

**Spatial Price Transmission and Market Integration  
in Agricultural Markets after Liberalization in  
Ghana: Evidence from Fresh Tomato Markets**

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**Dedication:**

To Africa, whose development is eminent with increasing transparency and fairness in  
global trade policy &  
To Helen, Benedict and Catherine with Love

## **Abstract**

Spatial price transmission or market integration measures the degree to which geographically separated markets share long-run market information on homogenous commodities. One very contentious issue in Ghana is the concern about the implications of trade liberalization for spatial price transmission and integration of local tomato markets i.e. whether or not price linkages between tomato markets in Ghana improved following the countries adoption of trade liberalization policy in the mid 1980s. Opposed to this contention is the view that well-functioning markets are necessary for the realization of the welfare impacts of trade liberalization. Despite insufficient empirical evidence on how Ghana's tomato markets performed following trade liberalization, prevailing public opinion and findings of advocacy studies blame supply gluts and perennially volatile, dispersed and often low prices of tomato on the importation of tomato products into Ghana. It is to verify this opinion and contribute to the policy debate that this study was conducted.

The main objective of the study is to determine the extent of post-liberalization price transmission and market integration between fresh tomato markets in Ghana. To achieve this objective, we sampled five major, fresh tomato markets, comprising two net tomato producer markets - Navrongo and Techiman and three net consumer markets – Tamale, Kumasi and Accra for the analysis. The dataset for the analysis includes monthly, secondary price series from 1.1992 to 4.2009, and primary, semi-weekly price and trade flow data collected by self-conducted market surveys between 3.2007 and 4.2009. The estimation is performed using Johansen's cointegration approach, and the threshold autoregressive and vector error correction models and their extensions.

We first test for the existence of cointegration between producer and consumer pairs of tomato markets. Then we estimate the speeds of price transmission between the market pairs under two sub-periods following trade liberalization in Ghana. The first sub-period, the high-tariffs period is from 1992 to 2000, while the second, a reduced-tariffs period is from 2001-2009. Our objective under this analysis is to determine whether price transmission and hence the factors responsible for market integration sufficiently improved over the two sub-periods. Lastly, we examine the importance of direct, inter-market trade flow vis-à-vis other factors in price transmission between the markets under study.

Results of the pair-wise cointegration analysis between surplus, producer and deficit, consumer tomato markets using both datasets reveal at least one significant, cointegrating vector between the market pairs, while results of the Johansen's multivariate cointegration approach of testing for cointegration between each producer market and all the consumer markets as a group demonstrate an integrated tomato marketing system. This implies that a common stochastic process, possibly the effective flow of the commodity and/or trade information, seems to determine price dynamics between markets. As a result, tomato prices between the markets do not drift apart in the long run, but always converge towards long run equilibrium following random, short run shocks on prices. Estimated, cointegration coefficients (the long run relationships between prices) range from 0.38 to 0.98, averaging 0.67, and appear to suggest a high degree of price transmission and market integration between fresh tomato markets in Ghana.

The results of the standard threshold autoregressive model reveal that the rate of price adjustment or error correction in each of the two periods under study is also high, averaging about 50.8% and 47.6% in the high-tariffs and reduced-tariffs periods respectively. Using an extended threshold autoregressive model which estimates speeds of price adjustment as time-varying parameters, we discover that adjustment speeds average about 64.5% under the high- and about 69.9% under the reduced-tariffs periods respectively. This confirms the cointegration results of rapid convergence of price deviations to long run equilibrium. Although the empirical evidence, overall is mixed, the findings of the extended threshold autoregressive model, the most ideal approach to modelling price adjustment between the markets, reinforce the view that there is no compelling evidence to blame trade liberalization as the sole cause of the gluts, price volatility and dispersion, and other marketing problems in fresh tomato markets in Ghana.

The findings of the vector error correction model support those of the threshold autoregressive model; they reveal high speeds of price adjustments, with deviations from equilibrium requiring an average of about 12 weeks to be completely corrected. Most importantly, we find significant price adjustment in both periods with and without trade from the results of the switching vector error correction model. This is evidence supporting the often underemphasized notion that direct, physical trade between markets may not be the sole

underlying factor determining price transmission and market integration. It appears, in this case, that other indirect mechanisms drive price transmission when autarky between markets occurs due to seasonality in production.

Lessons from the literature indicate that the added benefits of trade liberalization are contingent on the availability of complementary market infrastructure and policies. To that end, we recommend that appropriate investments should be made in road, transport, storage, processing and marketing infrastructure to improve the connection and reduce transaction costs between farm gates and net consumer markets, and between surplus producing areas and deficit consumer markets that are off the West African highway. Extensions to this study should consider the role of factors like seasonality, market power, road barriers, storage and processing on price transmission. Further research along these lines will improve our understanding of the problem and help develop more nuanced policy measures to ensure that farmers in Ghana reap the added benefits of trade liberalization.

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## **List of Acronyms**

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
BCM	Bivariate Correlation Models
BRM	Bivariate Regression Models
COCOBOD	Ghana Cocoa Board
CPI	Consumer Price Index
DGP	Data Generation Process
ECM	Error Correction Model
ECT	Error Correction Term
ESTJ	Enke-Samuelson-Takayama-Judge
GFDC	Ghana Food Distribution Corporation
HIC	Hannon-Quinn Criterion
IMC	Inter-Market Connectivity
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LOP	Law of One Price
MoFA	Ministry of Food and Agriculture
MSM	Markov-Switching Model
MS-VECM	Markov-Switching Vector Error Correction Model
PBM	Parity Bound Model
SAP	Structural Adjustment Programme
SRM	Switching Regression Models
SSA	Sub-Sahara Africa
SVECM	Switching Vector Error Correction Model
TAR	Threshold Autoregression
VAR	Vector Autoregression
VECM	Vector Error Correction Model

# **CHAPTER ONE**

## **1.0 Introduction**

### **1.1 Background**

For nearly three decades after the introduction of trade liberalization and other economic reform policies in most developing countries, several empirical investigations have attempted to confirm or refute some of the economic theories underlying the policy reforms. One of the core theories of trade liberalization is that the price mechanism of supply and demand plays a very crucial role in enhancing economic performance and welfare. This theory proposed that eliminating state interventions in marketing is the panacea for creating efficient markets and ensuring spatial price transmission or market integration – a measure of the degree to which markets at geographically separated locations share common long-run price or trade information on a homogenous commodity. Likewise, it has been revealed that well-functioning markets are required for trade liberalization to achieve its welfare objectives (Winters McCulloch, and McKay 2004).

The World Bank, IMF and governments of some developed countries who originally suggested the need for the present form of a liberalised global trading system in the Uruguay Round from 1986-1994, believed that, opening domestic markets to international trade by eliminating trade barriers and tariffs would improve economic growth and welfare in developing countries. Trade liberalization was particularly predicted to be an effective tool for improving price transmission between markets for agricultural commodities and inputs at the domestic and foreign scenes of developing countries (Stiglitz, 2002; WTO, 2003). Because of these expected benefits and given national budgetary constraints of most countries at the time, the proposal for a liberalized trade policy was subsequently adopted for implementation by most WTO members during the Uruguay Round of multilateral trade negotiations.

The supposed gains of a market-led development agenda through liberalized trade policies motivated Ghana to pioneer trade liberalization and liberalization-related macroeconomic reforms in Sub-Saharan Africa (SSA) in 1983. One of the most contentious current debates however, has been whether Ghana's domestic markets, especially for agricultural commodities, the largest contributor to GDP, transmit price shocks between them following agricultural tariffs reductions introduced under trade liberalization policy. This debate has heightened with the recent escalation of global food prices. The question here is: has the emergence of import trade liberalization policy for agricultural commodities improved spatial price transmission and market competitiveness for agricultural commodities in Ghana?

Empirical investigations of price responsiveness in agricultural markets in Ghana following trade liberalization policy report mixed results – generally high responsiveness for non-import substitutable commodities but low for import substitutable commodities (Alderman, 1992; Badiane and Shively, 1997; McCulloch, Winters and Cirera 2001). Aside these empirical findings, there is a general claim that import trade liberalization in Ghana opened domestic markets to subsidized and cheaper agricultural products from the EU, U.S.A, and Asia through import dumping, which in turn destroyed the price competitiveness of domestic products. In contrast, there is the belief that weak market institutions, poor infrastructure and high trader margins are the cause of inefficient arbitrage and lack of market competitiveness in Ghana's agricultural markets. In the case of fresh tomato, one of the commodities said to be gravely affected by trade liberalization policy in Ghana, views (e.g. in FAO, 2006) that huge surpluses of cheaper and subsidized tomato products from Italy is the biggest threat faced by local tomato farmers is, to the best of our knowledge, only anecdotal.

Whereas some of the above observations lack empirical basis, it is clear that the emergence of "healthy" marketing systems is crucial for the success of liberalised trade policy in Ghana (Alderman and Shively, 1996). More significantly, the welfare consequences (positive and negative) of the recent food price and current economic crises on any country will depend on the degree of price transmission across its local markets, and between the country's local markets and the world market. The accessibility of markets to producers and consumers, and the speed with which markets respond to price shocks locally and internationally are

therefore important determinants of the likely welfare-effects of any policy and economy-related crises.

The reason is not far-fetched; the socioeconomic environment of the poor in developing countries comprises several interlocking markets for agricultural produce, agro-based inputs, extension, finance, labour and information services, as well as for food and other consumer goods. Efficient marketing systems also determine producer income levels, food prices, availability and security for most households in developing countries. At the macro level, the degree to which a developing country's economy can withstand shocks accompanying global policy changes or economic downturn depends on the reliability and degree of price transmission across spatial markets within the economy, and between domestic and foreign markets (Ravallion, 1986). Though, the revealed implications of the 2007/08 food crises are mixed, a general view is that economies with integrated and efficient food markets and net production of food staples fared better than those with autarkic or poorly integrated markets during the crises (Heady et al, 2009).

Therefore, understanding the processes governing the performance of markets is essential. Such knowledge will inform current concerns on available, optimal options for dealing with the perennial food security problems of some developing countries, and adopting non-discriminatory and welfare-enhancing food policies by developed economies. Results of price transmission also have an informational value for resource allocation, food trade, food aid and distribution policy, and for hunger early warning systems (Romstad, 2008). This is because food price dynamics may signal the intensity of food supply, demand and level of market competitiveness and marketing costs as well as the structure of resource allocation by producers. Price transmission results may also benefit trade regulations such as the proposal in the Doha Round for the use of a "Green Box" policy by developing countries with peculiar needs to support their markets.

The above importance of price transmission studies notwithstanding, no empirical evidence on the nature of price transmission in Ghana has been recorded since the escalation in global food prices in 2007. Most analyses of price transmission in Ghana were conducted before 2001, while recent analyses are only advocacy reports. It is to provide evidence on the extent

of price transmission in Ghana's agricultural markets following the liberalization of agricultural markets that we conduct this study. The findings may assist in formulating policy options towards tackling food price hikes and engaging in the Doha Round of trade negotiations by Ghana.

Among previous studies of price transmission in Ghana are Alderman (1992) and Badiane and Shively (1997). These authors attempt to examine the intensity of agricultural price responsiveness due to policy shocks and document the implications of policy changes for income and poverty among producers and consumer groups in Ghana. Their findings reveal notable differences in price responsiveness between markets, which they attribute to the differences in the quality of market and transportation infrastructure and trader hoarding behaviour in the markets studied. Abdulai, (2000) also analyzed price transmission among maize markets in Ghana and reports the existence of a high degree of price transmission between three major regional maize markets. All these studies however predate the global food price escalations, apply single analytical techniques and focus solely on grain markets using only price data.

The fundamental dynamics of most markets viz. market integration and efficiency are not however just a binary case of autarky or perfect integration defined by only price relationships. Commodity transfer costs, especially between rural and urban markets of developing countries are crucial since they form a wedge between prices of homogenous commodities in spatially separated markets. The level of transfer costs may also determine the volume of trade that exists between markets in developing countries. Similarly, the flow of commodities or trade information between markets influences inter-market price differentials and per unit transportation costs. If inter-market trade volumes or information flow is high, per unit arbitrage of a commodity may be less costly and inter-market price differentials minimal. The reverse is true. This makes results of empirical analyses of price transmission that use price, transfer costs and trade flow data more insightful than approaches based solely on price data (Barrett and Li, 2002; Lloyd and Morgan, 2007; Stephens et al, 2008).

The main objective of our study is to determine whether or not price transmission between fresh tomato markets in Ghana improved over the post liberalization period. We achieve this objective by examining the rate of price transmission between fresh tomato markets across two sub-periods following trade liberalization in Ghana. The first sub-period (hereafter called the high tariffs period) is from January 1992 to December 2000, while the second sub-period (the low tariffs period) is from January 2001 to April 2009. A standard and extended version of the threshold autoregressive (TAR) model is applied to monthly wholesale prices of fresh tomato in this analysis. In addition, we investigate which mechanisms, other than physical trade flow, drive inter-market price transmission and market integration in Ghana by estimating price adjustment parameters in periods with and without trade. A switching vector error model (SVECM) is applied to a high frequency semi-weekly wholesale price series and trade flow information for this analysis.

The results of the second analysis are collaborative of the first. This is because trade liberalization, especially import tariffs reductions, would have meaningful implications for price transmission only if it impedes inter-market arbitrage processes, and if arbitrage, the movement of a commodity between markets by profit seeking traders, appears to be the sole determinant of price transmission. If trade flow is not the primary determinant of price transmission, then any effect of import trade liberalization on arbitrage might not necessarily impede price formation and the transmission of price signals.

Our study makes two important contributions. First, it examines the performance of tomato markets in the post liberalization period, especially after the reduction of agricultural import tariffs in Ghana. Secondly, it investigates if other factors, apart from direct physical trade, drive price and market integration between tomato markets in Ghana. Viewing physical, direct trade between markets, albeit implicitly, as the sole thrust of spatial price transmission is a common limitation of most previous studies. By using two different datasets - a high frequency, semi-weekly and a low frequency, monthly data for the analysis, this study also sets the pace for further studies to consider the issue of data frequency in price transmission analysis. We also digress from previous studies that used grain markets to determine price transmission and market integration by choosing fresh tomato, an import substitute in Ghana, as the commodity for our analysis.

## 1.2 Problem Statement

One of the points of dispute between advocates of anti-liberalization and those for free trade in recent times is whether spatial price transmission between markets in developing countries has improved since the implementation of liberalized market reforms. The purported ability of trade liberalization to integrate markets through supply and demand forces and offer farmers better prices and incentives was one of the motivations that led Ghana and most developing countries to subscribe to liberalization policy in 1983.

Trade liberalization in Ghana comprised the gradual abolition of state interventions in agricultural markets. The notion was that by liberalizing marketing channels and eliminating state interventions, import trade quotas and tariffs, Ghana's agricultural markets would become integrated and efficient. The import liberalization of Ghana's agricultural markets can be classified under two sub-periods – a high tariffs period when the import protection of agricultural markets was above 20%, and a reduced tariffs period with rationalized import tariffs rates of 0%, 5% and 10% after 2000 (FAO, 2006). For tomato, the commodity of interest in this study, tariffs reduction increased the importation of tomato products beyond the trigger volume after 2000, causing local tomato producers to lose their market share by 35% and local tomato prices to be perennially low, highly dispersed and volatile (ibid).

A common blame for this problem is the import dumping of cheaper tomato products from the EU on Ghana and the consequent reduction in competitiveness for locally produced tomato. Opponents of the import dumping theory, however, believe that government inability to strengthen market institutions and infrastructure to enable private sector effectively replace state institutions after liberalization is the cause of the problem.

The mixed opinions above exist because of an absence of concrete empirical evidence on the degree of price transmission between fresh tomato markets in Ghana. This empirical information dearth is critical since tomato is one of the commodities gravely affected by the changes brought about by trade liberalization policy. The motivation for this study is therefore to create the needed insight on the extent of price transmission between post-liberalization tomato markets in Ghana. Given the recent escalation of global food prices, knowledge on the nature of price transmission is particularly needed to contribute to a better

understanding of tomato markets in Ghana, help the policy debate and guide tomato production, marketing and consumption decisions.

The central hypothesis we test is that price transmission and market integration in Ghana's fresh tomato markets are high within the period of trade liberalization policy. To test this hypothesis, we analyse monthly wholesale price data from five major fresh tomato markets in Ghana. We do not intend to conduct an evaluation of trade liberalization policy in Ghana through this analysis since the available data for this purpose is unreliable and incomplete. Rather, we attempt to examine whether an integrated or a common domestic market characterised by strongly linked prices between net producer and consumer tomato markets, and serving as a precondition for liberalization to unfold its beneficial impacts, exists in Ghana following tariffs reductions for agricultural imports.

According to economic theory, trade liberalization has the potential to widen markets for products of developing countries and provide incentives for production, storage and processing. The actual net benefit from trade liberalization however depends on the ability of domestic markets to transmit price changes rapidly to each other, and on the competitiveness of domestic commodities. Since evidence on the nature of price transmission and competitiveness in fresh tomato markets is lacking, our study has a unique value in revealing the performance of Ghana's fresh tomato markets following trade liberalization. Such a revelation is useful in inferring the implications of the high imports of tomato products for domestic tomato markets and the contingent policies needed to mitigate the marketing problem of tomato in Ghana.

To the best of our knowledge, Mabaya (2002) and Stephens et al (2008) offer the only empirical market integration and price transmission analysis on tomato markets in SSA. The findings of the former are consistent with the theory of market integration and efficiency, and confirm the law of one price (LOP) when the linear market integration techniques are employed, but using the parity bound models (PBM), give results that show a high degree of market segmentation especially for markets not directly linked by public transportation. The latter revealed that direct trade flow between markets is not the most supreme determinant of price transmission between markets.

### **1.3 Objectives of the Study**

This study seeks in the general context to examine the nature of price transmission and integration between fresh tomato markets in Ghana. Specifically, the study will:

1. Verify the degree of cointegration between fresh tomato markets in Ghana.
2. Determine whether price transmission and market integration between fresh tomato markets in Ghana improved over the post liberalization period.
3. Investigate which other mechanisms, apart from direct physical trade flow, are responsible for inter-market price transmission and market integration in Ghana.
4. Make recommendations to policy and suggestions for further research.

### **1.4 Justification for the Study**

The mixed record of performance of Ghana's economy and controversy regarding which sectors benefited and which sectors lost following trade liberalization policy in Ghana raised many valid concerns. These include the debate on whether trade liberalization implied positive, negative or neutral effects, especially for the agricultural sector in Ghana. These mixed experiences are interesting and justify the need for empirical research towards answering the question regarding the state of agricultural market integration and price transmission in Ghana under a liberalized trade scenario. After several years of implementation, it is important to assess, through price transmission analysis, the extent to which trade liberalization eliminated inefficiency in domestic markets, one of the anomalies the adoption of trade liberalization policy in Ghana was meant to correct.

The results of price transmission analysis are very useful. They are one of the prerequisites for successfully formulating and implementing sound trade policies, and provide information on the spatial extent of markets which is necessary for evaluating market performance, conduct and structure. Results of price transmission and market integration analyses also help in determining the potential impact of trade and price policy reforms on production, consumption and trade (Tiepoh, 2000, Stigler and Sherwin; Tomek and Robison in Padilla and Tilmany, 2003). By signalling the degree to which domestic prices adjust to

changes in world prices, price transmission results may be useful in managing international trade in developing countries like Ghana.

