus, GA-BA and NR-BA showed asymmetric adjustment while adjustment was symmetric for CR-BA and AS-BA market pairs. The AIC values indicate that consistent TAR performed better than TAR model likewise consistent MTAR and MTAR models. Comparing model performance of the consistent threshold models, the consistent TAR specification for CR-BA and AS-BA also performed better than their counterpart consistent MTAR specification (i.e., they had minimum AIC values). Counter intuitively, the consistent MTAR specifications for GA-BA and NR-BA had minimum AIC values than their counterpart consistent TAR specifications; hence performed better in the consistent TAR. Model diagnostics for all specifications indicate the absence of serial correlation since the probability values of the Ljung-Box statistics were quite high. Therefore the models selected (indicated as ®) as the true model for further analysis and inference were the consistent TAR for CR-BA and AS-BA markets and consistent MTAR for GA-BA and

NR-BA markets. In this case the Engle-Granger test has low power than the selected specifications.

Table 4.11 Consistent - MTAR Specification

Parameters	GA-BA®	CR-BA	NR-BA®	AS-BA
τ	0.10691	-0.08648	-0.00026	-0.05793
ρ_1	-0.820(-5.278)	-0.350(-3.519)	-0.218(-2.224)	-0.312(-2.54)
ρ_2	-0.425(-4.162)	-0.606(-4.450)	-0.476(-4.487)	-0.523(-3.31)
$\rho_1 = \rho_2 = 0$	22.585***	16.092***	12.538***	7.069***
$\rho_1 = \rho_2$	4.510**	2.317	3.193*	1.455
Q (4)	0.743	0.366	0.993	0.948
Q (8)	0.097	0.759	0.995	0.967
AIC	-179.08	-105.52	-175.86	-173.63
Lags	0	0	0	2

® indicate selected models based on AIC. T-statistics are in parentheses and Q (4, 8) is probability values for Ljung Box statistics. ***, **, * are rejected at 1%, 5% and 10% respectively.

The consistent TAR in Table 4.10 for CR-BA with point estimates of $\rho_1 = -0.300$ and $\rho_2 = -0.659$ indicates that, approximately 30 percent of positive deviation (deviation above the critical threshold) and 66 percent of negative deviation (deviation below the critical threshold) from the equilibrium were eliminated within one month[6]. To illustrate further, assuming the price series were in equilibrium at period t, then the markets would move out of equilibrium in the presence of a shock. Through the forces of the invisible hands, the two markets move towards a new equilibrium position and during this process, part of the discrepancy from equilibrium would be eliminated. However, the rate at which the discrepancy would be eliminated as the two markets move towards the new equilibrium position depends on whether the direction of shock was a negative or positive in the case of asymmetry. If there was a positive shock, 30 percent of the discrepancy would be eliminated and 66 percent for negative shock for CR-BA regional price pairs. This implies 70 percent and 44 percent of positive and negative discrepancies from the equilibrium would still persist in the following months. So, the CR-BA markets respond much more quickly to shocks that squeeze profit margins than to shocks that stretch them (the direction of causality cannot be inferred at this point). Likewise in the AS-BA market pairings, the rates of adjustment for

[6] The use of the term positive and negative deviations hereafter with respect to the consistent threshold models means deviations above and below the estimated critical threshold values respectively.

positive and negative deviations were 23 percent and 58 percent respectively. There was also a faster response to shocks that squeeze profit margins than those that stretch them.

In Table 4.11, positive deviations were eliminated at the rate of 82 percent while negative deviations were eliminated at the rate of 43 percent for GA-BA market pair in the following months. This leaves 18 percent of the positive discrepancies from the equilibrium and 65 percent for the negative discrepancies. Unlike the other market pairs, there was faster response to shocks that stretched profit margins than those that squeezed them. The rate of adjustment for NR-BA market pair shows that 22 percent of positive deviations were eliminated in the following months while 48 percent of the disequilibrium was eliminated when there was a negative deviation. There was faster response to shocks that squeezed profit margins than those that stretched them (thus adjustment to equilibrium was faster when prices are falling). The estimated threshold value represents a proxy for transaction costs; since in spatial price transmission, it is often hypothesized that due to transaction costs traders will only respond to a deviation from the long-run equilibrium between two markets if the deviation exceeds certain threshold value. Considering the selected models, GA-BA and AS-BA markets only adjusted to bring the long-run relation back in line when the absolute price deviation exceeded 11 percent. Prices had to differ by 0.03 percent and 13 percent for NR-BA and CR-BA market pairs respectively to trigger adjustment to the equilibrium.

4.6 Short-Run Dynamic Inter-relationships

The market price data pairs exhibit causality given that they are cointegrated. However, the direction of causality cannot be determined from the cointegration test models. The error correction models presented in Table 4.12 and Table 4.13 were used to examine the short-run dynamics of price relationships. For market pairs that exhibited consistent threshold cointegration, threshold error correction (Table 4.12) was estimated. Momentum threshold error correction was estimated for market pairs exhibiting consistent momentum threshold cointegration (Table 4.13). The response of the dependent variable (local market) to the changes in the explanatory variable (central market) was generally distributed overtime other than instantaneous, hence in determining the optimal lag length HQIC, AIC and FPE selected 1 lag for NR-BA and 2 lags for the remaining market pairs. The model diagnostics indicated that the error correction models do not suffer from serial correlation since the probability value of the Ljung-Box statistics for all the lags were higher than the conventional accepted levels of significance. The probability values for the lags at 4 and 8 were presented as evidence.

Though the autoregressive conditional heteroscedasticity (ARCH) test ($x^2_{ARCH(1)}$) was slightly high for the CR error correction model (rejected at 10 percent significance), all test statistics were rejected at 5 percent and 1 percent levels indicating that there was no evidence of ARCH in the models. The F-Stat represents the joint significance of all variables on the right hand side of the equation. Each model was significant at 1 percent level indicating that at least one of the variables help in explaining the model. The adjusted r-square was also reported to show how much of the variation in the dependent variable was being explained.

The speed of adjustment coefficients represent how quickly long-run disequilibria were corrected. The threshold error correction model in Table 4.12 indicates that for the CR-BA market pair, CR had significant lagged error correction terms for both positive and negative deviations while BA had only the negative deviation from equilibrium been significant at conventional levels.

Table 4.12 Results of Threshold Error Correction Models

	ΔCR	ΔBA	ΔAS	ΔBA
Constant	0.006(0.374)	0.026(2.090)**	-0.002(-0.222)	0.014(1.246)
ΔBA	0.364(3.278)***		0.482(6.645)***	
ΔBA_{t-1}	0.031(0.247)	-0.048(-0.437)	-0.003(-0.034)	-0.072(-0.631)
ΔBA_{t-2}	0.018(0.149)	-0.101(-0.984)	0.103(1.166)	-0.167(-1.637)
ΔCR		0.274(3.278)***		
ΔCR_{t-1}	-0.093(-0.925)	0.000(-0.003)		
ΔCR_{t-2}	-0.243(-2.671)***	0.069(0.840)		
ΔAS				0.649(6.645)***
ΔAS_{t-1}			-0.029(-0.294)	0.120(1.066)
ΔAS_{t-2}			-0.205(-2.265)**	0.235(2.236)**
z_pos_{t-1}	-0.260(-2.381)**	-0.014(-0.146)	-0.214(-1.893)*	0.154(1.158)
z_neg_{t-1}	-0.446(-3.267)***	0.396(3.351)***	-0.534(-4.373)***	0.500(3.409)***
Q (4)	0.899	0.683	0.780	0.768
Q (8)	0.967	0.891	0.971	0.976
F –Stat	6.589***	3.068***	9.872***	8.086***
Adj. R^2	0.273	0.122	0.374	0.322
$F_{sr}-Stat$	3.602**	3.623**	14.975***	15.712***
$x^2_{ARCH(1)}$	3.586	0.521	0.662	0.944

z_pos_{t-1} and z_neg_{t-1} are the error correction terms showing adjustments to increasing and decreasing deviations from the long-run equilibrium respectively. T-statistics are in parentheses. F_{sr}-Stat is the F-statistics for the short-run granger causality.

Therefore, prices in the CR market responded to both positive and negative discrepancies in the long-run price equilibrium arising from a change in BA market prices. However, BA market responded only to negative discrepancies in the long-run price equilibrium that due to changes in the CR market prices. Long-run causality can therefore be characterized as bi-directional which implies there was asymmetric feedback of market information from both markets. AS market responded to both positive and negative discrepancies in the long-run equilibrium when there were changes in BA market prices. In the reverse scenario BA market responds to only negative discrepancies in the long-run when AS market price changes. The feedback mechanism was also asymmetric in nature for AS-BA pairs.

In both CR-BA and AS-BA markets, there were faster adjustments in response to negative deviations from the equilibrium compared with positive deviations; implying positive asymmetry. The point estimates of the adjustment parameters imply that CR prices adjusted to eliminate about 45 percent of a unit negative change, but 26 percent of a unit positive change in the deviation from the equilibrium relationship created by changes in the BA prices. As feedback response of BA market to CR market, BA market prices adjusted to eliminate 40 percent of a unit negative change in the deviation from the equilibrium created by CR market prices. In a similar way, AS market adjusted and eliminate 53 percent and 21 percent of negative and positive deviations from the equilibrium relationship respectively for changes created by BA market prices. In return, BA market adjusted to eliminate 50 percent of the negative deviation from the equilibrium created by changes in AS market prices.

The $F_{sr} - Stat$ is the test statistic for the null hypothesis of no short-run causality, thus the joint significance of the explanatory variables (central market). In the case of CR-BA market pair, the null hypothesis was rejected at 5 percent significance level and 1 percent for AS-BA market pairs. This indicates bi-directional causality between all market pairs; thus the markets were non-segmented and responded to each other. The contemporaneous effect was also significant across all market pairs. For instance in the same period, a 1 percent increase in BA market price generated 0.36 percent and 0.48 percent price increase in CR and AS markets resulting in a decline of 0.64 percent and 0.52 percent in marketing margins respectively. On the other hand, a 1 percent increase in CR market price increased BA market price by 0.27 percent and a 1 percent increase in AS market price increased BA market price by 0.65 percent.

The results from the momentum-threshold error correction in Table 4.13 provides interesting output for GA-BA markets given that the one period lagged error correction terms were significant for both positive and negative deviation from the equilibrium. Thus, GA market responded to both positive and negative deviations from the equilibrium relationship created by changes in BA market prices and vice versa.