Even though Ghana has one of the most vibrant economies in SSA, the country's markets are still constrained by the common problems, namely fragmented markets due to oligopolistic trader behaviour, poor marketing, transportation and communication facilities, and unstable policy environments and enforcement mechanisms that are often faced by developing economies. In this case, results of spatial price transmission and market integration are needed in implementing complementary policies to boost the trickledown effect of agricultural incomes to the poor at the farm gate (Baulch, 1997). The urge for full liberalization of agricultural markets and unilateral use of contingent policy options in the Doha Round by member countries also needs to be informed by evidence of the performance of markets viz. their ability to transmit demand and supply shocks to each other via price signals.

Market integration analysis also helps in determining the balance between food-surplus and food-deficit areas. This is crucial in identifying the direction, degree and distribution of the welfare-impact of trade policy scenarios in global economic models (Rapsomanikis et al, 2002). Prices signal relative scarcity and ensure producer specialization and optimal resource utilization. For instance, integrated markets often convey accurate price information that guides producer-marketing decisions, reduces price dispersion and leads to efficient product arbitrage processes (Alderman and Shively, 1991 reported in Abdulai, 2000). The concern of most countries following the recent food price escalations has been either the implementation of policies that guarantee self-food sufficiency, food importation or food production on land acquired abroad. In this case, knowledge of price signals is necessary for implementing the optimal policy options for each country.

The transmission of prices of a country's commodities between its domestic markets and across its borders is the panacea for realizing the welfare-impact of trade liberalization. In the same vein, trade liberalization is a catalyst for price transmission between domestic and foreign markets via border prices (Winters McCulloch, and McKay 2004). Therefore, any analysis of market performance in developing countries with hitherto restrictive trade

policies need to be done in the context of trade policy changes on market performance. Similarly, the welfare-impact of trade liberalization or any other policy changes within a country should be assessed in the setting of the policy's effect on price transmission between the country's markets and across its borders.

We noted earlier that one key motivation for implementing trade liberalization policy in Ghana is its ability to create markets for Ghana's local produce. Thus, after several years of implementation, it is important to assess the extent of price transmission and market integration achieved or the market distortions corrected as a result. This justifies the need for this study, which is conducted to assess the performance of markets of fresh tomato, one of the commodities whose marketing is supposed to have been negatively affected under trade liberalization policy in Ghana.

### **1.5 Organization of the Study**

In the following section, we define common terminology in the price transmission literature and review relevant literature on price transmission, market performance and trade policy. The purpose is to create a contextual basis for the rest of the study. In chapter three, a chronological review of the main econometric techniques used for price transmission analysis over the years is undertaken to provide a theoretical basis for adapting some of the analytical techniques to our data. An elaborate description of the study setting namely the nature of fresh tomato production, marketing and pricing following trade liberalization in Ghana is given in chapter four. This chapter also presents the characteristics of the markets under study and describes the nature and collection procedure of the data used for the analysis.

The results section consists of two chapters that are based on conference papers on the subject of price transmission between fresh tomato markets in Ghana. In chapter five, we present the first paper which addresses the objective two of the study i.e. to determine whether or not price transmission between fresh tomato markets improved following the reduction in agricultural import tariffs in Ghana. In the second paper constituting chapter

six, we report and discuss the results of the vector error correction model (VECM) estimated to achieve the objective three, which is set to ascertain which mechanisms, other than direct inter-market trade flow, drive price transmission and market integration in the fresh tomato markets under study. Results of tests for unit roots in and cointegration between the price series precede the major results in both papers. The final chapter summarizes the study, draws major conclusions from the findings and outlines relevant issues that need to be addressed by policy and in further research.

## **CHAPTER TWO**

### **2.0 Literature Review**

#### **2.1 Introduction**

Results of price transmission analysis become easy to interpret in the context of distinct definitions of the key concepts involved. This fact notwithstanding, the extensive literature on spatial price transmission and market integration analysis often contains some vaguely defined concepts, which may be elusive in their meanings to different market integration analysts. For this reason, a theoretical review of the common terminologies used in empirical studies of spatial price behaviour is presented in this chapter. The aim is to help lessen the confusion usually engulfing key terminologies in price transmission and market integration analysis and create a contextual basis for the rest of the study.

The chapter also addresses the connection between trade liberalization, price transmission and market integration, reviewing particularly the possible ways in which trade liberalization policy affects market performance. Finally, the chapter discusses empirical findings of previous studies about the underlying factors that often influence price transmission and market integration in developing country agricultural markets.

#### **2.2 The Theoretical and Conceptual Framework**

##### ***2.2.1 Spatial Price Transmission and Market integration***

Market integration analysis is one of the many approaches to examining the performance of markets. Earlier literature defines integrated markets as locations connected by trade and exhibiting high price correlations (Harris, 1979; Ravallion 1986, Goodwin and Schroeder; Roll etc). Later, market integration became synonymous to price efficiency and the law of one price (LOP). In this view, the concept stipulates that, if trade exists between a pair of markets for a homogenous product, the price of the commodity in the source market equals its price in the destination market plus transfer costs. Most commonly, market integration is

considered as a measure of the degree of flow of homogenous tradable commodities, information, standard measures, trading habits and prices over form, space and time between markets linked directly or indirectly by trade (Lutz, et al, 1994; Barrett 1996). In this sense, price transmission analysis measures the relationship between prices of a homogenous commodity in spatially or vertically separated markets in a country, or between world prices and a country's domestic prices of the commodity.

Fackler and Goodwin (2001) define market integration as a measure of the extent to which demand and supply shocks of a commodity in a given market are transmitted to another market. If a hypothetical shock,  $\varepsilon_A$ , shifts the excess demand of a good in market j and not in market i, the price transmission ratio i.e. the price elasticity of i with respect to j associated with this shock is defined by:

$$R^{ij} = \frac{\partial P^i / \partial \varepsilon_A}{\partial P^j / \partial \varepsilon_A} \dots\dots\dots(1)$$

Where  $R^{ij}$  is called the price transmission elasticity. If the expected value of  $R^{ij}$ ,  $E(R^{ij}) = 1$  then it implies perfect market integration, while  $E(R^{ij}) = 0$  implies market segmentation.  $P^i$  and  $P^j$  are the prices of the commodity in markets i and j respectively.

Based on the above definitions, three notions form the basis of price transmission and market integration analysis; they are the perfect, dynamic and asymmetric notions of price relationships postulated by the LOP, speeds of price adjustment and non-linear price adjustment processes respectively (Rapsomanikis et al, 2004). The focus of this study is price dynamics arising from the transmission of price shocks across geographically distinct fresh tomato markets in Ghana.

Since theoretically, two markets that are part of a marketing system but do not trade with each other may still be integrated, market integration does not automatically imply market competitiveness (Baulch, 1997; Fackler and Goodwin, 2001). For a pair of markets that trade with each other, competitive market equilibrium between them only exists if their prices obey the LOP i.e. the inter-market prices differ only by the value of the transaction

costs incurred in moving the commodity between the markets. In a similar sense, the physical connectivity of arbitrage processes between markets may not constitute market integration. This is a case of market segmentation or uncorrelated inter-market prices that occurs whenever the inter-market price differential equals (is less than) the transactions costs and traders are indifferent about participating in arbitrage. Since both phenomena implies the LOP, empirical results of spatial price transmission could be similar under markedly different market regimes (Baulch, 1997; Barrett and Li, 2002; Stephens et al, 2008).

The absence of market integration is called market segmentation. This occurs when supply and demand conditions fail to affect trade and hence prices of a homogenous commodity between markets. If the markets for a homogenous commodity are not spatially integrated, it is expected that the benefits or losses of any policy changes affecting some markets in the system may not necessarily accrue to those markets of the system outside the direct impact of the policy and disequilibrium in the marketing system as a whole may not be restored. The reason is that the impact of the shock is not transmitted throughout the system but rather absorbed by the particular market receiving the impact.

### ***2.2.2 Spatial Arbitrage***

Spatial arbitrage is the haulage of a commodity by profit-seeking market participants from a lower price to a higher price market to take advantage of the inter-market price differences between the markets and make profit. In competitive markets, the arbitrageurs' actions ensure that the prices of a homogeneous commodity in the two markets differ by no more than the transfer cost of moving the commodity between the markets. This view can be expressed by the spatial arbitrage condition as:

$$P_t^j - P_t^i \leq C^{ij} \dots\dots\dots(2)$$

Where  $C^{ij}$  is the transfer (transportation and transactions) cost of moving the commodity from market i to j.

In a highly competitive marketing system, whenever the price of a commodity is higher in one market than in others, arbitrageurs seeking profit will transport the commodity from the

lower price markets to the higher price one until an equality of inter-market price differences and transactions costs is achieved and arbitragers profits from trade are exhausted. The above arbitrage condition and the processes ensuring an equality of transfer costs and market margins imply a long run relationship or cointegration between the markets involved. Therefore market integration also means and is measured by cointegration of prices between markets.

### **2.2.3 The Law One Price (LOP)**

The law of one price (LOP) is the cornerstone of most empirical studies of market integration. The LOP in its strong form, expressed as  $P^j - P^i = C^{ij}$ , asserts that for a single homogenous commodity, if efficient arbitrage occurs and competitive equilibrium holds between two markets linked by trade, then a price change in one of the markets will be translated on a one-for-one basis (instantaneously) to the other market. A weaker form of the LOP allows for temporary deviations from equilibrium following a price shock, with the tendency however to return to this equilibrium in the long run.

Analysis of the LOP assume that market agents have all the relevant information required to undertake optimal arbitrage and there are no impediments to trade (Jensen, 2007). Since this assumption is rarely the case in practice, using the LOP as a measure of market integration is only idealistic. As noted in McNew (1996), the LOP is just a necessary condition for spatial price efficiency since it holds only when there are no obstacles to trade or when transportation costs between markets is insignificant.

### **2.2.4 Spatial Market Efficiency**

A market is efficient if it fully and correctly reflects all relevant information in determining prices of commodities sold within it (Fackler and Goodwin, 2001; Lence and Falk, 2005). In market integration analysis, efficiency means the exhaustion of all opportunities for improving arbitrage profits. In this case, the prices reflect all available information about demand, supply and transactions costs in them. The definition also shows that the price at time  $t$  has the best forecast value for the price at time  $t+i$ ,  $i = 1, 2, \dots, n$ , since it uses all available information of the market.

If the transfer costs for a commodity between markets are above the inter-market price difference, then the markets are spatially inefficient. In this case, a given price at time  $t$  may not have the best forecast value for the price at period  $t+i$ . It is important to distinguish between market efficiency, a phenomenon necessary for market equilibrium, and market integration, which merely signifies the flow of commodity and price information between markets, with or without arbitrage opportunities necessarily being fully exhausted. This means that the existence of trade is neither necessary nor sufficient for the attainment of both market efficiency and market integration (Barrett, 2001).

### ***2.2.5 Competitive Market Equilibrium***

Given the price for a homogenous commodity in two spatially separated markets  $i$  and  $j$ , the LOP and the point-space framework of Enke-Samuelson-Takayama-Judge (ESTJ), using the variables already defined, denote competitive equilibrium using the following spatial price relationships:

$$P_t^i \geq P_t^j + C_t^{ji} \dots\dots\dots(3) \text{ when trade occurs}$$

$$P_t^i < P_t^j + C_t^{ji} \dots\dots\dots(4) \text{ when trade does not occur}$$

Equation (3) indicates the case where trade flows from market  $j$  to  $i$  until the price differential between both markets equals the inter-market transfer costs, and the strong LOP condition is met. Alternatively, equation (4) represents the case of no trade<sup>1</sup> due to negative profit or the indifference of the market participants to engage in trade. Competitive equilibrium between a pair of markets could either therefore be due the LOP when inter-market price differentials equals transfer costs, or autarky between markets occurring when the inter-market price difference is less than transfer costs and trade is non-profitable to arbitrageurs. When this is the case, analytical results may suggest evidence of market integration even though the latter case is untrue.

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<sup>1</sup> The condition of no trade or autarky between markets  $i$  and  $j$  holds only in the case where the production and consumption areas of the commodity are mutually exclusive. Where this is not the case, arbitrageurs are motivated to move the commodity from low to high price area.

### ***2.2.6 Trade Liberalization Policy***

The theory of trade liberalization policy has a long history. However, the form of trade liberalization or free trade of concern in this study emerged in the early 1980s, when most developing countries, under the supervision of the World Bank and IMF, abandoned their then restrictive, foreign trade policies and liberalized domestic marketing channels from hitherto controlled distribution systems. Import trade liberalization means opening the market of a country to foreign goods, services and capital by minimizing the country's physical and policy trade barriers, and reducing export subsidies and import tariffs.

Liberalized trade in Ghana involved a systematic dismantling of the barriers to trade and allowing market forces to generate competition and guarantee efficiency in resource allocation, improve producer incentives and integrate the countries into the world economy (McCulloch, Winters and Cirera, 2001 and Hertel et al 2003).

The nature and degree of a country's liberalization is a measure of its openness to international trade in particular and economic openness in general. It is however worth noting that liberalised trade is only one of the several indicators of economic openness and one that often weighs lightly in the overall result of a country's economic success (Winters, McCulloch and McKay, 2004).

The connection between the concepts of trade liberalization on the one hand, and price transmission and market integration on the other cannot be overstated. As stated earlier, the transmission of prices of a country's commodities between its domestic markets and across its borders is needed for realizing the welfare-impact of trade liberalization. There is much empirical evidence to prove that well-functioning markets are necessary for trade liberalization to achieve most of its welfare effects, including the creation of more markets (Winters, McCulloch, and McKay 2004). Therefore, any analysis of market performance in developing countries with hitherto restrictive trade policies needs to be done in the context of the trade policy changes.

The following section outlines the history of trade liberalization policy in Ghana. The aim is to provide reasons for Ghana's subscription to this policy and present some facts on the

performance of Ghana's economy and domestic market following the implementation of liberalization policy.

### **2.3 The Implementation and Implications of Trade Liberalization Policy in Ghana**

Economic reforms and trade liberalization policy in Ghana commenced in 1982; and was reworked into a "fundable" format in 1983. The reforms became necessary due to economic crises in West Africa between 1981 and 1983. The crises resulted in the then poor performance of Ghana's economy viz. decade-long declining exports, deteriorating infrastructure, high inflation rate, a severe drought and the repatriation of about one million Ghanaian immigrants from Nigeria in 1983. Based on the belief that the poor economic indicators mentioned above emanated from Ghana's government's excessive control of domestic markets, and to enable the country to qualify for foreign development aid and loans to meet budget constraints, the government undertook economic reforms following recommendations from the IMF, World Bank and other international donors (World Bank 1986 in Acquay 1992; Berry, 1997).

The agricultural sector in the pre-liberalization period was subjected to a range of restrictive and distortionary interventions by the state with the aimed of raising the production of both arable and cash crops. Among these interventions were agricultural price controls, assembling and selling of marketable crop output by the Ghana food distribution corporation (GFDC), as well as distribution of subsidized fertilizer, seed and credit to smallholder farmers through the rural inputs and financial services commission. On the foreign scene, high export tariffs were placed on cocoa and export commodities to generate income for the government, while high import tariffs, quotas and bands were used to protect local industry (Ackah and Appleton, 2007; Alderman and Shively, 1991).

The implementation of trade liberalization meant the removal of the above interventions and the adoption of liberalised market policy. In the agricultural sector for instance, the Ghana cocoa produce buying company (COCOBOD) was reorganized to allow for competition with private firms in buying cocoa from farmers, while the grains marketing and distribution

boards, and the inputs and farm financial services commissions were completely abolished. In addition, the provision of input subsidies, farm credit and guaranteed prices for agricultural outputs was stopped (Greene, 1988; Alderman and Shively, 1996).

Tariffs liberalization in agricultural markets however lagged behind the other market reforms. In the post-liberalization tariffs regime of 0, 5, 10 and 20%, agricultural imports received the highest duty rate of about 20%. It was in 2000 that further liberalization reduced the agricultural tariffs rate to about 13% coupled with the abolition of all import bans and quotas (Aryeetey et al, 2000 in Ackah and Appleton, 2007). Other components of the reforms included currency devaluation, adoption of a floating exchange rate system, reduction in the size of the civil service, freeze on labour hiring and privatization of inefficient state enterprises. All these policy changes have direct and indirect implications for the agricultural production and marketing sectors.

Immediately following the implementation of trade liberalization, Ghana's economy showed an overall improvement between 1984 and 1989. This included an average of about 2.7% growth in agricultural production per annum between 1987 and 1998, which increased food production and boosted real GDP growth by about 20%. Ghana's exports and net inward financial transfers also grew more sharply in the same period, with inflation falling from almost a three-digit figure to 25%, and real minimum wages doubling between 1987 and 1989. In addition, the country's exports increased, with cocoa, timber and gold constituting about 80% of the value of the main exports (GPRS, 2000).

The IMF and World Bank attributed the economic improvements to the adoption of the trade reforms policy by Ghana. Others however believe that the positive performance followed a much better weather, agricultural growth recovery, increased foreign aid and imports, and a generally positive macroeconomic environment for cocoa, timber and gold. The latter view seemed to have been buttressed when the economy slumped from its supposed robust state to another crisis in the mid 1990s.

In recent times, Ghana's macroeconomic indicators have shown marked improvement. In 2008, for the third consecutive year, real GDP growth in Ghana remained 6% despite the

rise in global prices for oil and food. This growth emanated from 9.2% growth in industry, 7.3% growth in services, and 5% growth in agriculture which constitutes 35% of GDP (African Economic Outlook, 2009). This growth is however expected to decline below 6% in 2009 due to declining exports arising from the global recession, but reverse back to 6% in 2010 when Ghana begins the export of crude oil (ibid).

The mixed record of performance of the economy and controversy regarding which sectors benefited and which sectors lost following trade liberalization policy in Ghana raised many valid concerns. These include the debate on whether trade liberalization implied positive, negative or neutral effects, especially for the agricultural sector in Ghana. Most Ghanaians believe that the gains from almost three decades of trade liberalization for Ghanaian farmers have been next to nothing. Naturally, the IMF and World Bank have defended the policy reforms as necessary, given the budget constraints of the country at the time. Policy makers and academic too hold diversified views (Stiglitz, 2002).

These mixed experiences are interesting and justify the need for more empirical research towards answering the question regarding the state of agricultural market integration and efficiency in Ghana in a trade liberalization scenario. After several years of its implementation, it is important to assess the extent to which trade liberalization corrected sluggishness in price transmission and market integration, one of the anomalies the adoption of trade liberalization was meant to correct in Ghana's domestic markets.

#### **2.4 The Link between Trade Liberalization and Markets**

This section examines the link between trade liberalization and market performance viz. price transmission and integration. It reports evidence on the expansion or contraction of marketing opportunities following the implementation of trade liberalization policy in some developing countries. The section ends by drawing a theoretical link between trade liberalization and price transmission in a country's domestic markets or across its borders.