Table 4.13 Results of Momentum-Threshold Error Correction Models

	ΔGA	ΔBA	ΔNR	ΔBA
Constant	0.012(1.317)	-0.000(-0.026)	-0.000(-0.031)	0.010(1.044)
ΔBA	0.438(6.026)***		0.575(7.082)***	
ΔBA_{t-1}	0.072(0.708)	-0.037(-0.305)	0.014(0.141)	0.003(0.028)
ΔBA_{t-2}	0.147(1.614)	-0.116(-1.063)		
ΔGA		0.622(6.026)***		
ΔGA_{t-1}	-0.155(-1.449)	0.081(0.628)		
ΔGA_{t-2}	-0.113(-1.251)	0.021(0.190)		
ΔNR				0.581(7.082)***
ΔNR_{t-1}			-0.013(-0.135)	-0.048(-0.491)
z_pos_{t-1}	-0.543(-3.300)***	0.574(2.891)***	-0.179(-1.900)*	0.154(1.611)
z_neg_{t-1}	-0.297(-2.907)***	0.257(2.072)**	-0.421(-4.000)***	0.354(3.262)***
Q (4)	0.695	0.732	0.874	0.822
Q (8)	0.564	0.437	0.713	0.991
F-Stat.	10.183***	6.116***	13.122***	10.782***
Adj. R^2	0.382	0.256	0.366	0.318
$F_{sr}-Stat$	12.812***	12.240***	25.104***	25.443***
$x^2_{ARCH(1)}$	0.396	0.031	0.002	0.067

z_pos_{t-1} and z_neg_{t-1} are the error correction terms showing adjustments to increasing and decreasing deviations from the long-run equilibrium respectively. T-statistics are in parentheses. F_{sr}-Stat is the F-statistics for the short-run granger causality test.

Unlike the other market pairs, there was faster response to positive deviations from the equilibrium relationship compared to negative deviations; indicating negative asymmetry. In terms of the adjustment parameters, GA market adjusted to eliminate 54 percent and 30 percent of the positive and negative deviations respectively from the equilibrium relationship as a result of a change in the price of BA market. Likewise, BA market adjusted to eliminate 57 percent and 26 percent of positive and negative deviations from the equilibrium relationship respectively when there was a change in GA market price. The test for the null hypothesis of no short-run causality was rejected at 1 percent significance level, implying the presence of bi-directional causality in short-run. The significance of the adjustment parameters in both GA and BA also indicate bi-directional long-run causality. While NR market adjusted to eliminate both negative (42 percent) and positive (18 percent) deviations from the equilibrium relation created by changes in BA market prices, the BA market responded by adjusting to eliminate 35 percent of the negative deviations from the equilibrium relationship created by changes in NR market prices. There was also the evidence of bi-directional long-run causality from both markets. This was as well heterogeneous in nature given that the feedback responses were different. The joint hypothesis test of the central market variable was significantly different from zero, which also implies a bi-directional causality in the short-run for both markets. The contemporaneous impact of a 1 percent change in BA market price on GA and NR market were 0.44 percent and 0.58 percent respectively, allowing a 0.56 percent and 0.42 percent decline in their respective marketing margins. Also, a 1 percent increase in GA market price increased BA market price by 0.62 percent while BA market price increased by 0.58 percent for a 1 percent increase in NR market price.

4.7 Impulse Response Analysis

The results from the respective error correction models were used to develop impulse response functions. The impulse response function gives additional information about the long-run dynamic interrelationships among market pairs such as the time path needed to take the system back to equilibrium. Unlike the symmetric adjustment models, the response to a price shock is dependent of the history of the time series and the sign and magnitude of the postulated shock in asymmetric adjustment models (Potter, 1995). By definition, positive shocks are shocks that affect the profit margins of those involved in the local maize market positively (i.e. a decrease in the central market price) while negative shocks are shocks that affect the profit margin of the local traders negatively, thus squeezing the profit margins (i.e. an increase in the central market price). In uncovering the time period it takes for a unit shock in the central market price to be eliminated, impulse response was estimated from the error correction models presented above. According to Goodwin and Pigot (2001), the nonstationarity of price data and error correction properties may allow shocks to elicit responses that are temporary (such that there is a return to the initial time path of the variables) or permanent (such that there is persistent shift in the time path).

In demonstrating the estimation of the impulse response function, the CR-BA model pair in Table 4.12 indicates that a unit change in BA market price changes CR market price by 0.36 units. If this change was a 1 percent increase/decrease in BA market price (i.e., a negative/positive shock to traders marketing margin), then CR market price would respond by increasing/decreasing by 0.36 percent (i.e., traders' marketing margin declines/rises by 0.64

percent). The decrease or increase in profit margin of 0.64 is corrected asymptotically by a factor of 0.45 and 0.26 per period respectively in the following months as the BA prices continue to rise or fall. Similarly to the BA model, a 1 percent change in CR market price changes BA market price by 0.27 percent resulting in a shock of 0.73 percent to the marketing margin. This shock is corrected asymptotically by a factor of 0.40 and 0.014 per period respectively for decrease and increase in profit margins. The net results shown in Figure A.1 and Figure A.2 (see Appendix A) indicate the transmission of prices from BA market to CR market and vice versa. The shock to CR market margins return to the equilibrium level after experiencing a negative shock (i.e., an increase in BA prices) in 9 months while a positive shock approximately returns in 15 months to the equilibrium. In the case of the response of BA market to change in CR market prices, positive shocks persist for a very long time while negative shocks established equilibrium in 10 months.

The AS-BA markets pair also show that a 1 percent change in BA market price for maize changes the AS market price by 0.48 percent resulting in a shock of 0.52 percent in marketing margin. The 0.52 percent decrease in market margin is corrected by a factor of 0.53 per period and an increase in market margin is corrected by a factor of 0.21 per period in the subsequent months. Alternatively, a 1 percent change in AS market price result in the marketing margin of BA market changing by 0.35 percent. This 0.35 percent shock in market margin is corrected by a factor of 0.53 per period for a negative shock and 0.15 per period for a positive shock in the following months. As shown in Figure A.3 (see Appendix A), AS market adjust to establish equilibrium in 7 months for an increase in BA market price while a decrease in price takes about 19 months to establish equilibrium relationship. Similarly, BA market responds to AS market by establishing equilibrium relationship in 7 months for a negative shock and 25 months for a positive shock to marketing margins as shown in Figure A.4 (see Appendix A).