A primary impact of trade liberalization and the reduction of import tariffs is the transmission of international price changes, which could lead to the creation or destruction of markets (Winters McCulloch, and McKay 2004). Trade liberalization may create many marketing opportunities for a variety of commodities, or destroy existing opportunities of marketing. For instance, most firms in Kenya, Tanzania and Zimbabwe responded to foreign competition emanating from trade liberalization by contracting rather than expanding (Lall 1999 in Winters, McCulloch and McKay, 2004). The reasons attributed to these actions include lack of preparation by these firms for competition with multinational firms set up after liberalization, and the absence of policies to promote technical and infrastructural improvements for small firms. Therefore, by precluding contingent measures for protection, trade liberalization exposes domestic industries to being “rationalised” through strong strategic and anti-competitive behaviour of multinational companies.

In Bangladesh, liberalization increased the availability of inputs to producers and finished goods to consumers. A substantial improvement in the availability of goods, though at international prices, also occurred in Tanzania following trade liberalization (Grether, 2000; Booth, 1993 in Winters, McCulloch and McKay, 2004). This means, if trade liberalization opens up opportunities for investment (in logistics, transport and marketing facilities), it may expand markets and boost consumer satisfaction for capital and consumer goods by watering down monopoly power in the domestic scene.

Input or commodity market failures following trade liberalization in Ghana is reported by Jebuni and Seini (1992). The authors note that, after the removal of subsidies in Ghana, the response of the private sector was poor due to inadequate capital to purchase and supply inputs, as well as to uncertainty about the continuity of the reform process. This caused input scarcity, increased prices of inputs and raised effective interest rates for farmers who borrowed to purchase inputs. The effect was further worsened by the failure of the state to support the private sector that replaced the state corporations eliminated through the introduction of trade liberalization policy.

When potential market failures are neglected, then gains from trade liberalization to developing countries are significant, but when market failures are considered, the social

costs of market failures may exceed the benefits derived. Bussolo and Round (2003) illustrated this fact by showing that if price instability originates from exogenous and normally distributed shocks, it will smooth out following trade liberalization, and its effects can be neglected. If however inefficient markets, imperfect information, risk-averse behaviour of traders and liquidity constraints generate price instability, prices would remain volatile and disperse after liberalization.

According to Berry (2002); Stiglitz (2002); Reardon et al (1999) and Alderman (1995), trade liberalization may directly or indirectly influence price levels or variability of agricultural commodities in developing countries. In the direct sense, price variability increases with trade liberalization due to the high volatility associated with international markets. In protected markets, where local producers are insulated from external output shocks, producers ensure stable prices by using an implicit price determination process i.e. charging high prices when output is low, and taking lower prices at high output levels. This process is not practicable in liberalised and integrated markets where prices of local outputs are globally determined, most often, by only big countries with high production surpluses like the USA. In this sense, trade liberalization can prevent the establishment of efficient markets, especially in countries with poor market infrastructure (Deaton and Laroque, 1992).

The conclusion made from the above observation is that trade liberalization may improve the access of domestic producers to markets locally and globally by including more buyers and sellers. However, by allowing imports, the policy may expose a country's domestic produce to global price and output fluctuations. In the latter case, low in-come farmers of a perishable and import substitutable commodities like tomato stand to lose in the face of trade liberalization and absence of support in the provision of adequate market, transportation, storage and processing facilities.

The extent of creating or destroying marketing opportunities by trade liberalization depends on whether international prices are transmitted through the border into domestic markets. When a country liberalises its domestic market by reducing import tariffs, the price for the imported good at the domestic market is lowered. If it gets the same treatment for its

exported commodities from other countries, the price of the exports rises domestically. The following relations illustrate the theoretical concepts on the linkage between trade liberalization and price transmission. The imported price of a commodity in the domestic market  $P_m$  can be stated as:

$$P_m = P_w R(1 + tm) + C^{ij} \dots\dots\dots (5)$$

Where  $P_w$  is world market price of the commodity,  $R$  is the exchange rate,  $tm$  is a proportional tariff or tax, and  $C^{ij}$  is the transfer costs of importing the commodity from the foreign market  $i$  to the domestic market  $j$ . The  $P_m$  and  $P_w$  are assumed to be expressed in a common currency.

Alternatively, the price of an exportable commodity,  $P_l$ , can be expressed as:

$$P_l = P_w R(1 + t_x) + C^{ji} \dots\dots\dots (6)$$

Where  $P_l$  is local market price of the commodity,  $R$  is the exchange rate,  $t_x$  is the proportional tariff or tax, and  $C^{ji}$  the transfer cost of an exportable commodity from the domestic market  $j$  to the foreign market  $i$ .

In a liberalised economy for a given commodity, a price shock on  $P_m$  first triggers, through border prices, changes in the price of the commodity in markets close to the country's ports, borders and hub of information. These markets then lead the commodity's prices in interior markets in the price discovery process. The rate of price discovery however depends on whether price transmission mechanisms within the country for the commodity are strong or weak (Badiane and Shively, 1997). For a price shock on  $P_l$ , the effect is first transmitted through border prices of the commodity to the commodity's international price. The rate of transmission of price shocks in this case also depends on the degree of integration between domestic and border markets for the commodity.

Our analysis examines price linkages at the domestic level. Where the contemporaneous relationship between two prices,  $P_t^c$  and  $P_t^s$  respectively in an importing (net consumer) market and exporting (net producer) market for fresh tomato is stated as:

$$P_t^c = P_t^s + C_t^{cs} \dots\dots\dots (7)$$

Where  $C_t^{cs}$  is defined the transfer costs (including search and transportation costs, tax and risks) incurred in moving the commodity from the net producer and to the net consumer market.

Overall, it seems that the ability of trade liberalization to reduce or widen opportunities for the emergence of efficient markets and increased price transmission depends on the ability of border prices of a given commodity to influence the domestic prices of the same, and the extent of linkage between urban and rural markets in the country (Winters, McCulloch and McKay 2004). The extent of price transmission in turn depends on the quality of market and other economic infrastructure, seasonality effects, the behaviour of domestic market participants and other mechanisms as discussed below.

## 2.5 Mechanisms Driving Price Transmission

Understanding the mechanisms underlying price transmission could provide an insight into the nature of market performance and help make economic meaning from the results of price transmission and market integration analysis. This section discusses the determinants of market integration and efficiency reported in previous studies. Studies, based on the ESTJ equilibrium model of price transmission tend to attribute price transmission solely to the presence of direct, physical flow of trade between markets and either conclude that markets are integrated or segmented without investigating the reason for market integration or the absence of it (Abdulai, 2007; Fackler and Goodwin, 2001). Whereas the extent of market integration theoretically measures the speed of price adjustment due to the impacts of shocks on markets, in practice, physical factors play a role in determining the magnitude of the speed of adjustment by prices to market shocks. Empirical results of spatial market

integration are therefore enriched by assessing the role of possible determinants of market performance.

Recent literature on agricultural market integration and price transmission reports factors like trade policy distortions, wide marketing margins due to market power, the quality of commodity, inadequate trader access to finance and poor road connectivity between markets as impeding the transmission of price signals (Rapsomanikis et al, 2003). According to this observation, changes in the price of a commodity in a market may not be immediately transmitted to other markets due to non-trivial transportation and transactions costs, market power, foreign or domestic policy impediments, long supply chains and complex contractual arrangements between marketing agents, storage and inventory holding, as well as delays caused in transportation, processing or “price levelling”.

Osborne (2005) reported in Abdulai (2007) found larger markets in Ethiopia to be more competitive because of having better communication facilities than smaller ones. Goletti, Ahmad and Fahid (1995) in Fackler and Goodwin (2001) reported that structural factors like distances between markets, telephone density and labour strikes negatively affects market integration. Aker (2007) reported that information flow through mobile phones influence price transmission between grain markets in Benin. Goletti (1994) also found supply shocks caused by severe weather changes to have a negative influence on market integration.

The problem of inadequate transportation facilities and market information are particularly acute in developing countries. Trader surveys in Benin, Madagascar and Malawi indicated that about 50-60% of total transfer costs are transportation charges (World Bank, 2008). Lack of relevant market information on commodity distribution channels, prices, grades, quality standards and weights for traders in separate market locations often necessitate personal inspection of the commodity by traders. Transportation and market information problems increase transfer and search costs, and may reduce market integration and efficiency levels. Practical experiences show that factors such as concentration of production, long distances between producer and consumer markets, transportation bottlenecks and the perishable nature of tomato constitute impediments to arbitrage processes between tomato markets. Rapsomanikis et al (2003) reported that whereas

improvements in road quality increase the connectivity of markets and the number of market participants involved in trade, non-competitive or collusive behaviour of traders may be a setback to price transmission and market integration.

Therefore, since agricultural markets in the developing countries are not located in “smooth” environments uninfluenced by economic, policy and structural distortions, studies in market integration should increasingly examine the basis for market integration or otherwise. This should be done by treating the factors influencing market integration as endogenous and thus part of the models, rather than as exogenous variables. This study does not intend a rigorous impact assessment of the effects of these factors on market integration, but will explore the relative importance of trade flow vis-à-vis other mechanisms in driving price transmission between markets.

## **CHAPTER THREE**

### **3.0 A Review Empirical Techniques for Price Transmission and Market Integration Analysis**

#### **3.1 Introduction**

The analysis of price transmission spatially or vertically has attracted much attention over the last three decades and generated many analytical techniques. These empirical procedures are as varied as the definitions of market integration, and none of them proves flawless to be preferable in all cases. There is thus debate on which of the different techniques are relevant in which context of market integration analysis. This chapter undertakes a chronological review of the main econometric techniques used for price transmission analysis over the years. The purpose is to provide a theoretical context for some of the techniques applied to analysing the data of this study.

#### **3.2 Static Price Transmission Models**

The premier attempts of price transmission and market integration analysis use standard static techniques. These models viz. simple bivariate correlations and regression techniques, test for the LOP by assuming that prices in spatially linked markets are highly correlated. One advantage of the static market integration models is the ease of estimating them by using only price data. However, their assumptions of stationary price behaviour and fixed transactions costs make this class of models often underestimate the extent of market integration and render the assessment of the phenomenon crude and inappropriate (Barrett, 1996; Baulch 1997). For instance, two functionally isolated markets could appear integrated if commodity prices in each of them were influenced by a third market or inflation contemporaneously. The subclasses of the static approaches are described below.

### 3.2.1 Correlation Coefficients Models

Bivariate correlation models (BCM) measure the extent of market integration by examining the co-movement of price series at fixed transfer costs. If  $P_t^i$  and  $P_t^j$  are two contemporaneous price series in markets i and j connected by trade for a homogenous commodity, the correlation coefficient, r, is obtained by:

$$r = \frac{\sum_{t=1}^n (P_t^i - \bar{P}^i)(P_t^j - \bar{P}^j)}{\sqrt{\sum_{t=1}^n (P_t^i - \bar{P}^i)^2 \sum_{t=1}^n (P_t^j - \bar{P}^j)^2}} \dots\dots\dots(8)$$

Where  $\bar{P}^i$  and  $\bar{P}^j$  are the mean values of  $P_t^i$  and  $P_t^j$  respectively. The numerator represents the covariance of the series, while the denominator is a product of the standard deviations of the series. The sign and magnitude of r, where  $r \leq \pm 1$ , indicate the direction and extent of market integration respectively. A pair of markets with a high degree of integration will therefore have an r-value around positive one. The reverse is true for segmented markets.

Mohendra (1937) was the first to employ bivariate coefficient techniques to assess inter-market performance in India. His analysis revealed coefficients in the range of 0.43 to 0.86. Other authors such as Gupta (1973); Ejiga (1977); also used spatial price correlation to evaluate market integration (Fackler and Goodwin, 2001).

### 3.2.2 Static Regression Models

The bivariate regression models (BRM) of spatial price transmission and market integration analysis are closely related to the BCM in analytical mechanics but different in interpretation (Fackler and Goodwin, 2001). They are commonly specified as:

$$P_t^i = \beta_0 + \beta_1 P_t^j + \beta_2 T_t + \beta_3 R_t + (\varepsilon_t) \dots\dots\dots(9)$$

Where  $P_t^i$  and  $P_t^j$  may be in their first-differenced or logarithms form,  $T_t$  is transaction cost,  $R_t$  denotes other factors influencing prices and the  $\beta_i$ s are the coefficients to be estimated. The two markets i and j are perfectly integrated if  $\beta_1 = \beta_2 = 1$  and  $\beta_0 = \beta_3 = 0$ . Mundlak and Larson (1992); and Gardner and Brooks (1994) employed static regression models in analyzing market integration (Fackler and Goodwin, 2001).

### 3.3 Dynamic Price Transmission and Market Integration Models

Dynamic market integration models recognize and specify lead/lag relationships in spatial market analysis to account for the dynamic nature of price relationships and arbitrage processes due to delivery lags and adjustment costs (Fackler and Goodwin, 2001). The dynamic regression techniques are therefore more efficient in analysing price transmission and spatial integration of markets than their static counterparts.

In agricultural markets, where commodities, because of their bulkiness and production in rural areas exhibit significant delivery lags, the dynamic models significantly improved upon the premier techniques of market integration analysis. Unlike the static approaches that merely investigate whether markets are integrated or segmented, the dynamic methods check in addition the speed of adjustment by a given market price due to a shock on the price in a connected market. A review of four of the dynamic regression models used in market integration analysis is given below.

#### 3.3.1 Granger Causality Tests

Granger (1969) causality test provides evidence of whether price transmission is occurring between two markets, and in which direction. If  $P_t^i$  and  $P_t^j$  are two price series, then  $P_t^i$  granger-causes  $P_t^j$  if both current and lagged values of  $P_t^i$  improves the accuracy of forecasting  $P_t^j$  (Judge et al, 1988). This definition is synonymous to the concept of market efficiency defined earlier. In its later versions with error correction and vector autoregressive (VAR) extensions, Granger-causality tests examines the degree to which both current and past price changes in one market explain current prices changes in another (Baulch, 1997).

Typical Granger causality models are specified in equations (10) and (11).

$$P_t^i = \sum_{k=1}^n a_k P_{t-1}^j + \sum_{k=1}^n b_k P_{t-k}^i + \varepsilon_{1t} \dots \dots \dots (10)$$

$$P_t^j = \sum_{k=1}^m c_k P_{t-1}^j + \sum_{k=1}^m d_k P_{t-k}^i + \varepsilon_{2t} \dots \dots \dots (11)$$

The equation (10) postulates that,  $P_t^i$  is dependent on  $P_{t-1}^j$  and  $P_{t-k}^i$ , lagged prices in markets j and i respectively; conversely, equation (11) postulates the same for  $P_t^j$ . The  $\varepsilon_{1t}$  and  $\varepsilon_{2t}$  are uncorrelated error term series.

Four categories of Granger Causality are possible:

- i. **No Causality or Independence of  $P_t^i$  and  $P_t^j$ :** This is the case when the coefficients of the lagged exogenous variables,  $P_{t-1}^j$ , in equation (10) and  $P_{t-k}^i$  in equation (11) respectively are not statistically different from zero i.e.  $\sum a_i = 0$  and  $\sum d_k = 0$ .
- ii. **Unidirectional Causality from  $P_t^j$  to  $P_t^i$ :** This occurs when  $P_t^i$  is not predictive of  $P_t^j$  when the latter is predictive of the former. This is possible if  $P_t^i$  does not incorporate price information from the market j or if the market information is inefficient. Statistically, this means the coefficients of  $P_{t-1}^j$  in equation (10), as a group, are statistically different from zero i.e.  $\sum a_i \neq 0$ , while the coefficients of  $P_{t-k}^i$  in equation (11), as a group, are statistically not significant from zero i.e.  $\sum d_k = 0$ .
- iii. **Unidirectional Causality from  $P_t^i$  to  $P_t^j$ :** This is the reverse of case ii above. Here,  $P_t^j$  fails to be predictive of  $P_t^i$  for the same reason given above. In this case, the coefficients of  $P_{t-1}^i$  in equation (11), as a group, are statistically different from zero i.e.  $\sum d_k \neq 0$ , while the coefficients of  $P_{t-k}^j$  in equation (10), as a group, are statistically zero i.e.  $\sum a_i = 0$ . It means the market is informational inefficient.
- iv. **Bilateral Causality:** Bilateral causality or feedback exists when both sets of the lagged exogenous variables, as a group, are statistically different from zero in both equations. i.e.  $\sum a_i \neq 0$  and  $\sum d_k \neq 0$ .

Testing for the significance of the lagged exogenous variables involves estimating a restricted model and a full model and then applying the following F-test:

$$F^* = \frac{(RSS_R - RSS_{UR})}{m} \bigg/ \frac{RSS_{UR}}{(n - (k + 1))} \dots\dots\dots(12)$$

Where  $RSS_R$  is the residual sum of squares from the restricted model,  $RSS_{UR}$  is residual sum of squares from the unrestricted model,  $n$  is the total number of observations,  $m$  is the number of restrictions and  $k$  the number of parameters to be estimated.  $F^*$  follows a  $\chi^2$  distribution with  $m$  and  $n - (k + 1)$  degrees of freedom. Significant Granger coefficients mean that shocks to prices in one market evoke significant responses in another, with a lag.

Granger and Elliot (1967) first used Granger causality to examine price relationship of 18<sup>th</sup> century prices of wheat in England. Alexander and Wyeth (1994) used Granger causality tests within the context of cointegration to evaluate the spatial integration of Indonesian rice markets. The authors discovered that Granger causality tests enrich the empirical analysis of market integration.

Empirical weakness of Granger causality tests includes their sole dependence on the statistical difference of the coefficients of the lagged exogenous variables in the models to infer the relationship between the contemporaneous and lagged prices. According to Fackler and Goodwin (2001), a statistically significant relationship that is inconsistent with the conventional notions of market integration could exist and be mistaken as evidence of market integration. Granger causality tests are also sensitive to omitted variable biases.

### ***3.3.2 Ravallion's and Timmer's Concepts of Market Integration***

Ravallion's (1986) model specifies a radial framework of numerous rural markets linked to a central market, and his test for market integration determines whether the price of a commodity in a given rural, producer market is influenced by its price in a central market.

The basic Ravallion functions, specifying price formation in  $N$  markets in a system are given by:

$$P_1 = f_1(P_2, P_3, \dots, P_N, X_1) \dots\dots\dots(13)$$

$$P_i = f_i(P_1, X_i), (i = 2, 3, \dots, N) \dots\dots\dots(14)$$

Where  $N = 1$  denotes a central market;  $N = 2, 3 \dots N$  represents the radial rural markets,  $P_1$  is price of the commodity in the central market,  $P_i$  is Price of the commodity in the  $i^{\text{th}}$  rural market, and  $X_i$  specifies a vector of non-price variables (time trend or seasonal dummies) influencing demand and supply in the local markets.

The dynamic models (15) and (16) derived from the basic functions are written in their autoregressive forms as following:

$$P_{1t} = \sum_{j=1}^n a_{1j} P_{1t-j} + \sum_{k=2}^N \sum_{j=0}^n b_{kj} P_{kt-j} + c_1 X_{1t} + e_{1t} \dots \dots \dots (15)$$

$$P_{it} = \sum_{j=1}^n a_{ij} P_{it-j} + \sum_{j=0}^n b_{ij} P_{1t-j} + c_i X_{it} + e_{it} \dots \dots \dots (16), \forall i=2,3,\dots,N$$

Where  $a_{ij}$ ,  $b_{ij}$ , and  $c_i$  are the parameter estimates, and  $j$  ( $j = 1, 2 \dots n$ ) is the lag lengths. In many cases, equation (15) is under-identified and only the equation (16) is run by regressing the current price in the  $i^{\text{th}}$  rural market ( $P_{it}$ ) on its own lagged values ( $P_{it-j}$ ), the lagged values of  $P_{1t}$  ( $P_{1t-j}$ ), and the common exogenous influences on price ( $X_{it}$ ).

The Ravallion approach differentiates between three forms of market integration:

**i. Market Segmentation** occurs when prices in the local market are independent of lagged prices in the central market. i. e.  $b_{ij} = 0$ , for all  $j, i = 0$ .

**ii. Short-run market integration** (Strong form) between the central and rural markets means price changes in the central market reflect immediately and fully in the local markets without lagged effects. In this case,  $b_{i0} = 1$  and  $a_{ij} = b_{ij} = 0$ , for all  $j = 1, 2 \dots n$ . The weak form of short run market integration is consistent with a less perfectly competitive market structure in that it expects the lagged effects of price changes in the central market on prices in the local market to vanish on average. The statistical condition is that:

$$b_{i0} = 1 \text{ and } \sum_{j=1}^n (a_{ij} + b_{ij}) = 0 \dots \dots \dots (17)$$

iii. **The long-run** criterion for market integration implies that, over the long run, price changes in the central market should in a dynamic fashion equal price changes in the local markets. This criterion requires that all contemporaneous and lagged price effects sum to one:

$$\sum_{j=1}^n a_{ij} + \sum_{j=0}^n b_{ij} = 1 \dots\dots\dots(18)$$

Ravallion applied his model to monthly price data in evaluating the spatial linkages among rice Markets in Bangladesh.

Timmer (1987) assumed that the central market price is predetermined relative to the local market prices and makes two modifications to the Ravallion model. He used the logarithm of the prices and employed a single lag rather than the six lags used by Ravallion. Timmer revealed that a first-order model, as specified in (19), is sufficient to capture the price dynamics between the central and local markets.

$$P_t^i = c_0(P_t^l - P_{t-1}^l) + (c_0 + c_{li})P_{t-1}^l + c_{li}P_{t-1}^i + \gamma X_{it} + \mu_{it} \dots\dots\dots(19)$$

Given long run equilibrium,  $P_t^l - P_{t-1}^l = 0$ . Assuming also that  $\gamma = 0$ , then  $c_0 + c_{li}$  and  $c_{li}$  are the contributions of the central and local market price history respectively to current prices. In well-integrated markets, the former will have a stronger influence on the current local price. To this end, Timmer specified the index of market connectivity (IMC) or of market concentration as a ratio showing the relative influence of the contributions of the lagged effects of the central and local market prices on the current price of the local market.

$$IMC = \frac{c_{li}}{c_0 + c_{li}} \dots\dots\dots(20)$$

IMC lies between zero and infinity, and the closer it is to zero, the greater the degree of short-run market integration. **IMC < 1** implies there is a high degree of short-run integration

between the central and the rural markets, with small lagged effects.  $IMC > 1$  implies there is a low degree of short-run market integration.

### 3.3.3 Cointegration Analysis

The cointegration of a pair of markets means that the dynamics of the price relationships in the two markets may not obey the LOP in the short-run, but in the long run converge towards the LOP. If two price series,  $P_t^i$  and  $P_t^j$ , in two spatially separated markets contain stochastic trends and are integrated of the same order, say I (d), the markets are said to be cointegrated if there is a linear relationship between the price series. In other words, if the test of stationarity proves that  $P_t^i \sim I(1)$  and  $P_t^j \sim I(1)$ , then  $P_t^i$  and  $P_t^j$  are cointegrated if  $\beta$  is such that  $P_t^i + \beta P_t^j \sim I(0)$ . This also implies that  $\varepsilon_t \sim I(0)$ . If the price series are cointegrated, their response adopts a long run equilibrium relationship (Prakash, 1997). Cointegration also implies Granger causality.

Two commonly employed approaches to obtaining cointegration vectors and determining market integration exist. They are the two-step approach of Engel and Granger (1987) used for bivariate models and the Johansen (1990) variance autoregressive (VAR) approach, which is used in multivariate analyses. The first step in employing any of the two approaches is confirming that all the price series for the analysis are non-stationary and integrated of the same order. This involves testing the stationarity properties and the order of integration of the price series individually under a null hypothesis of non-stationarity of the series (unit roots) using the Dickey-Fuller (DF), augmented Dickey-Fuller (ADF), Phillips-Perron (PP) procedures or a host of other approaches to unit root tests.

An observed price series,  $P_t^i$  for the market i is tested for stationarity using the DF (1979) by running a regression of equations (21) or (22) below.

$$P_t^i = \beta P_{t-1}^i + \varepsilon_t \dots \dots \dots (21) \text{ or}$$

$$\Delta P_t^i = (\beta - 1)P_{t-1}^i + \varepsilon_t \dots \dots \dots (22)$$

Where  $\varepsilon_t$  is identically and independently distributed with a zero mean and constant variance ( $\varepsilon_t \sim iid(0, \sigma^2)$ ). The null hypothesis of non-stationarity is  $\beta = 1$ .

Similarly, the augmented Dickey-Fuller (ADF) test estimates the price series,  $P_t^i$ , as an autoregressive (AR) pattern in equation (20) below:

$$\Delta P_t^i = \alpha + \beta P_{t-1}^i + \gamma_t + \sum_{i=1}^n \delta_i \Delta P_{t-i}^i + \varepsilon_t \dots \dots \dots (23)$$

Where  $\Delta P_t^i$  is the first difference of the price series;  $\alpha$  is a constant term;  $\gamma_t$  is a time trend; and n is the number of lags needed to eliminate serial correlation in the series. A failure to reject the null hypothesis,  $H_0: \beta = 1$ , implies that the series exhibits a unit root (I [1]), otherwise the series is stationary. In the first case, the procedure is repeated for the first difference of the price series.

Once the price series are shown to be I[1] but their differences are I[0], they are candidates for cointegration analysis. The test for cointegration typically evaluates an equation such as (24) using OLS:

$$P_t^i = \alpha + \beta P_t^j + \varepsilon_t \dots \dots \dots (24)$$

Where  $\beta$  measures the long run linear relationship between the individual price series,  $P_t^i$  and  $P_t^j$  are as earlier defined, and  $\varepsilon_t$  is the estimated residual error of the long run relationship. Cointegration simply measures whether the above prices  $P_t^i$  and  $P_t^j$  move together; that is whether the differential given by  $\varepsilon_t$  is stationary.

*The Engle and Granger (E-G) Cointegration Approach*

The first step of the Engle and Granger procedure involves estimating equation (24) above using OLS. A Dickey-Fuller (DF) test on the residuals is then performed to determine their order of integration by running the regression below:

$$\Delta \hat{\varepsilon}_t = \alpha_1 \hat{\varepsilon}_{t-1} + e_t \dots\dots\dots (25)$$

Where  $e_t$  is a white noise term.

If we cannot reject the null hypothesis of  $|\alpha_1| = 1$ , we can conclude that the residual series contains unit root, and the two series are not cointegrated. Conversely, a rejection of the null hypothesis means that the residual sequence is stationary, and the series are cointegrated. Given that two series  $P_t^j$  and  $P_t^i$  are I(1) and the residuals are stationary, then the series are integrated of order (1, 1).

The hypothesis of no cointegration may also be tested by verifying the unit root properties of  $\varepsilon_t$  using an improved version of the DF called the augmented Dickey-Fuller (ADF) test. This test is conducted by estimating the equation:

$$\Delta \hat{\varepsilon}_t = \delta + \alpha_1 \hat{\varepsilon}_{t-1} + \gamma_t + \sum_{j=2}^n \phi \Delta \varepsilon_{t-j} \dots\dots\dots (26)$$

Where  $\Delta$  denotes a first-order difference in the estimated residual term (i.e.  $\Delta \varepsilon_t = \varepsilon_t - \varepsilon_{t-1}$ ), and  $n = 1, 2 \dots n$ , are lag lengths. If the null hypothesis of  $|\alpha_1| = 0$  is rejected, then the residual series from this equation are stationary [I (1)], and since the two price series are integrated of the same order, then they are cointegrated of the order (1, 1).

The E-G approach to testing for cointegration is limited in a multi-variable case because it lacks a systematic approach for the separate estimation of multiple cointegration vectors. In addition, the reliance of E-G on two steps i.e. generating a residual series  $\hat{\varepsilon}_t$  in the first step and then using  $\hat{\varepsilon}_t$  to estimate an equilibrium equation in the second step means estimation errors from step 1 could be carried into step 2. In addition, where more than one variable is involved, the test of cointegration using the E-G yields results that are fairly sensitive to the variable selected for normalization.

*Johansen and Juselius Technique*

In a multivariate case, the test for cointegration using the E-G technique yields results that are sensitive to the variable selected for normalization. In this case, a multivariate generalization of the Engel-Granger method proposed by Johansen and Juselius (1990) is used. This method is especially efficient in dealing with multivariate price series obtained from markets in which the direction of causality of price transmission among the markets is unknown (Johansen, 1995, and Ln and Inder, 1997 in Motamed et al, 2008). This is because of the technique’s ability to treat all the markets as endogenous and handle the response of the different variables to market shocks simultaneously. In addition, the Johansen Method overcomes the problem of normalization encountered in the E-G method, and allows the use of variables with different orders of integration i.e. I (0) and I (1) for the analysis.

The following vector autoregressive equations are estimated under the Johansen’s approach:

$$\Delta P_t = \theta_{0t} + \sum_{i=1}^{k-1} \Gamma_{0i} \Delta P_{t-i} + \eta_{0t} \dots \dots \dots (27)$$

$$P_{t-k} = \theta_{1t} + \sum_{i=1}^{k-1} \Gamma_{1i} \Delta P_{t-i} + \eta_{1t} \dots \dots \dots (28)$$

Where  $P_t$  is a vector of time-ordered prices,  $\eta_t$  is the p-dimensional vector of random errors,  $\Delta$  is the first difference operator,  $\theta$  (monthly intercepts to account for seasonality), and  $\Gamma$  p-dimensional vectors and matrices of coefficients to be estimated, respectively. The vectors of random errors,  $\eta_{0t}$  and  $\eta_{1t}$ , are used to construct likelihood ratio test statistics that determine the number of unique cointegration vectors in  $P_t$ .

Two test statistics are used for the null hypothesis of no cointegration. The first test statistic, known as the trace test, evaluates the null hypothesis that there are at most r-cointegrating vectors in  $P_t$  represented by:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i) \dots \dots \dots (29)$$

Where  $\hat{\lambda}$  denotes  $p - r$  smallest correlations of  $\eta_{0t}$  with respect to  $\eta_{1t}$  and  $T$  is the number of observations.

The second maximum likelihood ratio test, known as the maximal Eigen value test, evaluates the null hypothesis that there are exactly  $r$  cointegrating vectors in  $P_t$  and is given

$$\text{by: } \lambda_{\max} = (r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \dots \dots \dots (30)$$

Because  $\ln(1) = 0$ , the expression  $\ln(1 - \lambda_i)$  will be equal to zero if the prices are not integrated. The accuracy of the  $\lambda_{\text{trace}}$  and  $\lambda_{\max}$  depend on the sample size, number of lags and the data series used (Cheung and Lai, 1993 in MacKinnon et al, 1998). Generally however, the further the estimated characteristic roots are from zero, the larger the  $\lambda_{\text{trace}}$  and  $\lambda_{\max}$  statistics.

The null and alternative hypothesis for the  $\lambda_{\text{trace}}$  and  $\lambda_{\max}$  for a case of  $k$  ( $k = 1, 2, \dots, k$ ) price series are:

$\lambda_{\text{trace}}$		$\lambda_{\max}$	
Null Hypothesis	Alternative Hypothesis	Null Hypothesis	Alternative Hypothesis
$r = 0$	$r > 0$	$r = 0$	$r = 1$
$r \leq 1$	$r > 1$	$r = 1$	$r = 2$
$r \leq 2..$	$r > 2...$	$r = 2...$	$r = 3...$
$...r \leq k$	$...r > k$	$... r = k$	$...r = k+1$

If none of the  $k$  null hypotheses above are rejected under the trace and maximum Eigen value tests, it is concluded that either there is no cointegrating vectors (i.e. no evidence of the LOP) or the null hypotheses are falsely rejected due to failure to account for other variables. If the null hypothesis  $r = 0$  is rejected and the second and third null hypotheses are not rejected; it is concluded that there are two cointegrating vectors. If all  $k$  null hypotheses are rejected; then it is concluded that there are  $k$  cointegrating vectors and thus a

confirmation of cointegration among the data series<sup>2</sup>. Critical values for the trace and maximal Eigen value test statistics are obtained from the Johansen and Juselius Table.

Ardeni (1989) and Baffes (1991) applied cointegration analysis to verifying the LOP in international commodity markets. The former revealed that prices would be generally cointegrated if non-stationarity in price series did not exist. Though this revelation is supported by Engel and Granger (1969), Ardeni did not find evidence of cointegration in international commodity markets and concluded that the LOP was not supported in international markets for the basic commodities that he considered. Baffes on the other hand pointed out that cointegration tests alone are insufficient in establishing the LOP. Alderman (1993) also used cointegration test to evaluate the integration of grain markets in Ghana.

Even though, cointegration has an advantage over the earlier methods because it deals with the problem of non-stationarity of time series data in the levels, the standard approach implicitly assumes a linear relationship between price series and stationary transactions costs. This assumption is misplaced because non-linearity in market relationships arises from arbitrage conditions, unsynchronized price cycles, discontinuous trade and non-stationary transactions costs (Baulch, 1997; McNew, 1996; McNew and Fackler, 1997; Fackler and Goodwin, 2002; and Barrett and Li, 2002 reported by Rapsomanikis, 2003). This means the use of linear cointegration analysis is justified only when the long run equilibrium relationship between prices is expected to remain fixed throughout the period of the study. According to Alexander and Wyeth, (1994) in Baulch (1997), cointegration is neither necessary nor sufficient for testing market integration, but is only a pre-test for other econometric techniques of market integration analysis.

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<sup>2</sup> This condition however does not make economic sense since for a number of N series; the number of cointegrating vectors should be N-1.

### **3.4 Switching Regime Regression Models (SRM)**

Usually, prices are related nonlinearly, contrary to the assumption in much of the premier price transmission literature that there exist linear price relationships. Nonlinearity in price relationship result from the influence of transactions costs and trade flows on price dynamics, and motivate the introduction of a class of models collectively called switching regime models (SRM). The idea of switching regression models was first introduced by Quandt (1958) for dealing with structural changes in time series data.

Extensions of the SRM in market integration analyses are founded on the basis that the behaviour of commodity markets is not just a binary case of segmentation or perfect integration, but consists of a spectrum of trade regimes with varying gradations of inter-market linkages. The SRM in price transmission analysis emerged with Spiller and Wood (1988), who estimate the probabilities of observing the asymmetric dynamics of gasoline transfer costs in the USA. Since then, SRM have been used by Sexton, Kling and Carman (1991); Obsfeld and Taylor (1997); Baulch (1997); Meyer and von Cramon-Taubadel (2000); Goodwin and Piggott (2001), Barrett and Li (2002), and others.

Commonly, the SRM obviate the problems of strict classifications of markets into integrated or segmented cases, by establishing probabilistic limits within which distinct spatial arbitrage regimes are likely to hold. The following subsections consider in detail three types of SRM that are topical in market integration and price transmission analysis – the threshold autoregressive (TAR) models, the parity bound models (PBM) and the Markov-switching models (MSM). Variants of these models will be applied later for analyzing our data used for the research papers in chapters five and six.

#### ***3.4.1 Threshold Autoregression (TAR) Models***

The TAR models explicitly recognize the influences of transactions costs faced by traders on spatial market integration and account for them (without necessarily using actual transactions costs data). The idea is that, inter-market price differentials must exceed thresholds bands arising from transactions costs, before provoking existing market equilibrium and causing price adjustment to ensure market integration. To this end, TAR

models provide both a probability of being outside the band – a measure of the extent of violating the arbitrage condition, and a probability of being inside the band – the state at which markets eliminate these violations to return to market equilibrium

Implicitly, TAR models also assume that real, but often unobserved transactions costs, divide trade between markets into two regimes - one in which trade occurs and the other without trade. This is because the models recognise that trade does not occur within the thresholds formed by transactions costs and prices, since trade is unprofitable within thresholds.

If  $d_{ijt} = P_t^i - P_t^j$  is the price difference between  $P_t^i$ , the price of a market under investigation and  $P_t^j$ , the price of a reference market at time t for a homogenous commodity, an estimate of how this price difference responds to a given price difference in a previous period is:

$$\Delta d_{ijt} = \rho d_{ijt-1} + \varepsilon_t \dots\dots\dots (31)$$

Where  $\Delta d_{ijt} = d_{ijt} - d_{ijt-1}$  and  $\varepsilon_t \sim N(0, \sigma^2)$  is the estimated residual. The only parameter estimated,  $\rho$ , is the speed of the price response which measures the extent to which price differences in the previous period are corrected and is the basis for calculating half-lives (van Campenhout, 2006). The above model however does not account for nonlinear effects due to inter-market transactions costs. To account for the transactions costs, requires estimating the TAR long run equilibrium relationship:

$$P_t^i - \beta_1 P_t^j = \varepsilon_t \dots\dots\dots (32)$$

If  $\varepsilon_t = \rho \varepsilon_{t-1} + e_t$  and  $P_t^i$  and  $P_t^j$  are the price series, then a cointegration of the price variables is a function of the autoregressive process for  $\varepsilon_t$ . This means as  $\rho$  approaches one, deviations from the equilibrium become non-stationary and thus the two price series become non-cointegrated. Assuming that  $\varepsilon_t$  follows a threshold autoregressive process, with a two-regime scheme, the behaviour of  $\varepsilon_t$  may be represented as following:

$$\rho = \begin{cases} \rho^{(1)} & \text{if } |\varepsilon_{t-1}| \leq c \\ \rho^{(2)} & \text{if } |\varepsilon_{t-1}| > c \end{cases} \dots\dots\dots(33)$$

Where  $c$  denotes the value of the threshold, which gives rise to the alternative regimes and  $\varepsilon_{t-1}$  is the variable used to capture the threshold behaviour, and has a lag value of 1 denoting a delay parameter ( $d$ )<sup>3</sup>. Similarly, a vector autoregressive (VAR) specification of the threshold model is stated as:

$$\Delta P_t = \begin{cases} \sum_{i=1}^l \alpha^{(1)} \Delta P_{t-i} + \theta^{(1)} \varepsilon_{t-1} & \text{if } |\varepsilon_{t-1}| \leq c \\ \sum_{i=1}^l \alpha^{(2)} \Delta P_{t-i} + \theta^{(2)} \varepsilon_{t-1} & \text{if } |\varepsilon_{t-1}| > c \end{cases} \dots\dots\dots(34)$$

Where  $P_t$  is the vector of prices being analysed.