Heading on to error correction models in Table 4.11, the GA-BA pair of market shows instantaneous response of 0.44 percent by GA market to a 1 percent change in BA market price leading to a 0.56 percent decrease or increase in traders' marketing margin. A decline in marketing margin is corrected by a factor of 0.30 per period and an increase in the margin is corrected by a factor of 0.54 per period in the following months. As a feedback mechanism, a 1 percent change in GA market price leads to a change in 0.38 percent in GA marketing margin. The correction factors for negative and positive shocks in the marketing margins are respectively 0.26 and 0.57 per period in the months that follow. Unlike the other markets, GA market adjusts quickly in 7 months when marketing margins are been stretched than when squeezed (taking about 12 months). Similarly, BA market takes 7 months to establish equilibrium for positive shocks in margin and 15 months for negative shocks. These results are shown in Figure A.5 and Figure A.6 respectively in Appendix A.

Finally in the NR-BA markets, NR market responds instantaneously by 0.58 percent to a 1 percent shock in BA market prices while BA market responds by the same percentage to a 1 percent change in NR market prices. This leads to a decrease or increase in 0.42 percent in marketing margin. The decrease in market margin is corrected by a factor of 0.42 and 0.35 per period respectively for NR and BA models while an increase is corrected by a factor of 0.18 and 0.15 per period respectively. Referring to Figure A.7 in Appendix A, the NR market takes about 22 months to return to its initial level when there is a positive shock and 10 months when there is a negative shock. Alternatively, BA market adjusts to establish equilibrium in 26 months for positive shocks and 12 months for negative shocks as shown in Figure A.8 in Appendix A.

The motivating factors of the causes of asymmetry depend on the characteristics of the maize market. However, in assessing the Ghanaian maize market, the presence of market power may not be an option since the market appears to be competitive enough for traders to enjoy excess margins (Shively, 1996). Moreover, Abdulai (2000) rules out menu cost since price determination is through private negotiation between traders and purchasers. Also, the government is not involved in the trading and pricing in the maize market making government intervention void. Due to the high penetration rate of mobile communication in most parts of the country, information flow is easier and quicker making search cost a minimal option in causing asymmetry. 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 behavior potentially stands as a motivating cause of asymmetry. The negative asymmetry found in price transmission between Brong Ahafo and Greater Accra maize markets is motivated by the loss of goodwill (Heien, 1980) and/or the fear of losing market share (Ward, 1982). As indicated by Langyintuo (2010), maize in the Greater Accra market is supplied by Brong Ahafo, Ashanti and Eastern Regions given the high demand. Hence traders may be slow in passing on price increases from only the Brong Ahafo maize market given the multiple sources of supply. They may switch to other supply regions or wait for prices to increase from the other sources before transmitting the price shock across.

5 SUMMARY AND CONCLUSION

The continuous strive for market efficiency through market reforms with the hope 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 warrant knowledge about the state of the regional agricultural markets in the last decade. Moreover, the purported ability of the Ghanaian maize marketing 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 regional market linkages in the Ghanaian agricultural sector. Using monthly data on regional maize wholesale prices from 2002 to 2010, the study examines: whether regional level maize wholesale markets are integrated, the nature of price response between market pairs and the length of time needed for a deviation from the equilibrium to be corrected.

Prior to answering the issues at hand, a descriptive analysis of the data was presented to give an idea of the variability in prices among the regional markets. Results show that the variability in regional prices as determined by the coefficient of variation was on the average approximately 50 percent. Also, the seasonal variation indicates that prices were on the average 22 percent higher than the annual average during periods of high prices and 21.5 percent lower in periods of low prices. The univariate analysis indicates that price series in all the markets have constant seasonal pattern and a unit root. The test for market integration using the Johansen, Engle and Granger and Threshold cointegration tests reveal that all the four market parings were integrated. The results complement the early studies (Abdulai, 2000; Alderman and Shively, 1991; Alderman, 1992; Badiane and Shively, 1998) of market integration in the Ghanaian market, which potentially can be attributed to the noninterventionist role of the government, improvement in communication infrastructure and the different degrees of self-sufficiency that create arbitrage between the regional markets.

Considering the various approaches for analyzing market linkages and their limitations compounded with robustness, the consistent (momentum) threshold autoregressive model was selected to best model the adjustment mechanism of regional prices. The adjustment mechanism between the regional markets after a shock was characterized by asymmetry; such that deviations must exceed certain critical threshold before triggering adjustment to the equilibrium. With the exception of Brong Ahafo and Greater Accra market pairs which exhibited negative asymmetry, all the other market pairs exhibited positive asymmetry; where traders responded faster to shocks that squeezed their marketing margin than those that stretched them. Though not perfectly comparable given the different levels of data, the Brong Ahafo and Greater Accra negative asymmetry findings counter the positive asymmetry findings of Abdulai (2000) for Techiman (in Brong Ahafo) and Accra (Greater Accra) market linkages. The speed of adjustment was higher between Brong Ahafo and Greater Accra as well as Ashanti region markets than with the Northern and Central region markets. This was possibly due to the good road network linking Brong Ahafo to Greater Accra and Ashanti as compared to the Northern region. For Central region, not much trade exists with the Brong Ahafo maize market since demand for maize in the Central region according to Langyintuo (2010) is mostly supplied by Eastern region. The linkage between Brong Ahafo and Ashanti regions indicates that equilibrium was established within 7 months for negative deviations while for Greater Accra the same amount of time was needed to establish equilibrium for positive deviations. Brong Ahafo prices did not appear to respond when price increases were from Northern, Ashanti and Central regions since the respective speed of adjustment parameters were insignificant hence lasting more than two years to establish equilibrium.