The test to determine whether the dynamics of the relationships among prices are linear or whether they exhibit threshold effects uses the general nonparametric test of nonlinearity following Tsay (1989). The test is based on the null hypothesis that there no is threshold effect. Given a standard autoregressive model based on the residual term such that:

$$\varepsilon_t = \gamma + \alpha \varepsilon_{t-1} + e_t \dots\dots\dots(35)$$

Tsay (1989) denotes each combination of  $\varepsilon_t$  and  $\varepsilon_{t-1}$  as a set of data and orders individual data sets according to  $\varepsilon_{t-1}$ , the variable relevant to the threshold behaviour. Recursive residuals are obtained by estimating the autoregressive model for an initial sample; then for sequentially updated samples obtained by adding a single observation. A test of linear threshold is given by the regression F-statistic obtained by regressing the recursive residuals

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<sup>3</sup> Thresholds relate to some delay parameter  $d$  in adjusting to the error term  $\varepsilon_t$ , such that  $|\varepsilon_{t-d}| \leq c$  defines the threshold. As discussed below, Tsay's test is used to check for the relevant value of  $d$  to use, but most analyses assume a delay parameter of  $d = 1$ .

on the explanatory variables,  $\varepsilon_{t-1}$ . The Tsay test also helps in obtaining the delay parameter,  $d$ , which defines threshold autoregression in (33). The test is run for alternative delays, and the delay with the largest F-statistic is selected as the optimal (Goodwin and Piggott, 2001).

Once the null hypothesis of absence of linear threshold effects is rejected, the level of the threshold,  $c$ , which defines the two regimes, can be established using a nonparametric estimation strategy following a two-dimensional grid search technique to estimate the thresholds. Two grid search techniques are common - one that maximizes a likelihood function (Obsfeld and Taylor, 1997) and one that minimizes a sum of squared error criterion (Balke and Fomby, 1997).

Prakash (1997), Obsfeld and Taylor (1997), and Goodwin and Piggott (1999), having examined the LOP within the framework of TAR models, established that carefully accounting for unobservable threshold effects due to transactions costs, reduces the likelihood that one rejects the hypothesis of market efficiency. Goodwin and Grennes (1998) also used threshold autoregressive (TAR) models with actual transactions costs data to evaluate market integration. They revealed that market integration, in the respective contexts of their analyses, is stronger when threshold effects are considered (Fackler and Goodwin, 2001).

Notwithstanding their strength in measuring the degree to which markets violate the spatial arbitrage condition (by providing both a probability of being inside and outside the band) and the speed at which these violations are eliminated, TAR models are criticized for their assumption that transactions costs are constant over time. This assumption can be unrealistic, for example in developing countries like Ghana where poor transportation facilities hamper the free flow of goods especially in the rainy season and cause seasonal variations in transportation costs as a result. There is also a difficulty with the TAR models in practically identifying the threshold variable and estimating the associated threshold values (ibid).

### 3.4.2 Parity Bound Models (PBM)

Parity bounds models (PBM) explicitly consider transaction costs and trade flow data, in addition to price series, in analysing market integration. Unlike the conventional dynamic approaches, which strictly accept or reject a null hypothesis at a given significance level, PBM have the advantage of allowing for a continuum of inter-market price relationships within the range of perfect market integration and market segmentation. The following subsection examines in full the PBM following Baulch (1997) and a mention of its extension by Barrett and Li (2002).

#### *Baulch's Parity Bounds Model*

Baulch (1997) first applied the PBM to price transmission and market integration analysis. He noted that market integration should not merely be assessed using co-movement of prices, but also transfer costs - transportation, loading and offloading, storage and processing charges, as well as traders' nominal profits. According to Baulch, transfer costs determine the "parity bound" within which the price of a homogenous commodity in two geographically separated markets varies independently. To this end, Baulch using nominal price series with data on transfer costs series obtained from extrapolated cross-sectional transfer costs data, and by accounting explicitly for the possibility of discontinuous trade between markets assessed the efficiency of inter-market arbitrage for different periods.

The model builds on the following theory. If  $P_t^i$  and  $P_t^j$  are prices of the commodity in two markets  $i$  and  $j$ , assuming that market  $i$  supplies to  $j$ ; and  $C_t^{ij}$  the transactions costs of moving the commodity from market  $i$  to  $j$ , then three regimes that define trade between the markets are defined as follows:

**Regime 1 (located at the parity bounds):** When the transfer costs equal the inter-market price differential i.e.  $P_t^i - P_t^j = C_t^{ij}$ . In this case, given no impediments to trade between the markets, a one-on-one co-movement of prices between the two markets occurs and the spatial arbitrage conditions are binding.

**Regime 2 (located inside the parity bound):** When transfer costs exceed inter-market price differential, i.e.  $P_t^i - P_t^j < C_t^{ij}$ . Here, trade is not expected to occur where producer and consumer markets are specialized since profitable arbitrage opportunities are exhausted. Where there is no specialization of production and consumption between the market pairs, market i ships to market j.

**Regime 3 (located outside the parity bound):** When the price spread exceeds the transfer costs i.e.  $P_t^i - P_t^j > C_t^{ij}$ . Here, the spatial arbitrage conditions are violated. This could indicate that impediments to trade exist and are *prima facie* for market segmentation. In this case, market j ships to market i.

It is worth stating that; regime 1 is consistent with the theory of market integration only where production and consumption areas are completely distinct. When production and consumption areas are non-specialized, then regimes 2 and 3 are consistent with the concept of market integration, and there exists between markets a higher likelihood of trade flow reversals depending on the magnitude and sign of the inter-market price differentials.

On the basis of the above, Baulch's model is specified as a maximum likelihood function in equation (36) below:

$$L = \prod_{t=1}^T [\lambda_1 f_t^1 + \lambda_2 f_t^2 + (1 - \lambda_1 - \lambda_2) f_t^3] \dots \dots \dots (36)$$

Where  $\lambda_2$  and  $\lambda_1$  are the estimable probabilities of the market being in regimes 1 and 2 respectively,  $1 - \lambda_1 - \lambda_2$  is the probability of the market being in regime 3. By maximizing the likelihood function, the upper and lower parity bounds within which the extrapolated transfer costs vary, given the magnitude of the observed price differentials, can be determined.

The three regimes are:

**Regime 1:** Occurs at the parity bounds and implies competitive integration or tradable equilibrium:

$$f_t^1 = \frac{1}{\sigma_e} \phi \left[ \frac{Y_{jit} - K_t}{\sigma_e} \right] \dots \dots \dots (37)$$

**Regime 2:** Occurs inside the parity bounds; implying competitive non-trading or segmented equilibrium:

$$f_t^2 = \left[ \frac{2}{(\sigma_e^2 + \sigma_u^2)^{1/2}} \right] \phi \left[ \frac{Y_{jit} - K_t}{(\sigma_e^2 + \sigma_u^2)^{1/2}} \right] \times \left[ 1 - \Phi \left[ \frac{(Y_{jit} - K_t) \sigma_u / \sigma_e}{(\sigma_e^2 + \sigma_u^2)^{1/2}} \right] \right] \dots \dots \dots (38)$$

**Regime 3:** Occurs outside the parity bounds and implies non-competitive equilibrium or disequilibrium:

$$f_t^3 = \left[ \frac{2}{(\sigma_e^2 + \sigma_v^2)^{1/2}} \right] \phi \left[ \frac{Y_{jit} - K_t}{(\sigma_e^2 + \sigma_v^2)^{1/2}} \right] \times \left[ 1 - \Phi \left[ \frac{-(Y_{jit} - K_t) \sigma_v / \sigma_e}{(\sigma_e^2 + \sigma_v^2)^{1/2}} \right] \right] \dots \dots \dots (39)$$

Where  $Y_{ijt} = \ln \{ |P_t^i - P_t^j| \}$  represents the absolute value of the natural logarithms of the price differential between markets i and j at period t,  $K_t$  is a logarithm of a vector of exogenously determined transfer costs extrapolated from known transfer costs in a single period. The parameters  $\sigma_{v(e)}$ ,  $\sigma_u$  and  $\sigma_v$  are the standard deviations of the error terms  $e_t$ ,  $u_t$  and  $v_t$ ; while  $\phi(\cdot)$  and  $\Phi(\cdot)$  are the standard normal density and distribution functions respectively. To obtain the probability estimates  $\lambda_1$ ,  $\lambda_2$  and  $1 - \lambda_1 - \lambda_2$  respectively for the three regimes, the logarithm of the likelihood function is maximized with respect to the estimated  $\lambda_1, \lambda_2, \sigma_e, \sigma_u$  and  $\sigma_v$ .

The three error terms are introduced to cater for the deviations of the inter-market price difference from the transactions costs in the three regimes. The  $e_t$  - allows transfer costs to vary between periods due to seasonality or changing capacity utilization in the transportation sector. The  $u_t$  captures the extent to which price differentials fall short of parity bounds when there is no trade, and  $v_t$  measures by how much price differentials exceed transfer

costs when the spatial arbitrage conditions are violated or the extent to which markets are prevented from trading due to transportation difficulties, government controls, oligopolistic pricing and other trade flow impediments.

Barrett and Li made significant extensions to Baulch's PBM in 2002. Their extension distinguishes between market integration and competitive market equilibrium, and permits the likelihood of market integration occurring in the absence of trade (a segmented equilibrium), or trade occurring without price transmission (imperfect market integration). Barrett and Li (2002) also incorporated actual trade flow and transfer costs data into price series for their analysis. The inclusion of these datasets and the distinction between all possible (six) trade regimes makes Barrett and Li's approach more informative and useful for policy purposes (Mabaya, 2003). For a complete review of this extension, see Barrett and Li (2002), Mabaya (2003) and Negassa et al (2004).

The PBM has been generally criticised for being static in nature, and for failing to take the time series nature of prices, transactions costs and trade flow into consideration. This means that the PBM merely specifies probabilities of belonging to the various regimes but provide no clues about the persistence of deviations from the short-run to long-run equilibrium (Abdulai, 2007). If prices at time  $t$  affect trade flow at time  $t+1$ , as is likely, the efficacy of the PBM may be reduced in capturing the resultant price adjustment. In addition, forcing transfer costs to be symmetric is an unrealistic assumption, not to mention the practical difficulty involved in measuring transactions costs accurately. As Fackler and Goodwin (2001) noted, "PBMs are nothing more than flexible models of the price spread distribution; the believability of their interpretation rests very strongly on the believability of the distributional assumptions". Practically, the often lack of trade flow and transaction costs data from secondary sources, limit the use of PBMs.

### ***3.4.3 Markov Switching Models***

Markov-switching models (MSM) are probabilistic models specified on the notion that the current state of a system uniquely determines the future evolution of the system. MSM are therefore variants of state-space models. The MSM are thought to be the best alternative to linear models of market integration analysis because they prove superior to others in

forecasting turning points and identifying trend breaks (Erlandsson, 2005, 2003). This class of models and their extensions in the form of Markov-switching vector error correction models (MS-VECM) also helps in explaining non-linearities in data as well as providing adjustment processes by which deviations from long-run equilibrium relationships are corrected for.

Hamilton (2001), who extended Goldfeld and Quant's (1973) Markov-switching model to a time series context, first proposed MSM for time series analysis. His model decomposes time series data into finite sequences of distinct stochastic processes or regimes such that the current process in each regime is linear, but a combination of the past processes is non-linear. In general, the core idea of the premier Markov-switching models is to describe the stochastic process that determines the change from one regime to another in cases where the data generation process (DGP) follows a markov chain. This is done using a transition matrix that describes the probability for regime switches. Even though given probabilities remain unchanged over time, the regime probabilities at time  $t$  depend on the realized regime at time  $t - 1$ .

The standard Markov-switching model is formulated based on the following theory. If  $y_t$  is a time series variable with a finite set of  $M$  regimes such that each  $y_t$  is associated with an unobservable regime dummy variable  $s_t$ ; i.e.  $s_t \in (1, \dots, M)$  and  $s_t = 0$  or  $1$ . Then a basic Markov-switching specification of an autoregressive process for  $y_t$  in a two-regime case is:

$$\begin{aligned}
 y_t &= \phi_1 y_{t-1} + \varepsilon_{1t} && \text{if system is in regime 1} \\
 &&& \dots\dots\dots (40) \\
 y_t &= \phi_2 y_{t-1} + \varepsilon_{2t} && \text{if system is in regime 2}
 \end{aligned}$$

Where  $\phi_1$  is the autoregressive parameter of the series when the current regime is 1, and  $\phi_2$  is the parameter when the current regime is 2. As commonly the case,  $\varepsilon_t \sim iin(0, \sigma^2)$ .

Since the stochastic processes  $\{s_t\}$  that determine the current regime are unobserved, transition probabilities are used to infer the regime at a given time  $t$ . A Markov chain with the stationary transition probability matrix  $p_{ij}$  for the process  $\{s_t\}$  is specified as follows:

$$p_{ij} = \text{Prob}(s_t = j / s_{t-1} = i), i = 0, 1; j = 0, 1 \dots \dots \dots (41)$$

Where  $s_t$  is a state variable assuming the value  $j$  and depending on its lagged value  $s_{t-1}$ . Each  $p_{ij}$  denotes the probability of regime-switching from regime  $i$  to  $j$  i.e. the probability that state  $i$  is followed by state  $j$ .

In Markov switching models, the transition probabilities  $\{p_{ij}\}$  of the likelihood of reverting from one regime to the other in the next period are assumed to be constant. This may be demonstrated as a transition matrix in the two-regime system as follow:

$$p_{ij} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}$$

A limitation of the standard MSM is its restriction to just two regimes. Many extensions to the model however introduced exogenous variables, autoregressive parameters, vector autoregressive processes etc., and this has resulted in several variants of the model with more than two regimes (Erlandsson, 2005). The Markov-switching vector error correction model (MS-VECM) following Krolzig (2002) and Bruemmer et al (2009) is one of such extensions, which is currently among the new techniques in the price transmission literature. The general form of the extended model is:

$$\Delta P_t = \alpha_0(s_t) + \alpha_1(s_t)(\beta' P_{t-1}) + \sum_{i=1}^k \Gamma_i \Delta P_{t-k} + \varepsilon_t \dots \dots \dots (42)$$

Where  $P_t$  is a vector of commodity prices,  $\alpha_0$  is a vector of intercept terms,  $\alpha_1$  is a vector of price adjustment coefficients,  $\beta$  is a cointegrating vector and  $\Gamma$  denotes the matrices of short run adjustment coefficients. In the above representation, only the vector of the

intercept term and the long run price adjustment coefficient,  $\alpha_0$  and  $\alpha_1$ , respectively are regime-dependent, but any of the other variables, including the error term,  $\varepsilon_t$ , could be modelled to depend on regime changes as well (see Bruemmer et al, 2009: 213).

The Markov switching autoregressive model has been applied with success to a variety of time series data (Hamilton, 1988, 1989; McCulloch and Tsay, 1994b; Bruemmer, et al 2009). The model's advantage is that it does not require an explicit transition variable but allows changes between regimes to depend on unobserved state variables. This means regime shifts in the MS-VECM unlike in the TAR or standard VECM, are driven by unobservable transition variables. In this way, the MS-VECM allows the modelling of regime-specific behaviour in markets where unobserved state variables such policy and other random, immeasurable shocks trigger disequilibrium and cause price adjustment processes.

### **3.5 Conclusion**

The principal conclusions to make following the review of the techniques employed in the literature to assess price transmission and market integration are that the various empirical tests, though building upon the limitations of preceding approaches, have their own limitations. The most critical limitations of the latest approaches include their failure to use explicitly other relevant variables like transfer costs and trade volumes to analyze price transmission and market integration. As pointed out in earlier sections, trade flow information and transfer costs, in addition to price data constitute the three most relevant variables that holistically explain market behaviour.

Fackler and Goodwin (2001) support the above view by reporting that “evaluating spatial market integration based on price data alone might provide information about spatial relationship among prices, but it is essential to regard the institutions and facts of the marketing system when interpreting such results”. The above observation means that analysing market integration and price transmission without sufficiently documenting related market variables like trade costs and volume yields less informative results on market performance.

This study applies two non-linear price transmission models viz. the threshold autoregressive (TAR) and the vector error correction (VEC) models which account for transactions costs and trade flow to analyze the data. Due to inadequate transportation, marketing and storage facilities in Ghana, transaction costs forms a major component of the wholesale price of fresh tomato in the consumer markets. Similarly, the volume and direction of trade of fresh tomato in Ghana varies markedly from one season to the other. Therefore, accounting for transaction costs and trade flow, in addition to using price data in this study, is expected to draw us nearer to the truth on the nature of price transmission and market integration in Ghana than did previous studies.

## **CHAPTER FOUR**

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### **4.0 The Study Setting and Data**

#### **4.1 Introduction**

This chapter presents the study setting, types of dataset and data collection procedures. First, the study setting including a general context of fresh tomato production and trade in Ghana is outlined. Then we highlight the specific characteristics of fresh tomato markets namely market participants and price statistics. We also describe the data requirements, data sources and collection procedures. Finally the criteria for sampling and characteristics of the markets from which the data is gathered for this study are presented.

It should be noted that most of the facts presented in this chapter derive from qualitative information on tomato production and marketing that we gathered through self-conducted, semi-weekly market surveys that begun in March 2007 and is still ongoing in the five major tomato markets under study.

#### **4.2 Tomato Production and Trade in Ghana**

Tomato is the most important vegetable produced and consumed in Ghana. Tomato production in Ghana started long before the country's independence in 1957. Commercial production of the crop however followed the economic reforms and trade liberalization policy in 1983. At the commencement of the policy reforms, many redeployed public sector workers became smallholder producers of staple crops and vegetables like tomato for consumption and for the market. Increasing yields of tomato due to improved producer expertise, technology and high profits in years of good harvests and prices gave impetus over the past two decades to the cultivation of tomatoes as a largely commercial enterprise. Tomato is thus currently one of most important income generating vegetables cultivated in Ghana.

The crop is cultivated continuously throughout the year in two tomato production systems. A rain-fed production system practiced largely in Southern Ghana with a bimodal rainfall pattern, and a dry season, irrigated system in the Upper East Region (UER) of Ghana where the rainfall pattern is unimodal. The rain-fed tomato crop is cultivated between June and November, while the irrigated tomato farming is between October and April. Both systems employ labour-intensive technologies at all stages of the production cycle viz. planting, weeding, and fertilizer, pesticides and irrigation water application, as well as in harvesting and marketing. Below is a timeline illustrating tomato production and supply patterns in Ghana.

**Figure 4.1: A Timeline of Production and Supply of Fresh Tomato in Ghana**



An average tomato farm size in Ghana is about one acre in rain-fed or large irrigation areas, and 0.25 acres in small-scale irrigated fields (dry season gardens) in Ghana. Erratic, but torrential rainfall in the wet season and limited availability of water from irrigation facilities and high temperature in the dry season constrain tomato production levels especially between March and June, and sometimes cause low output levels within this period. Sources of water for irrigation include large scale or small-scale lakes, rivers, dugouts and wells. Since all producers of tomato are specialized in producing the crop for the domestic market, their production decisions are mostly influenced by price dynamics in the domestic market.

Inter-market domestic trade in tomato in Ghana predates the implementation of trade liberalization policy. Currently, among the vegetables with significant inter-market trade flows in Ghana, tomatoes have the highest volume, and enjoy a growing and significant demand. Like grain markets, the marketing of tomato, like its production, is subject to no

government support in the post-liberalization period. Direct state interventions akin to those in grain markets did not exist in pre-liberalised tomato markets either; but the use of quotas or bans on imports of tomato paste by the government in the pre-liberalization period ensured stable producer prices and incomes.

The tomato marketing system in Ghana seems to be competitively imperfect; it is characterized by perennial gluts, highly volatile and dispersed prices. This is a problem believed to have both domestic and foreign causes. Domestically, itinerant wholesalers operate market barriers to entry by potential competitors. These entry barriers placed by semi-formal associations of tomato sellers, allow only a limited number of registered members of the associations to sell tomatoes in the consumer markets. Though the cost of becoming a registered member of an association is not exorbitant, existing members generally do not encourage new membership. To sell tomato in the central markets, non-members of the associations have to engage the services of commission agents. As noted by Lutz (1995), barriers to entry raised by traders' associations in the consumer markets may harm effective arbitrage and distribution of tomato between surplus producer and deficit consumer markets.

Following trade liberalization, and with improvement in telecommunication and mobile phone technology, both farmers and traders increasingly have access to price and market information. Farmers are however at the receiving end of the negotiation process because of the perishable nature of tomato, the bargaining power of wholesalers and their use of barriers to block entry by more traders. Anticompetitive practices of traders who employ market power typically lead to producer prices falling or rising less quickly compared to retail prices. Because of this, the producer-retail price margin may widen.

From the foreign scene, dramatic increases in the influx of cheap tomato products from Europe, Asia and America over the last two decades reduced the demand for local tomato. Government statistics show that tomato concentrate imports increased by about 650% from 3300 tonnes to 24740 tonnes between 1998 and 2003. Within the same period, the market share of local tomato declined from 92% at 215000 tonnes in 1998 to 57% at 200000 tonnes in 2003 (Table 4.1). At the regional level, Ghana also imports significant quantities of fresh

tomato from Burkina-Faso between the months of March and May when local output quality and levels are low.

**Table 4.1: Tomato Production and Import Levels in Ghana (1998-2003)**

<i>Year</i>	<i>Production (MT of Fresh Tomato)</i>	<i>Imports (MT of Tomato Paste)</i>
1998	216200	3,269
1999	215000	10,347
2000	200000	9,953
2001	200000	12,169
2002	200000	16,133
2003	200000	24,740

Source: Ghana Statistical Services

Though there is no empirical evidence to support this fact, it appears that rising levels of tomato imports and contemporaneous decline in real prices of locally produced tomato has generated a public view that blames trade policy reforms for reducing competitiveness in local producer markets, more so for agricultural commodities with import substitutes, in Ghana. Anecdotal evidence shows that high imports of cheaper tomato products into Ghana imply price uncertainty for both producers and traders.

As noted in Issah (2007), allowing imports as a condition of trade liberalization exposes producers to price and income risks, and makes tomato production a very risky venture. Traders, especially wholesalers complained about the effects of cheaper tomato products on the sale of their commodity. Even though most tomato consumers in Ghana prefer fresh tomato to imported tomato paste, the lower price of the latter, its high shelf life and viscous texture for soups make it a perfect substitute for fresh tomato.

Tomato processing is not yet significant in Ghana. Due to inadequate processing facilities and ineffective preservation and storage methods, post harvest losses of fresh tomato in Ghana are very high during the peak harvesting period. A few tomato-processing plants installed by the government to promote local production, reduce post harvest losses and

stabilize prices, became unprofitable and bankrupt in 1989 following trade liberalization. One of these, located in the Upper East Region was revamped in 2007.

Transportation difficulties and high marketing risk in transporting perishable commodities like tomato from net producer to net consumer markets were also observed as critical factors limiting the flow of fresh tomato between markets. Less perishable commodities like grains and to some extent, livestock may be supplied to and have the chance of competing with imported substitutes in consumer domestic markets in a liberalised economy. However, tomato and other perishable commodities are usually too risky for arbitrage by wholesalers between markets poorly connected by transportation. This is particularly so in developing countries where transportation, storage and processing facilities are often inadequate.

It was observed during our market surveys that most of the itinerant wholesalers operate between the producing areas and only those net consumer markets well linked by road to the producing areas. This shows that whereas arbitrage of tomato by wholesalers between surplus producer markets and deficit consumer markets connected by major trunk roads is pronounced, arbitrage processes and levels may not be significant between producer and consumer markets that are connected by bad quality and feeder roads. This is obviously a risk adverse strategy by wholesalers to minimize transfer costs and/or losses that may result from delays in transport or transportation breakdown associated with bad roads.

Processed imported tomato products can however be easily imported to all markets and thus have a comparative marketing advantage over locally produced fresh tomato. In addition, the relatively lower prices and longer supply chains of imported tomato may enhance the welfare of consumers in interior markets poorly connected with net, local tomato producing areas. Nevertheless, given the likely welfare-reducing effects of low import prices on poor, rural households that depend on tomato production for their livelihood and on the development of competitive tomato production and storage sectors in Ghana, subsidized imports may lead to net welfare losses overtime. Examining the integration of producer markets to deficit markets off trunk roads in future studies could further shed light on the above observation.

### 4.3 The Structure of Tomato Markets in Ghana

In the last section, we presented the context of tomato production and trade in Ghana. In this section, we describe the structure of Ghana's tomato markets, examining specifically the category of market participants, marketing and pricing patterns in the five markets under study.

Unlike grain markets in SSA in which numerous petty traders of all calibre are involved from commodity assembling at the farm gate to retailing, relatively few traders with clearly defined activities participate in the tomato marketing system in Ghana. In addition, arbitraging activities in grain trade usually occur on market days (three or seven day's week) in market locations. Tomato is however marketed mostly at farm gates in producing areas, and transaction activities in both producer and consumer markets occur on market and non-market days alike since the commodity is perishable.

Selling tomato at farm gates eliminates the additional transportation costs, drudgery and risks that producers may incur in moving tomato from the farm gates to the local markets. Wholesalers on the other hand get higher quantity per crate at the farm gates than in the local markets and may avoid the payment of market tax by buying from farm gates. For both producers and wholesalers, conducting transactions at the farm gates is a faster way of reducing spoilage of tomato and marketing risks, and ensuring good prices. We discovered during the market surveys that the more farmers or traders delay in selling their tomato, the higher the likelihood for them to receive lower prices later or even incur total losses through spoilage.

The main functionaries in Ghana's fresh tomato markets include: itinerant wholesalers, retailers, transporters, and assemblers or commodity brokers, who operate during low supply periods.

- i. Wholesalers:** Tomato wholesalers in Ghana are mostly female, itinerant traders called market women or market queens (in the local parlance). These travel from large consuming centres to buy the produce at roadside near the farms, or at local and

village tomato markets at the producing areas. Wholesalers are therefore responsible for long-distance, inter-market arbitrage of tomato from low-price, net producer markets to high-price and urban, net consuming markets. Their role of providing transportation, and taking marketing risks in shipping the commodity in hired or owned trucks from the farm gate to consumer markets is therefore crucial. This is especially so because of the bulky and perishable nature of tomato. Wholesalers constitute about 10% of the number of market participants in Ghana's tomato markets.

- ii. Retailers:** Retailers constitute a large percentage, over 80% of the number of tomato traders in Ghana. Tomato market retailers operate both in the net producer and net consumer markets. In the net consumer markets, they buy tomato from wholesalers and sell it to consumers or restaurant operators. The retailers in the producer markets buy directly from producers for further distribution to consumers and food restaurant operators in the producer markets. In the lean supply season, producer market retailers may act as assemblers who buy small quantities of tomato from farmers, bulk and sell it to the itinerant wholesalers. Compared to wholesalers, retailers' marketing activities entail fewer risks. They may also benefit from purchasing the commodity on credit from wholesalers.
  
- iii. Transporters:** Transporters in tomato markets include truck owners, drivers and porters who ship the commodity between spatial markets for a fee from wholesalers. Transportation charges for conveying a crate of tomato from net producer to net consumer markets is the major component of transaction costs and vary with fuel prices as well as the distance between the producer and consumer markets. Over the period of the market survey, inter-market transfer costs (TC) between Navrongo as a producer market, and Tamale, Kumasi and Accra as consumer markets increased by about 32.25%; while the TC between the producer market Techiman and the consumer markets rose by 63%. This may be because Techiman's tomato is harvested in a rainy season when the quality of roads to the farm gates is poor.

- iv. Assemblers/Commissioned Agents:** Another category of market functionaries, commission agents or commodity brokers who form a small proportion of the traders in the marketing system exists during surplus or scarce supply seasons to link up producers to wholesalers or vice versa.

Transactions activities in producer tomato markets start around dawn and end in the late afternoon, and involve on-the-spot negotiation for the price per crate of about 52kg. Following the purchase, the commodity is packed into trucks and transported immediately to the urban consuming areas. Express transportation reduces risks of spoilage, which may be high because tomato is very perishable under the hot tropical weather conditions, transportation bottlenecks and the sometimes long distances between producer and consumer markets. To ensure a quick shipment to the consuming centres, the wholesalers may pay high transport charges to transporters.

In the producing areas, the market entry barriers created by wholesalers associations imply fewer buyers, low competition and market power by wholesalers, and hence lower farm gate prices. Tomato farmers' associations also exist and attempt to bargain for fair prices with the wholesalers, but producers lack as much bargaining power as traders, especially in times of gluts of the commodity. In some cases, tomato producers may enter into long-term market relationships viz. supply contracts, preferred supplier agreements and cronyism with wholesalers to ensure good prices for their produce.

Farmers reported that wholesalers not only offer them low prices per crate, but also use bigger crates to buy tomatoes at peak harvests seasons. During this period, prices can be so low that the cost of paying labour to harvest the crop may not even be recovered. Price variability can also be very drastic. For instance, the price per crate could be as low as GH¢2.00 Cedi at peak harvest but rise as high as GH¢30.00 during lean periods. Our market surveys observed wholesale prices at Navrongo as a producer market to be as low as GH¢10.00 during a glut in March 2007, but is GH¢90.00, an increase of 80%, just two months later (May 2007) due to scarcity. Also note that the price volatility in Kumasi and Accra, are the highest (Table 4.2).

Apart from the seasonal nature of these price variations, we suspect that collusive behaviour between traders as well as temporary shocks to transfer costs may also contribute to high price spreads between producing and consuming areas in Ghana. In fact we found price variations to be related with temporary commodity gluts and scarcities. This however does not represent overproduction or production deficits, but is suspected to arise largely from autarky between net producer and some consumer markets poorly linked by road.

**Table 4.2: Market Descriptive Statistics<sup>4</sup>**

<i>Market</i>	<i>Min. Wholesale Price (GH¢)</i>	<i>Mean Wholesale Price (GH¢)</i>	<i>Max. Wholesale Price (GH¢)</i>	<i>Standard Dev.</i>
Navrongo	10.00	33.00	90.00	15.80
Tamale	12.00	32.80	90.00	15.30
Techiman	6.00	31.50	70.00	16.20
Kumasi	8.00	41.70	96.00	29.60
Accra	10.00	53.40	95.00	22.00

Source: Own

The high risks involved in transporting a perishable commodity like tomato from farm gates in surplus producer markets, over poor quality roads, to deficit markets deters the arbitraging activities of tomato traders. Perhaps creating strong linkages between rural farmers and urban markets will help farmers get competitive markets and reasonable prices for their produce. Improvement in storage, processing and market facilities are also crucial in this case, as is support from empirical market research findings in the present trade liberalization scenario.

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<sup>4</sup> The data from which these statistics are computed is collected through self-conducted , semi-weekly market surveys from March, 2007 to April, 2009 in the five markets.

#### 4.4 Data Requirements and Sources

Two types of datasets are used for the analysis – primary and secondary data. The primary data (collection still ongoing) is gathered by administering market integration questionnaire semi-weekly in five tomato markets in Ghana. The subseries of the primary data used in the study covers a period of six tomato production seasons or 26 months (March 2007 to April 2009). The source of the primary data is wholesalers, transporters, farmers and executive members of the tomato traders' associations in the markets under study. This data include prices, marketing and transportation costs per crate, trade volumes measured as the number of truck shipments of tomato per week into net consumer markets, and distances between net tomato consumer and producer markets. In addition, qualitative data on sources of the commodity, means and quality of transportation facilities and fuel costs, and marketing infrastructure is collected. Even though the analysis uses only the price, transfer costs and trade flow data, the additional market information enriches our discussion of the results.

The secondary data include monthly wholesale price series of tomato for the five markets collected from the local branches of the marketing and information departments of the ministry of food and agriculture (MoFA). Though wholesale prices dating back to the 1980s exist, to ensure data consistency and reliability, the period covered by the secondary data used for the analysis is 1992:1 – 2008:8., i.e. the early to the immediate post-liberalization period. The secondary prices in Cedi per Crate (52kg) were converted to real prices using agricultural commodity CPIs with January 2002 as the base month. One of the markets, Accra, is left out of the analysis involving the secondary data for lack of a statistically large number of observations.

The importance of our complete dataset cannot be understated. We noted the critical role transactions costs play in influencing price levels and differentials under the review of non-linear market integration models in chapter three. Our survey for instance reveals that the marketing of tomato involves high transportation costs, while the supply of fresh tomato exhibits seasonal reversal in trade flow due to changes in the source of supply from Navrongo in Northern Ghana to Techiman in the middle of Ghana. Since these two

variables, varying transaction costs and trade flow (in addition to traders' behaviour) affect price dynamics, ignoring them would be a critical limitation to analysing price transmission.

Most of the price data available from secondary sources in Ghana has a monthly frequency. Generally, research has revealed that using data with high sampling frequencies often increases the power of statistical analysis and tests (Choi 1992, in Choi L. and Chung S. B., 1995). Time series market data of lower frequencies may fail to capture some relevant market phenomena that occur in the wide interval between one observation and next. For instance, Lutz et al 1994 found that if the average coefficient of variation for daily agricultural commodity prices in Benin was 10 percent for most markets, this rose to 20 percent and even 30 percent during periods of changing market conditions (e.g. from peak supply to scarcity). In addition, secondary prices from official sources were shown to deviate by 10 to 30 percent from price series collected by self-conducted market surveys (ibid).

One of the principal contributions of the study was thus the generation of the twice-weekly market data we described above. Since the market surveys used to collect the data are continuously administered, the data we use is a complete set. Self-gathered market data has an additional importance for commodities, like tomato, whose markets in Ghana experience a high degree of unpredictable price variability between glut and lean supply periods. The use of market surveys by the researcher also provides, in addition to the quantitative data, useful market information to provide a context within which empirical results can be interpreted

#### **4.5 Market Sampling and Data Collection Techniques**

The five (5) major tomato markets forming the sources of the data were purposively sampled due to the significant quantities of tomato distributed from or in them. A regional stratification of the production areas allowed for the inclusion of markets from the different ecological zones in Ghana and from net tomato producing and net tomato consuming regions. Two of the markets, the Navrongo and Tamale markets are located in the northern

and savannah belt of Ghana; another two, Techiman and Kumasi are located in the southern and forest region of Ghana, while Accra is located in capital and coastal area (Figure 4.2).

**Fig.4.2: A Map of Ghana showing the Markets in the Study**



In the northern savannah zone, Navrongo is a net producer market while Tamale is a net consumer market. In the middle forest belt, Techiman is a net producer market while Kumasi is a net consumer market. Accra is the largest net consumer market among the five markets and in Ghana, while Techiman is the largest net producer market. Net producer

markets are defined as those that are net exporters of tomato, while net consumer markets are net importers of the commodity.

The most important tomato supply market between December and May is Navrongo and smaller producer markets around it. Between June and November, the supply source switches from Navrongo to Techiman and satellite markets in the vicinity of Techiman (see Fig. 4.1). This means that in either of the two sub-periods in the year, all tomato markets in Ghana are supplied, and thus theoretically linked indirectly, by one of these net producers. In the analysis therefore, Navrongo and Techiman are labelled producer markets (denoted s) while Tamale, Kumasi and Accra are consumers markets (denote c). Price transmission and integration between these markets are determined using the data and econometric models, which we describe in chapters five and six.

The collection process for the semi-weekly data involves one enumerator visiting each market location twice weekly to collect information on prices, transaction costs, supply sources and levels (at the reference markets), per unit prices of fuel, distances between supply and reference markets as well as other descriptive market information on supply, demand and market characteristics. The main source of the primary data is tomato wholesalers, retailers and transporters, who were interviewed using specially designed market integration questionnaires.

From the detailed market information collected, only the wholesale prices per crate of tomato and trade flow data were used for the empirical analysis. The price per crate of tomato is the price of the best quality of tomato available at the reference market at the time of the survey. To get the trade flow information and source of tomato supply, the enumerators recorded the number of trucks and main sources of fresh tomato delivered to the reference market on the day of the survey. This information enabled us to determine which producer market, namely Navrongo or Techiman, is the predominant source of supply (trade) on the date of the survey. Since both producer markets supply fresh tomato in two different seasons within the year, then a period of trade (supply) from Navrongo implies a period of no trade (supply) from Techiman. The reverse is also true.

It should be noted however that the trade and no trade periods which we specify in the switching vector error model (see chapter 6) are not wholly exclusive. The task on each day of the market survey was to identify the producer market supplying the highest quantity of tomato to the reference market and assume that trade exists between the two markets on the given date. The commonness in the major source of supply of tomato per season for all tomato markets across Ghana is however a theoretically necessary condition for market integration. The spatial separation of the two major net producer markets also signals reversal in the direction of trade flow seasonally.

#### **4.6 Conclusion and Outlook**

The price transmission and market integration literature often raises several cautions against basing the conclusions of empirical price integration analysis solely on the results of econometric models. They suggest that price transmission results should be interpreted within the context of the environment defining the markets under study. Our presentation and discussion of the results in chapters five and six is thus done within the context of the production, trade and market characteristics of Ghana's tomato markets presented above.

Ideally, our primary data includes all the relevant datasets for market integration analysis recommended by the latest approaches – the TAR and VEC Models - applied in this study. Given the dynamics observed in the tomato marketing system viz. nontrivial transfers costs, use of market power by traders and changes in the quantity and direction of flow of tomato due to seasonality, non-linear techniques of price transmission such as the TAR and other regime switching models are the appropriate analytical techniques for our data.

In chapters five and six, we present the major findings of the study in the form of two research papers extracted from this study. The results of each paper are preceded by procedures to ascertain the unit roots properties of the data using the augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. We also conduct cointegration analysis between net producer/net consumer markets in each paper to achieve our first objective of determining whether there is a long run equilibrium relationship

between the market pairs under study. The maximum likelihood approach of Johansen (1991) is used for the cointegration analysis.

Even though the Johansen's method is not appropriate for analysing our non-linear price series, nevertheless cointegration analysis provides a prima facie evidence for ascertaining the presence of long run equilibrium relationships between prices, which in turn is a prerequisite for applying the TAR and VEC models. Since we are interested in the integration between the main producer and consumer markets, we conducted pair-wise estimations of each of the models to examine the relationship between each producer market and the other four markets in the study. All the analyses in the study are based on the logged values of the price series.