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 behaviour of traders in the maize market suitably motivates as the potential source of asymmetry. Traders were slow in passing on price increases from Brong Ahafo to Greater Accra for fear of loss of customer share and goodwill due to the multiple sources of supply to Greater Accra maize market.

6 RECOMMENDATIONS AND LIMITATION OF THE STUDY

In the view of policy makers; inventory and stock behaviour of traders can be improved through the investment in storage facilities given the seasonal nature of the commodity. This can ensure even flow of maize throughout the season and hamper traders’ response to both positive and negative shocks. It is also recommended that policy initiatives be directed towards ensuring efficient transportation of agricultural commodities across regional markets. These include investment in 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.

A limiting concern of the study is that, the approach does not examine the underlying causes of the findings linked to asymmetry. The causes are only based on understanding of the maize marketing operations. It would therefore be worthwhile if future studies employ methodologies that examine these potential causes of asymmetry. Also, a better understanding of the market would be observed if future studies explore the transmission mechanics from rural to urban areas because most traders also purchase their supplies from the rural areas. Producer prices are currently difficult to come by and so rural-urban price transmission could be an approximation of examining producer price transmission which has not been explored yet.

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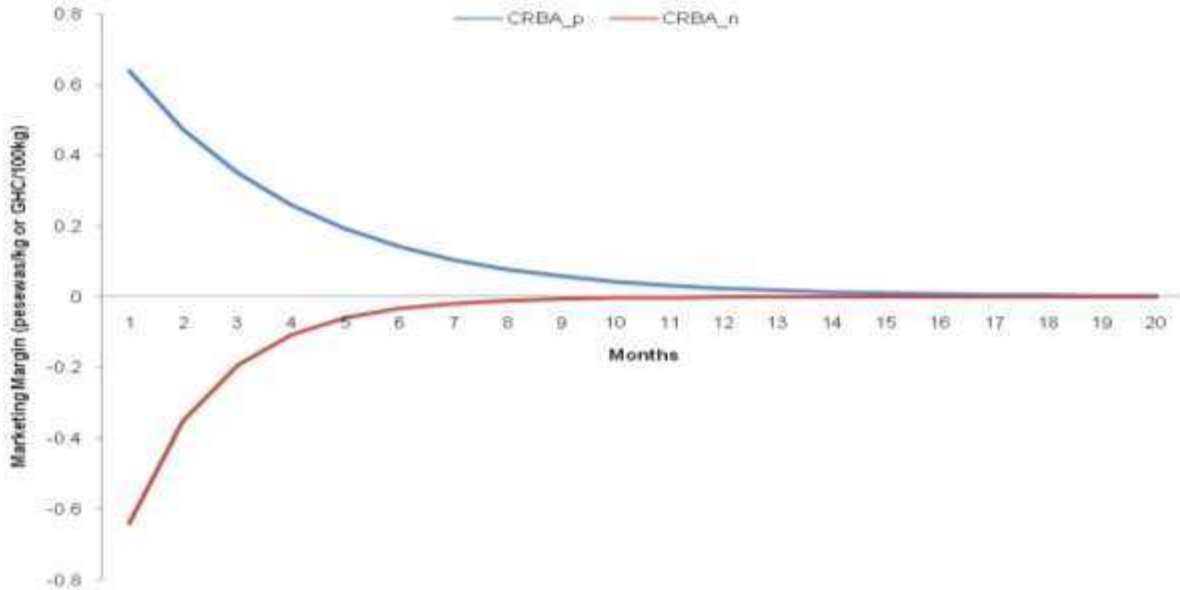
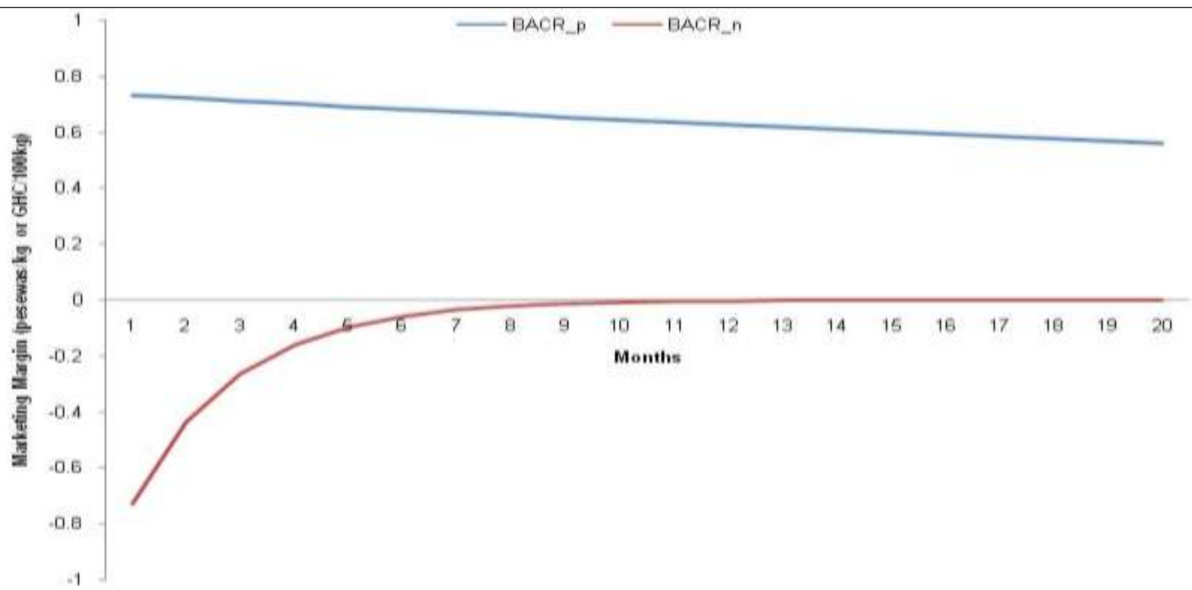
APPENDIX A