## **CHAPTER FIVE**

### **5.0 The Implications of Agricultural Import Liberalization for Price Transmission between Tomato Markets in Ghana<sup>5</sup>**

#### **5.1 Introduction**

One of the most contentious debates in the last two decades has been whether or not the implementation of market reforms in developing countries improved price transmission between agricultural commodity markets at the foreign and domestic scenes (Rashid, 2004; Bediane and Shively, 1997). Spatial price transmission or market integration measures the degree to which markets at geographically separated locations share common long-run price or trade information on a homogenous commodity. The purported ability of trade liberalization to integrate markets – foreign to domestic markets and domestic markets to each other, through supply and demand forces and offer farmers high price incentives was a major economic need that led Ghana and most developing countries to subscribe to liberalization policy in 1983.

Trade liberalization policy and price transmission are strongly linked. By opening up domestic markets and monopolies to foreign competition, trade liberalization has the potential to widen domestic markets and consequently improve market integration and efficiency in the domestic scene through high export price incentives; or to destroy domestic markets by reducing market integration and efficiency through low import price disincentives. In either case, the resultant effect depends on the level of the domestic prices of a country's commodities relative to the border prices of the same. Likewise, the ability of domestic markets of a country to transmit prices between themselves and across the country's borders is necessary for realizing the welfare impact of trade liberalization (Winters, McCulloch, and McKay 2004). It is therefore

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<sup>5</sup> This paper was presented orally at the Tropentag 2009 Conference, October 6-8, Hamburg, Germany.

not surprising that most empirical studies often set out to explore the connection between trade liberalization and price transmission, and how the two influence each other.

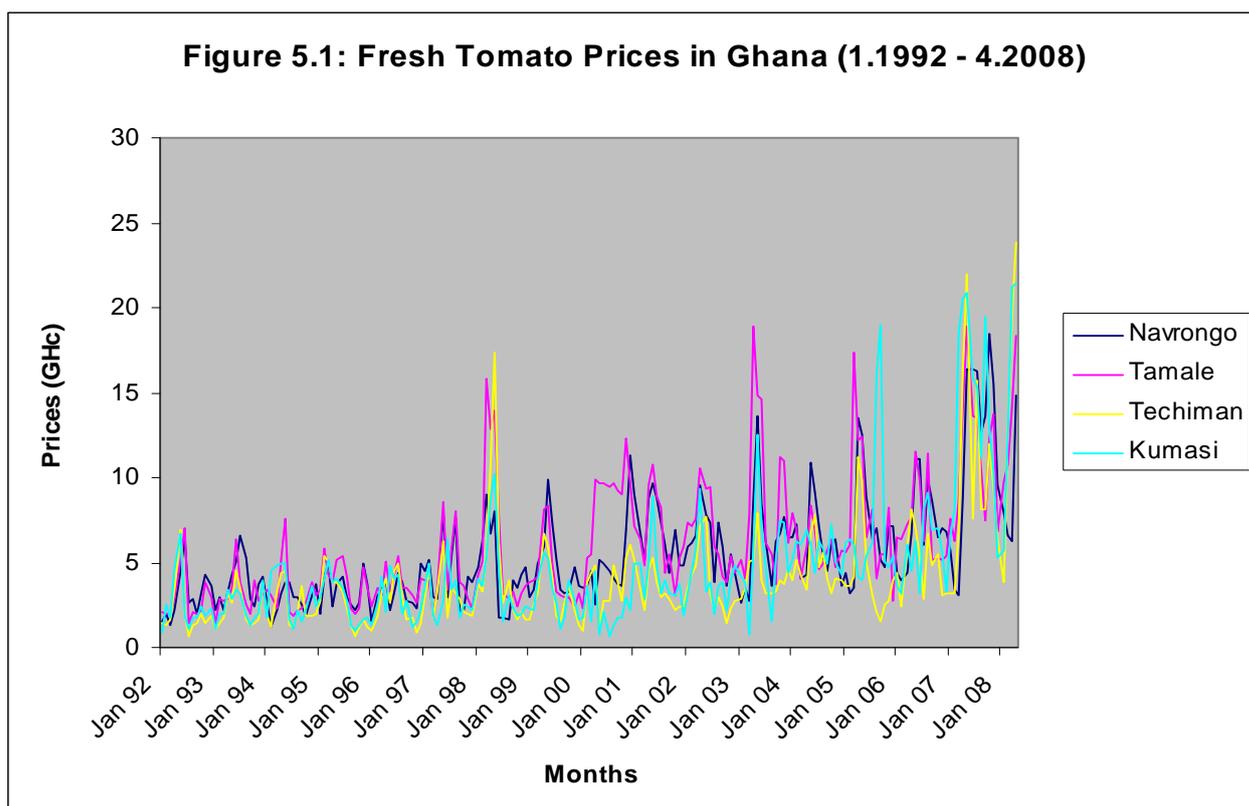
In this chapter, we attempt to assess the impact of agricultural import trade liberalization through the reduction in agricultural tariffs in 2000 on price transmission between fresh tomato markets in Ghana. As we noted earlier, Ghana's reduction in tariffs for agricultural products increased the importation of often cheap and high quality agricultural commodities into Ghana.

For tomato, the commodity under study, the increased importation of tomato products into Ghana is believed to have lowered the demand and created a price disincentive for locally produced tomato. This is because, given their low price, high shelf life and quality, imported tomato products are excellent substitutes for locally produced fresh tomato. The question is have changes in the extent of price transmission between fresh tomato markets occurred following the reduction in agricultural import tariffs and the consequent influx of cheap tomato products into Ghana?

Liberalization policy in Ghana comprised the abolition, in 1990, of state involvement in the production, distribution and marketing of agricultural outputs and inputs. The notion was that, Ghana would achieve market-based development via the emergence of integrated and efficient domestic markets for locally produced staples and increased access to foreign markets for her exports by eliminating state interventions, import trade quotas and tariffs, and liberalizing domestic marketing channels. Two decades after the implementation of trade liberalization policy, few empirical investigations (Alderman, 1992; Bediane and Shively, 1997; Abdulai, 2000) of the performance of agricultural markets in Ghana report either weak or mixed results. A general, public opinion is that Ghana's decision to expose her domestic market to free trade has negatively affected the domestic market for agricultural commodities in Ghana.

Fresh tomato is one of the commodities believed to be affected by trade liberalization policy in Ghana. Anecdotal evidence shows that prices of fresh tomato are generally low, very volatile and dispersed with seasonality i.e. very low at peak periods of harvests and high at lean periods (see Figure 5.1). The price volatility has implied a major source of risks for

tomato farmers and traders. The import dumping of cheaper tomato products from the EU on Ghana is blamed as the main cause of the marketing problem of tomato in Ghana. Opponents of the import dumping view however believe that government inability to strengthen market institutions and infrastructure to enable private sector effectively replace state interventions after liberalization is the major cause.



The opposing views of the implication of trade liberalization policy for the performance of domestic markets are empirically baseless. To the best of our knowledge, no empirical proof of the performance of fresh tomato markets since the advent of trade liberalization policy in Ghana exists. Since evidence on how well markets functioned following liberalization will be useful for policy debate and its evaluation (Dercon and van Campenhout, 1998), we attempt to provide such evidence on the dynamic adjustment path of fresh tomato markets from January 1992 to date in Ghana.

In this chapter, we examine the performance of Ghana’s fresh tomato markets in two sub-periods following trade liberalization. The first sub-period (hereafter called the high tariffs

period) is from January 1992 to December 2000, while the second sub-period (the low tariffs period) is from January 2001 to April 2009. Both periods follow a transitional period (between 1984 and 1990) in which liberalization policy gained ground and the marketing system adjusted to the new policy environment. The level of import protection of agricultural markets up to 2000 was about 20% or more. The tariffs rates were gradually rationalized to rates of 0%, 5% and 10% after 2000, with the agricultural protection tariffs falling to about 13% alongside the complete removal of import quotas and bands in 2001 (FAO, 2006).

We examine changes in the extent of price transmission and market integration via changes in transactions costs (measured by thresholds), speeds of price adjustment and half-lives across the two sub-periods – 1992 to 2000 and 2001-2009. One would expect the speed of price adjustment between markets to be higher in the low tariffs period than in the high tariffs period, and transaction costs to fall with the observed improvements in the quality of road, transportation and information technology in the low tariffs period.

The central hypothesis tested is that price adjustment parameters and thresholds in fresh tomato markets in Ghana did not change over the two periods i.e. there have been no improvements in the speed of spatial price adjustment and levels of transaction costs between the net producer and net consumer fresh tomato markets in Ghana. A rejection of this hypothesis would dispel the notion that trade liberalization policy left local producers of agricultural commodities, especially tomato farmers, worse off. Tomato is the commodity of interest in the analysis because it is one of the commodities affected by import trade liberalization policy in Ghana.

The findings show no evidence to support the claim that trade liberalization worsened price transmission and integration between fresh tomato markets in Ghana. Impediments arising from oligopolistic behaviour of traders, seasonal production and poor connectivity of surplus producer markets with potential consumer markets off the West African highway, may be setbacks to the ability of liberalization and improved quality of road and transport infrastructure in eliminating the supply gluts, dispersed and volatile prices as well as other signals of market failure in Ghana's tomato markets.

In the following section, we describe the study setting by examining the nature of fresh tomato supply, trade flows and the data used for the analysis. Then we specify, in section 5.3, the standard TAR model and its extended variant used for the analysis, while justifying the relevance of the model for estimating price transmission and market integration in the target markets. This sets the stage for section 5.4 where we present and discuss the results of the analysis. The final section concludes the chapter and outlines suggestions for policy and further research.

## **5.2 The Dataset**

The data used for this analysis was collected from the local branches of the marketing and information departments of the Ministry of Food and Agriculture (MOFA) located in the five markets under study. It comprises wholesale level prices per crate of fresh tomato from two producer and three consumer tomato markets in Ghana. Though wholesale prices dating back to the 1980s exist, we used only the series collected in the post trade liberalization period, specifically from January 1992 to April 2009. We present in detail the nature of the secondary data used in this analysis in chapter four.

To capture the dynamics in price adjustment parameters and transaction costs over the period, we divide the dataset into two. Price series from 1.1992 to 12.2000 were gathered in a high import tariffs period, while the series from 1.2001 – 4.2009 represent tomato prices after import tariffs rates were reduced. The market of Accra was dropped from this analysis for lacking a statistically sufficient number of observations. The specification of the sub-periods is based on the pattern of Ghana's agricultural import liberalization policy. According to the FAO (2006), import surges of tomato products into Ghana exceeded the trigger volume in 2000 and local producers have since lost their market share by about 35%.

The spatial separation of the two major net producer markets and consequent seasonal reversal in the source and levels of production<sup>6</sup> creates variations in the prices and inter-market transfer costs of tomato. This market characteristic makes the data – prices and transaction costs non-stationary and provides an ideal case for employing the TAR model in analysing price transmission and market integration between the markets under study. As noted below, the standard TAR model and its extension are capable of capturing non-linearities in the price series due to reversals in the direction of trade flow and non-constant transactions costs. Practically, transactions costs and trade flow reversals have the potential to modify arbitrage conditions and the nature of price transmission and market integration between markets.

We estimate price adjustment parameters, thresholds and adjustment half-lives between market pairs separately for each period, and examine changes in the estimated coefficients across the two periods. The producer markets, Navrongo and Techiman are the reference markets in the analysis. Since Ghana experienced high rates of inflation during the 1990s and first half of the 2000s, we deflated the secondary price data using consumer price indices for food (CPIs) published by the Ghana Statistical Services<sup>7</sup>. The hypothesis that the price series are non-stationary is tested using the augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. All prices are expressed in the new Ghana Cedi and the price series are transformed into their natural log values for the analysis.

### **5.3 Methodology**

The observed reversal in trade flow due to seasonal changes in the source of supply implies a variation in inter-market transportation costs which is the main component of transaction costs, and suggests the likelihood of the presence of threshold effects in price dynamics in the tomato marketing system in Ghana. Our use of the TAR model is to account for these threshold effects. The extension of the TAR to include a time trend in the adjustment parameters and thresholds, unlike the standard equilibrium TAR (SETAR) model, is particularly efficient in

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<sup>6</sup> Techiman produces more tomato and has a longer supply period than Navrongo.

<sup>7</sup> We used March 2007 as the base. A choice of March 2007, the month in which the observations of the primary data start, makes both series comparable.

estimating inter-market price adjustments and transactions costs (thresholds) when markets are characterised by non-constant arbitrage boundaries delineated by transaction costs (threshold) and trade flow reversals. Both variants of the TAR model employed use price series explicitly but assume transaction costs implicitly in the estimation process.

The general theoretical framework of the TAR model employed is described below. Assuming the price difference or inter-market price margin between a pair of spatially separated net consumer market,  $c$ , and net source market,  $s$ , is given by  $d^{cs} = P_t^c - P_t^s$ , the TAR model, as noted earlier on, estimates the response of the price difference (determined by the magnitude of transaction costs) at time  $t$  to the price difference at time  $t-1$ , i.e. the effect of  $d_{t-1}^{cs}$  on  $d_t^{cs}$  as follows:

$$\Delta d_t^{cs} = \rho d_{t-1}^{cs} + \varepsilon_t \quad (1)$$

Where  $\Delta d_t^{cs} = d_t^{cs} - d_{t-1}^{cs}$  is the change in the price difference between periods  $t-1$  and  $t$ , and  $\rho$  is the speed of price adjustment measuring the rate at which the price difference in period  $t-1$  is corrected to achieve price equilibrium between the market pair  $c$  and  $s$ . The residual term, as usual, is assumed to be  $\varepsilon_t \sim N(0, \sigma^2)$ .

Since practically, transactions costs are expected to significantly influence price adjustment and have been observed through our market survey to vary over time between producer/consumer market pairs, using equation (1) is inappropriate because it ignores this fact. A threshold autoregressive form of (1), which allows the price adjustment process to vary according to whether the lagged price margin  $d_{t-1}^{cs}$  is below or above a threshold,  $\tau^{cs}$  (a proportional measure of the inter-market transaction costs) is ideal. This form of the model is specified as follows:

$$\Delta d_t^{cs} = \left\{ \begin{array}{l} \rho^{out} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} > \tau^{cs} \\ \rho^{in} d_{t-1}^{cs} + \varepsilon_t, \text{ if } -\tau^{cs} \leq d_{t-1}^{cs} \leq \tau^{cs} \\ \rho^{out} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} < -\tau^{cs} \end{array} \right\} \quad (2)$$

Where  $\rho^{in}$  is the adjustment parameter when the price margin is below  $\tau^{cs}$  and  $\rho^{out}$  is the adjustment parameter when the absolute value of the price margin exceeds  $\tau^{cs}$ . It is assumed that there is no adjustment inside the band, i.e.  $\rho^{in} = 0$  and adjustment within the band formed by transactions costs (thresholds) is thus purely a stochastic process. The threshold variable ( $\tau^{cs}$ ) delineates the trade mechanism into a three trade-regime where price adjustment occurs only in the outer regimes when  $d_{t-1}^{cs} < -\tau^{cs}$  or when  $d_{t-1}^{cs} > \tau^{cs}$ . In these two outer regimes, which are assumed to have equal threshold band widths, profitable arbitrage opportunities exist and need to be fully exploited.

A limitation of the model (2) is however its assumption of a constant threshold value over time. We stated in section 5.2 that transaction costs are rarely constant in Ghana's fresh tomato markets; they vary with the season, direction of trade flow and international crude oil prices. This necessitates an extension of the TAR framework to include a time trend. The extension following van Campehout (2006) specifies the TAR model such that the adjustment parameters and thresholds vary with time,  $t$ . The extended model, like (2), is also a three-regime symmetric model that assumes no price adjustment within the band formed by the thresholds. This is specified as:

$$\Delta d_t^{cs} = \left\{ \begin{array}{l} \rho^{out} d_{t-1}^{cs} + \rho'_{(t)} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} > \tau_{(t)}^{cs} \\ \rho^{in} d_{t-1}^{cs} + \rho'_{(t)} d_{t-1}^{cs} + \varepsilon_t, \text{ if } -\tau_{(t)}^{cs} \leq d_{t-1}^{cs} \leq \tau_{(t)}^{cs} \\ \rho^{out} d_{t-1}^{cs} + \rho'_{(t)} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} < -\tau_{(t)}^{cs} \end{array} \right\} \quad (3)$$

Where  $\rho'_{(t)}$  and  $\tau_{(t)}^{cs}$  denote the time-varying speed of price adjustment parameter and threshold variable respectively, and all other notations are as already defined. The  $t$  represents time from 0 to T, such that at  $t=0$ , the threshold is  $\tau_0^{cs}$  and at  $t=T$  the threshold is given by  $\tau_T^{cs}$ . Both  $\tau_0^{cs}$  and  $\tau_T^{cs}$  are determined by grid search.

With the assumption of stationarity within the bands, the models we actually estimate using (2) and (3) are respectively:

$$\Delta d_t^{cs} = \left\{ \begin{array}{l} \rho^{out} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} > \tau^{cs} \\ \varepsilon_t \quad \text{if } -\tau^{cs} \leq d_{t-1}^{cs} \leq \tau^{cs} \\ \rho^{out} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} < -\tau^{cs} \end{array} \right\} \text{ and } \Delta d_t^{cs} = \left\{ \begin{array}{l} \rho^{out} d_{t-1}^{cs} + \rho'_{(t)} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} > \tau_{(t)}^{cs} \\ \varepsilon_t, \quad \text{if } -\tau_{(t)}^{cs} \leq d_{t-1}^{cs} \leq \tau_{(t)}^{cs} \\ \rho^{out} d_{t-1}^{cs} + \rho'_{(t)} d_{t-1}^{cs} + \varepsilon_t, \text{ if } d_{t-1}^{cs} < -\tau_{(t)}^{cs} \end{array} \right\}$$

The idea of threshold effects in analysing time series data was introduced by Balke and Fomby (1997), but Goodwin and Piggott (2001) first applied the TAR model to analyse price transmission, while van Campenhout (2006) applied the standard TAR model and its extension with a time trend to analyse price transmission between maize markets in Tanzania. A limitation of the model often reported by some of these studies is that the asymptotic distribution of the threshold parameter is non-normal. As such, unbiased standard errors and confidence intervals cannot be obtained (Chan 1993 in Van Campenhout, 2006). The other limitation of constant transactions costs over time is however addressed when a time trend is added to the standard TAR model such that both the thresholds and adjustment coefficients are estimated as time-varying parameters.

## 5.4 Results

This section presents and discusses the results of the analysis. The section focuses on the differences between the estimated speeds of price adjustment, their associated half-lives and thresholds (transaction costs) across the high- and low tariffs periods. We do not estimate the simple autoregressive (AR1) form of the model but only the standard TAR and its variant. The results enable us to verify whether there are changes in the estimates across the two sub-periods, and thus an improvement in the inter-market transmission of fresh tomato price signals following the reduction of agricultural import tariffs in Ghana.