Figure A.1 Response of CR Market Price to Shock in BA Market Price



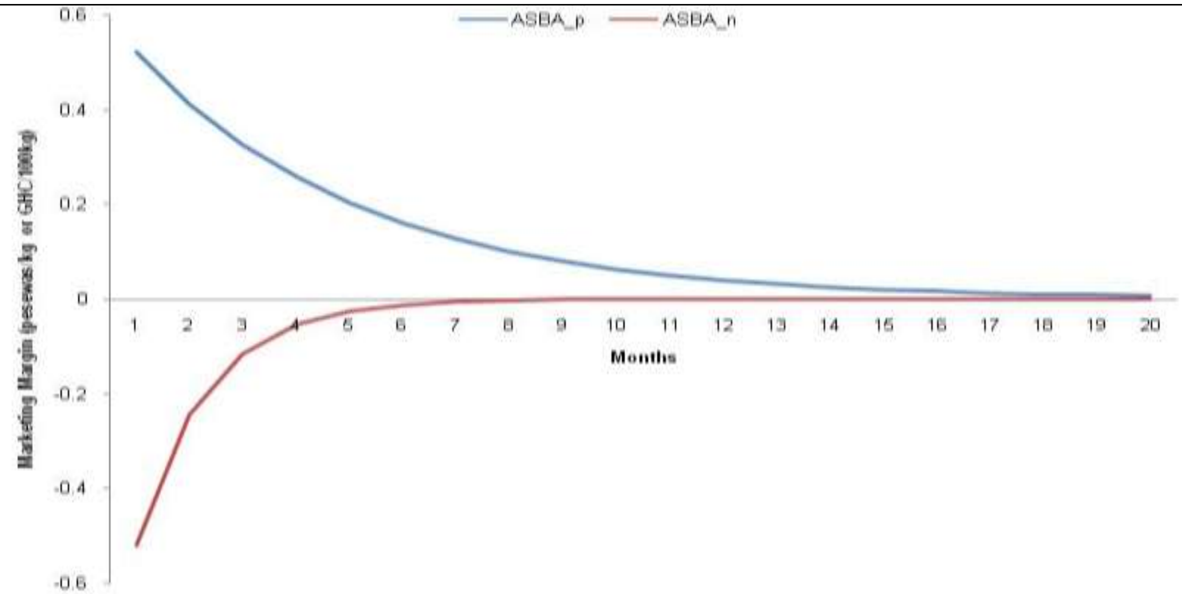
CRBA_p and CRBA_n refer to CR market responses to positive and negative shocks to the marketing margin respectively.

Figure A.2 Response of BA Market Price to Shock in CR Market Price



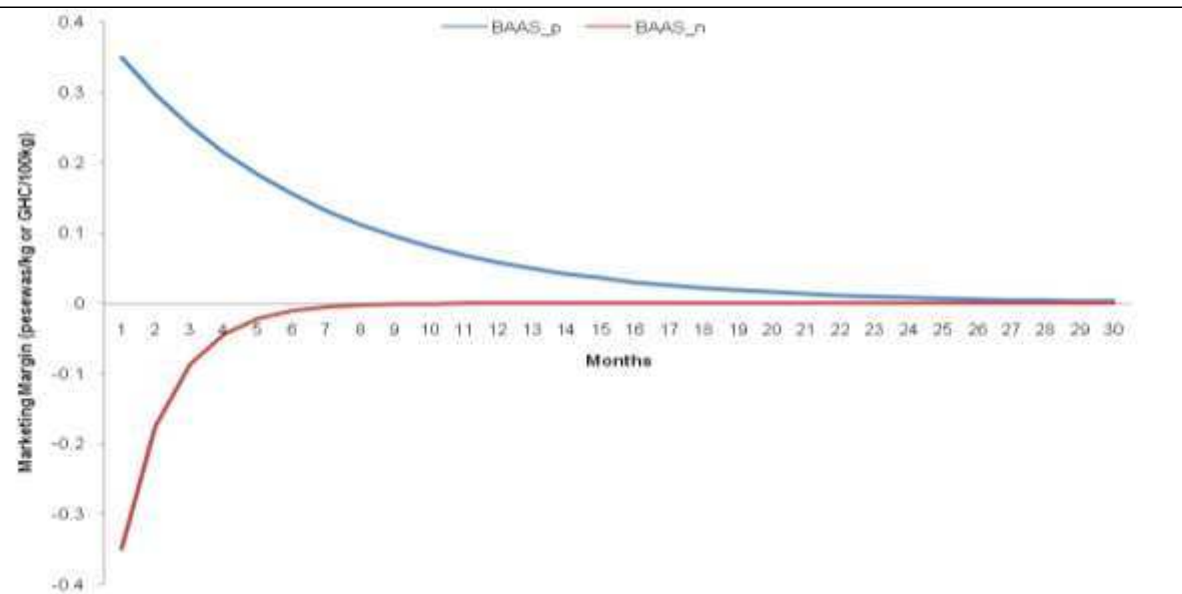
BACR_p and BACR_n refer to BA market responses to positive and negative shocks to the marketing margin respectively.

Figure A.3 Response of AS Market Price to Shock in BA Market Price



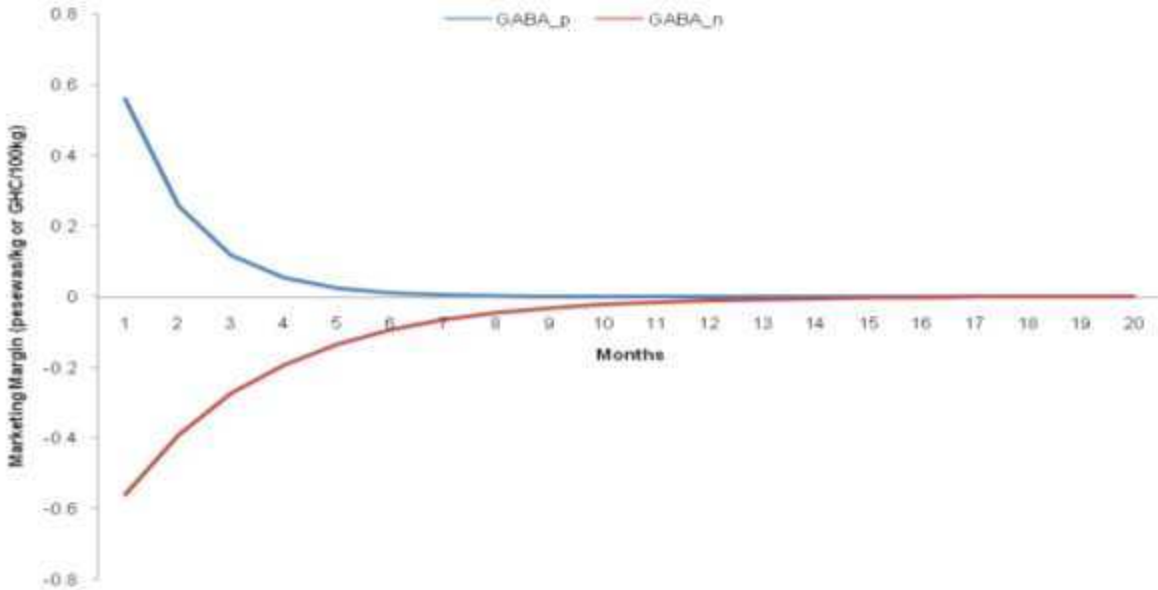
ASBA_p and ASBA_n refer to AS market responses to positive and negative shocks to the marketing margin respectively.

Figure A.4 Response of BA Market Price to Shock in AS Market Price



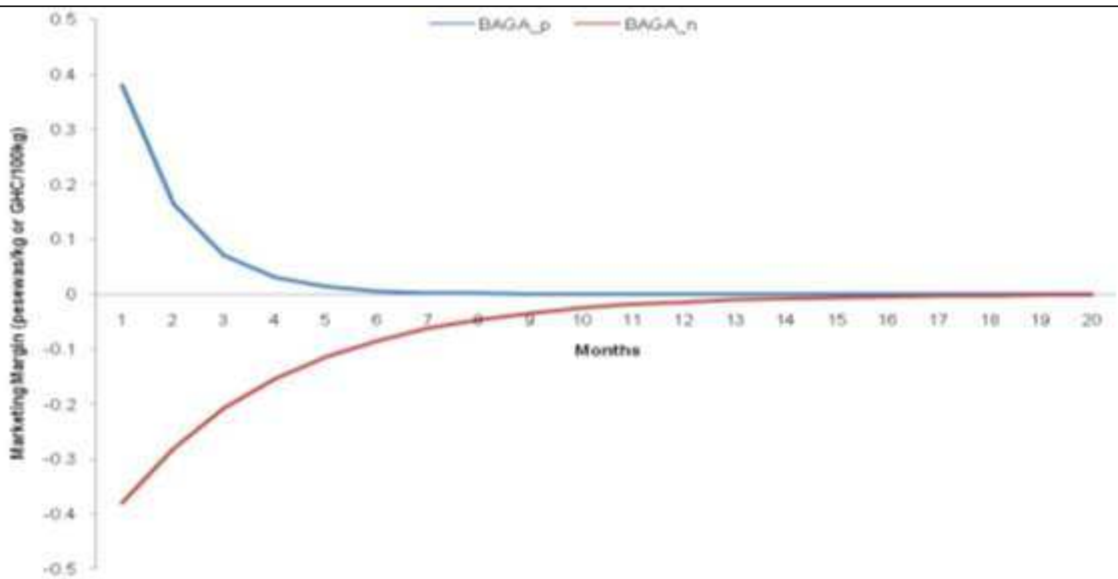
BAAS_p and BAAS_n refer to BA market responses to positive and negative shocks to the marketing margin respectively.

Figure A.5 Response of GA Market Price to Shock in BA Market Price



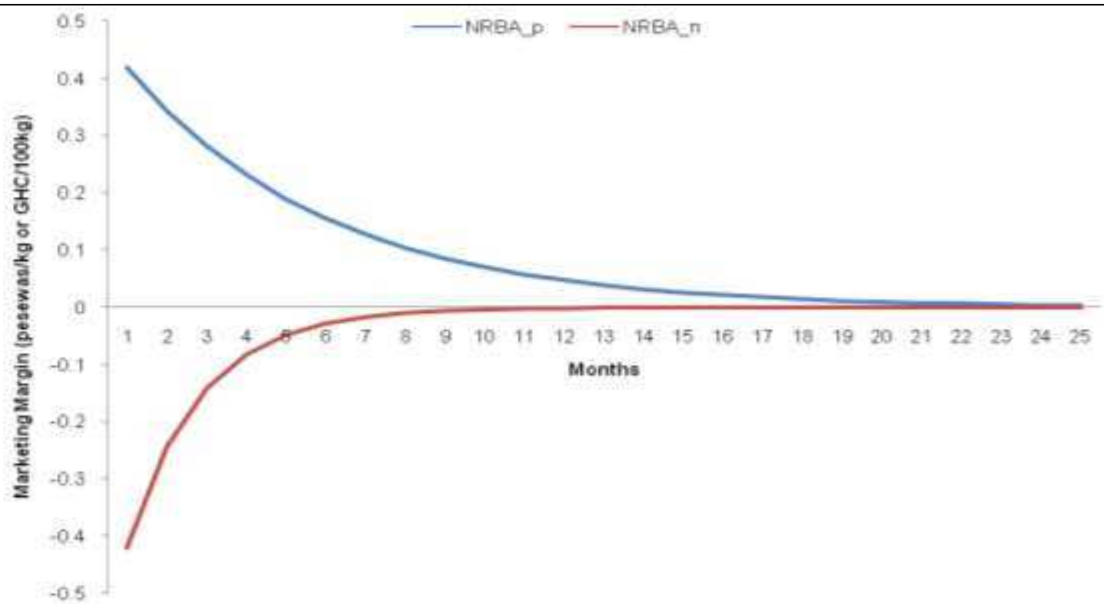
GABA_p and GABA_n refer to GA market responses to positive and negative shocks to the marketing margin respectively.

Figure A.6 Response of BA Market Price to Shock in GA Market Price



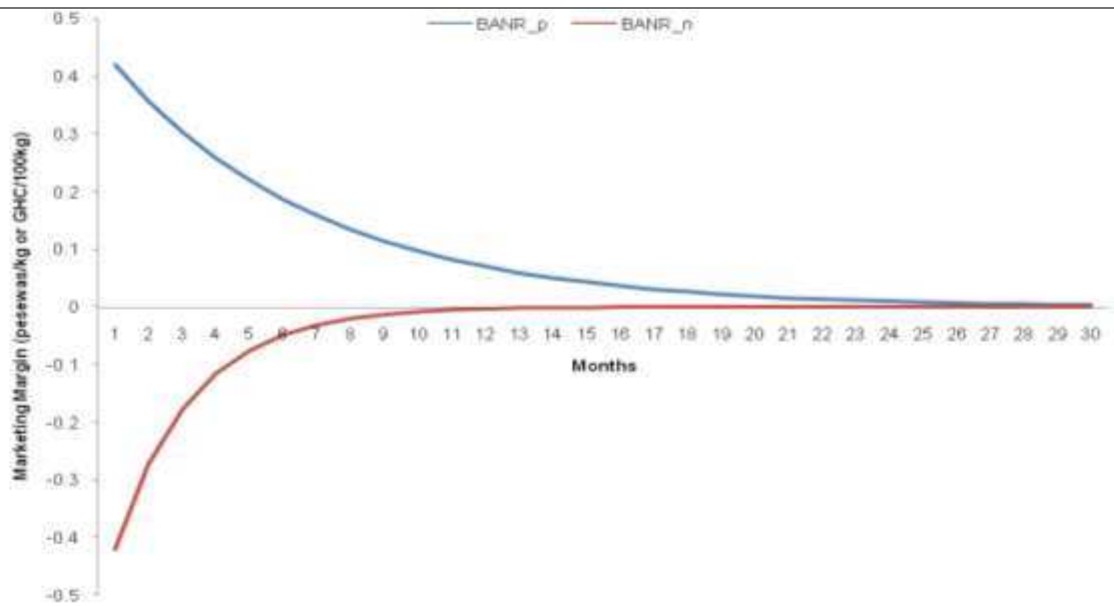
BAGA_p and BAGA_n refer to BA market responses to positive and negative shocks to the marketing margin respectively.

Figure A.7 Response of NR Market Price to Shock in BA Market Price



NRBA_p and NRBA_n refer to NR market responses to positive and negative shocks to the marketing margin respectively.

Figure A.8 Response of BA Market Price to Shock in NR Market Price



BANR_p and BANR_n refer to BA market responses to positive and negative shocks to the marketing margin respectively.

LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criterion
APT	Asymmetric Price Transmission
ARCH	Autoregressive Conditional Heteroskedasticity
AS	Ashanti
BA	Brong Ahafo
BIC	Bayesian Information Criterion
CR	Central Region
FIFO	First-In-First-Out
GA	Greater Accra
GFDC	Ghana Food Distribution Corporation
HEGY	Hylleberg, Engle, Granger and Yoo
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
MoFA-SRID	Ministry of Food and Agriculture – Statistical Research Information Directorate
M-TAR	Momentum-Threshold Autoregression
NR	Northern Region
OLS	Ordinary Least Squares
PBM	Parity Bound Model
PP	Philip Perron
SONACOS	la Société Nationale de Commercialisation des Oléagineux du Sénégal