### 5.4.1 Results of Unit Root and Cointegration Tests

Following the traditional approach of time series analysis, we first test the hypothesis of unit roots in the levels and first differences of each price series using the ADF and KPSS tests. Visually examining the graphical plot of the series in Figure 5.1 reveals the unlikelihood of a non-zero expected mean in the levels of the series and justifies the inclusion of a constant in the equations used for the unit root tests.

No obvious persistent trending behaviour is however observed in the graphical plots of the data. We note that the few deviations from the gently sloping trend line are corrected quickly to prove the purely stochastic nature of a trend component. Based on these observations, we omit a deterministic trend in both the tests for unit root and in the Johansen's cointegration model. The chosen lag lengths in both tests are based on the Hannan-Quinn criterion (HIC). The Gauss software was used for both the cointegration and unit root analysis. The results of the unit roots test are presented in Table 5.1.

**Table 5.1: Results of ADF and KPSS Unit Root Tests on the Monthly Price Series**

<i>Series</i>	<i>ADF Test</i>		<i>KPSS Test</i>	
	<b>Levels</b>	<b>First Diff.</b>	<b>Levels</b>	<b>First Diff.</b>
<b>Navrongo</b>	-1.568	-8.729**	2.271**	0.028
<b>Tamale</b>	-1.018	-8.550**	2.337**	0.053
<b>Techiman</b>	-0.684	-9.002**	2.000**	0.051
<b>Kumasi</b>	-0.743	-11.223**	2.236**	0.059

Source: Own

The asterisks \*\* and \* denote rejection of the null hypothesis at the 1% and 5% significance levels. The respective critical values at the 1% and 5% significance levels are -3.43 and -2.86 for the ADF test and 0.347 and 0.463 for the KPSS test at the price levels; and -2.56 and -1.94 for the ADF and 0.347 and 0.463 for the KPSS test at the first differences of the prices.

The results of the ADF test, considering the suggested lag lengths, show that at the 1% and 5% critical values of -3.43 and -2.86, the null hypothesis of unit root,  $H_0: \rho = 0$  i.e. the series is non-stationary, cannot be rejected for all four price series in their levels. As expected, the null hypothesis is rejected after taking a first difference of all series and testing for stationarity. The KPSS results confirm those of the ADF test; by these, we strongly reject the null hypothesis of no unit roots (i.e. the series is stationary) in the level of the prices series at the 1% and 5% significance levels, but cannot reject the null hypothesis at the first difference of the price series. Therefore, the series under the study are (first) difference stationary processes i.e. they have unit root or are I (1).

With the proof that the price series is non-stationary, we proceed to test for cointegration between net producer/net consumer market pairs using Johansen's, maximum likelihood VAR

approach (see chapter three). The results of the cointegration test between the market pairs are presented in Table 5.2.

**Table 5.2: Johansen's Cointegration Test Statistics**

<i>Market Pair</i>	<i>Test Statistic (Trace Test)</i>	
	<b>Ho: r = 0</b>	<b>Ho: r = 1</b>
<b>Navrongo - Kumasi</b>	61.22**	4.81
<b>Navrongo – Techiman</b>	64.04**	6.08
<b>Navrongo - Tamale</b>	48.61 **	1.96
<b>Techiman -Kumasi</b>	56.04**	5.78
<b>Techiman - Tamale</b>	48.31**	7.75

Source: Own

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

The results provide evidence in favour of cointegration between the four tomato market pairs under study. The null hypothesis of  $r = 0$ , implying an absence of a cointegration relation is rejected for all the market pairs at both the 1% and 5% significance levels. We cannot however reject the null hypothesis of one cointegrating relation, i.e.  $r = 1$  between pairs of net producer/net consumer markets. Therefore, there exists at least one stationary cointegration relation ( $r = 1$ ) between the pairs of net producer and net consumer price series measured monthly, and by implication among the system of markets considered.

The findings imply that similar stochastic processes, possibly induced by efficient information flow, drive the behaviour of prices in the system of markets (Motamed et al, 2008). Therefore tomato prices in the producer and consumer markets do not drift apart in the long run. The proof of cointegration is also evidence for a common domestic tomato market in Ghana, where inter-market prices adjust to achieve market long-run equilibrium. We suspect that price transmission and market integration did not just arise following tariffs reductions but pre-existed the reduction of import tariffs. Perhaps the seasonal nature of tomato production, with either the Navrongo or Techiman market being a major source of supply to the other

markets in the system at a point in time, and recent improvements in roads, means of transportation and information flow via mobile phones, explains this outcome.

Since a good quality, trunk road connects the system of markets under study, concluding that a common domestic tomato marketing system exists in Ghana as a whole may be hyperbolic. It is likely that cointegration may be lacking between net producer and consumer markets poorly connected by road. The evidence of at least one cointegrating relation between the market pairs however provides an ideal setting for us to use the TAR techniques to explore the nature of price transmission and market integration between the markets.

#### ***5.4.2 Results of the TAR Models***

We estimate two forms of the TAR models – the standard TAR model (2) without time trend and its extension with time trend in the threshold and adjustment parameter in the model (3). Our analysis is symmetric, examining price responses in the net producer markets due to shocks on the consumer markets. The estimation was done using the Stata software. The results of the standard TAR model (Table 5.3) show a mix pattern of price transmission and market integration across the two periods.

The estimated thresholds ( $\tau^{cs}$ ) – a proportional measure of the amount that inter-market price differentials must exceed before provoking price adjustment – are higher for the market pairs Tamale-Navrongo (0.21) and Techiman-Navrongo (0.45) in the reduced- than in the high tariffs period. The reverse holds true for the estimated  $\tau^{cs}$  for the Kumasi-Navrongo (0.31), Tamale-Techiman (0.54) and Kumasi-Techiman (0.19) market pairs.

On average, the threshold between the pairs of net producer and net consumer fresh tomato markets would have to be at least 36.4% above the inter-market price margin under the high tariffs period and about 34% above the price margin under reduced tariffs period to trigger price adjustment in the outer bands. The above means, whereas both negative and positive inter-market price variation of up to an average of 36.4% from their equilibrium values did not trigger arbitrage in the first period, price divergence of up to an average of 34% did not trigger arbitrage following tariffs reductions. The proportional “trigger” transaction costs therefore fell by 2.4 percentage points following the reduction of tariffs.

**Table 5.3: Adjustment Parameters, Thresholds and Half-lives (Standard TAR Model)**

<i>Market Pair</i>	<i>Dist. (Km)</i>	<i>High Tariffs (1992-2000)</i>			<i>Reduced Tariffs (2001-2009)</i>		
		$\tau^{cs}$	$\rho^{out}$	$\hat{\lambda}^s$	$\tau^{cs}$	$\rho^{out}$	$\hat{\lambda}^c$
Tamale-Navrongo	190	0.13	-0.491** (-5.87)	1.03	0.21	-0.663** (-6.80)	0.64
Techiman-Navrongo	460	0.30	-0.394** (-5.09)	1.39	0.45	-0.295** (-4.28)	1.98
Kumasi-Navrongo	610	0.37	-0.500** (-5.71)	0.99	0.31	-0.488** (-5.45)	1.04
Tamale-Techiman	270	0.70	-0.378** (-4.88)	1.46	0.54	-0.384** (-5.09)	1.43
Kumasi-Techiman	150	0.32	-0.778** (-7.73)	0.46	0.19	-0.548** (-6.06)	0.87

Source: Own

The asterisks \* and \*\* denote significance of the adjustment parameters at the 5% and 1% levels respectively, with the t-values of the speeds of price adjustment given in the brackets.  $\rho^{out}$  is the estimated adjustment speed in the outer regimes.

The half-lives of price adjustment,  $\hat{\lambda}^s$  and  $\hat{\lambda}^c$ , for the producer and consumer markets respectively, are measured in months. The t-values are in the brackets.

There is significant evidence of price adjustment, demonstrated by high speeds of convergence of price deviations to long run in both tariffs periods. All the inter-market speed of adjustment parameters ( $\rho^{out}$ ) are also significantly different from zero. This supports the cointegration results and proves that trade information does flow between the market pairs. Considering individual pairs of markets, we find that the speed of price adjustment between the markets pairs improved fairly, by about 0.172 (17.2%) only for Tamale-Navrongo after tariffs were reduced in 2000. Price adjustment between all other market pairs declined or remained the same (such as between Tamale and Techiman) across the two periods. Especially notable is the decline in the speed of price adjustment between Kumasi and Techiman by about 0.230 (23 percentage points).

Overall, fresh tomato prices adjusted faster to market shocks in the period of high tariffs where the mean value of the speed of adjustment is about 0.508 (50.8%), than in the reduced tariffs period with the adjustment speed of 0.476 (47.6%). This signifies a 3% decline in the

rate of price transmission between the producer and consumer markets and hence in the level of spatial integration of the tomato markets over the two periods. This happened despite the reduction in transfer costs by about 2.4% over the same period.

A look at the estimated half-lives of price adjustment reveals that disequilibrium and unexploited arbitrage opportunities persisted a little longer in the reduced tariffs period than in high tariffs period. The half-lives of price adjustment suggest that prices need, on average, 1.2 months (5 weeks) under the reduced tariffs period to correct half of the deviations from price equilibrium following market shocks as against the one month needed under the high tariffs period to correct half of the deviations. As with the estimated adjustment parameters and thresholds, these findings are also mixed. Whereas, the time required (half-life) for Tamale-Navrongo to correct half of the deviations from equilibrium reduced rapidly from about one month to 0.6 months (under three weeks), the half-life of adjustment between Navrongo and Techiman increased from 1.4 months (6 weeks), from the first period to two months in the second.

The results of the standard TAR model therefore reveal mixed patterns in the inter-market speeds of price adjustment, adjustment half-lives and levels of transaction costs across the two periods. It appears that investments in transportation facilities, market infrastructure and road improvement; especially the asphaltting of the 460Km stretch of the West Africa highway between Techiman and Navrongo, in the last decade of trade liberalization policy in Ghana reduced the proportional costs of moving tomato from producer to consumer markets by about 2%. The costs reduction has not however led to an increase in the speed of price transmission between markets as would be expected. This is because the speed of price transmission and by extension the degree of market integration in fresh tomato markets declined by about 3% in the period following the elimination of high import tariffs in Ghana.

The above findings imply that, despite the obvious improvement in information technology as well as road, transport and market infrastructure, leading to decline in transaction costs in the distribution level of the supply chain, other opportunities for efficient transmission of tomato price signals between producer and consumer markets following tariffs reductions deteriorated. Recalling the observations made earlier, we suspect that the import surge of

cheap tomato products into Ghana, the oligopolistic behaviour of wholesalers, seasonality, road barriers and toll gates, and risks to trade may jointly undermine the potential of the improved infrastructure in boosting price transmission and the market competitiveness of locally produced tomato.

By including a time trend in the extended TAR model, we may obtain further evidence to verify the above suspicion. Since transfer costs in the markets under study are non-constant, estimating the TAR model with the speeds of adjustments and thresholds specified as time-varying parameters may yield more economically interpretable results than those of the standard TAR model. The results of the extended model are presented in Table 5.4.

**Table 5.4: Price Adjustment Parameters, Thresholds and Half-lives (Extended TAR Model)**

<i>Market Pair</i>	<i>High Tariffs (1992-2000)</i>				<i>Reduced Tariffs (2001-2009)</i>			
	$\tau_{(t)}^{cs}$	$\rho^{out}$	$\rho'_{(t)}$	$\hat{\lambda}^s$	$\tau_{(t)}^{cs}$	$\rho^{out}$	$\rho'_{(t)}$	$\hat{\lambda}^s$
<b>Tamale-Navrongo</b>	0.18	-0.845** (-4.33)	0.0050* (1.95)	0.4	0.16	-1.186** (-4.98)	0.098** (2.44)	NA <sup>8</sup>
<b>Techiman-Navrongo</b>	0.43	-0.229* (-1.44)	-0.0033 (-1.33)	2.7	0.40	-0.073 (-0.58)	-0.0049** (-2.13)	9.2
<b>Kumasi-Navrongo</b>	0.46	-0.588** (-3.12)	0.0012 (0.47)	0.8	0.35	-0.451** (-2.32)	-0.0011 (-0.34)	1.00
<b>Tamale-Techiman</b>	0.50	-0.501** (-3.38)	0.0021 (1.05)	1.0	0.67	-0.115 (-0.70)	-0.0082** (-2.33)	5.7
<b>Kumasi-Techiman</b>	0.19	-1.387** (-5.95)	0.0091** (3.00)	NA	0.19	-0.947** (-3.74)	0.0075* (1.69)	0.23

Source: Own

Notes:  $\tau_{(t)}^{cs}$  is the average value of the threshold estimates at the beginning and end of each sample and is estimated with trend. The adjustment speed coefficient  $\rho^{out}$  is estimated without time trend while coefficient  $\rho'_{(t)}$  has a time component in it. \* and \*\* denote significance of the speeds of price adjustment at the 10% and 5% levels respectively. For economy of space, we report both the adjustment coefficients with and without time trend, but only the average threshold values. The t-values are in the brackets.

<sup>8</sup> Estimated half-lives are not available (NA) for market pairs that exhibit over adjustment, namely Kumasi-Techiman in sub-period I and Tamale-Navrongo in the second sub-period.

We find that the tomato producer-consumer market pairs have averagely similar trigger-threshold values across the periods, with the inter-market price differential now having to surpass about 0.352 (35.2%) of the price margin in the first period and 0.354 (35.4%) in the second to provoke price adjustment in the outside bands where arbitrage profits remain unexploited. This signifies a marginal, 0.2 percentage point increase in proportional inter-market transaction costs between markets from the high- to the low tariffs period and provides little statistical evidence for any meaningful conclusions to be drawn. Nevertheless, since the threshold estimates here are similar to the corresponding estimates under the standard model, it is possible that the 0.2% increase is due to the recent surge in international crude oil prices, otherwise the improvement in road quality, transportation, telecommunication and market infrastructure over the period of trade liberalization would have led to a decline in actual transaction costs.

A rise in the threshold value by about 17% from 0.50 under high tariffs to 0.67 under reduced tariffs between Tamale and Techiman may be due to institutional impediments to trade flow such as road barriers and toll gates, rather than physical impediments to trade such as poor quality of roads, means of transportation and market infrastructure. For instance there are more than six police check points and toll gates along the about 270Km road separating Tamale and Techiman. Two of these barriers were created under the high tariffs period.

The speeds of adjustment of the extended TAR model estimated without time trend ( $\rho^{out}$ ) are significant and of the correct sign for all five market pairs in the high tariffs period. The average adjustment coefficient for these market pairs is -0.645, and higher than the corresponding average (-0.508) in the standard TAR model. In the reduced tariffs period,  $\rho^{out}$  is significant in two cases namely Kumasi-Navrongo, with an adjustment speed of -0.451, and Kumasi-Techiman with the adjustment speed of -0.947. This implies an average adjustment speed of -0.699, which is also higher than the estimate (-0.476) pertaining under the standard model. Between two market pairs, Kumasi-Techiman in the first period and Tamale-Navrongo in second period, there is the tendency for the model to overestimate price adjustment to yield the values -1.387 and -1.186, which are greater than one. The adjustment parameters increased in all cases except between Navrongo and Techiman, the two producer markets.

Comparing the average significant adjustment speeds of -0.645 (64.5%) under the high tariffs and -0.699 (69.9%) under the reduced tariffs period, the rate of price adjustment was faster (about 70%) in the reduced tariffs period than it was (about 65%) in the high tariffs period. The about five percentage points (5%) increase in the average speed of adjustment is expected, given improved transportation, information flow and marketing infrastructure, and the just marginal rise (0.2%) of proportional transaction costs in the second period. The high rate of price adjustment (-0.947 or 95%) and lower threshold value (0.19) and half-life (0.23 months) between Kumasi and Techiman is consistent with the geographic market structure. The two markets are the nearest among the pairs of markets under study, being separated by just about 150Km and connected by a fairly good road in the second period. Tomato wholesalers usually buy tomatoes from Techiman and sell them in Kumasi within a period of just one day.

The price adjustment coefficients estimated with time trend ( $\rho'$ ) are mostly lower and less significant than those estimated without trend under the extended TAR model. The significant adjustment coefficients lack the correct sign in four cases under both periods. The estimates show that only Tamale-Navrongo (-0.00050) and Kumasi-Techiman (-0.0091) under the high tariffs period significantly error correct, by less than 1% towards market equilibrium. Deviations half-lives vary from 0.4 months (< 2 weeks) between Navrongo and Tamale in period I to 9.2 months between Navrongo and Techiman in period II.

It is noted that even though the extended TAR model is generally, theoretically more suitable than the standard TAR and its results meet our a priori expectations, the inclusion of a trend in estimating the error correction coefficients represents a restriction that gives the model a poor fit, especially when the sample size is small (see van Campenhout, 2006). Nevertheless, the speeds of adjustment estimated without trend in the extended TAR model meet our a priori expectations than those estimated under the standard model. The estimation process may be improved by using longer price series.

## 5.5 Conclusions and Recommendations

We demonstrate in this paper using the standard TAR model and its extension to include a time trend (van Campenhout 2006) that the speed of price transmission and degree of market integration between tomato producer and consumer markets shows a mixed pattern following import trade liberalization in Ghana. The estimated speeds of price adjustment in the high (1992-2000) and low (2001-2009) tariffs periods were generally high and significant, signalling the tendency of inter-market price differences to converge towards long-run equilibrium across both periods under the two models applied. This agrees with findings by Mabaya (2002) in Zimbabwean tomato markets and Abdulai (2000) and Alderman (1992) in Ghanaian grain markets, and implies that fresh tomato markets in Ghana were strongly integrated throughout the liberalization period.

Comparing the error correction coefficients from the standard and extended TAR models however, we do not find a clear pattern on the performance of fresh tomato markets following liberalization. Whereas the standard model reveals an average decline in the speed of price adjustment by about 3 percentage points from 0.508 (50.8%) under high tariffs to 0.476 (47.6%) under reduced tariffs, the extended model, shows an increase in the average speed of adjustment by about 5 percentage points i.e. from -0.645 (64.5%) under high tariffs to -0.699 (69.9%) following reduction in tariffs.

On the contrary, the estimated proportional transaction costs under the standard model suggest a declined in their average value by 2.4 percentage points from 0.364 (36.4%) to 0.340 (34%) following the reduction of agricultural import tariffs, whereas the average corresponding estimates obtained from the extended model increased by about 0.2 percentage points from 0.352 (35.2%) to 0.354 (35.4%) across the two sub-periods. Despite its poor fit due to the restrictions introduced by the inclusion of a time trend, the extended TAR model which estimates the thresholds and error correction coefficients as time-varying parameters yields the expected results.

Examining the performance of producer-consumer markets on pair-wise basis, the mixed pattern of price transmission over the period of trade liberalization in Ghana is revealed.

Estimated price adjustment coefficients and half-lives under the standard model increased for the market pairs Tamale-Navrongo and Tamale-Techiman after agricultural import tariffs were reduced, while the corresponding estimates for Techiman-Navrongo, Kumasi-Navrongo and Kumasi-Techiman dropped across the two periods. Similarly, the results of the extended model show an increase in the adjustment coefficients and half-lives in all cases except between Techiman and Navrongo, the two producer markets, following the reduction in tariffs. This means that opportunities for arbitrage and utilization of trade information generally improved following the reduction in the tariffs rates.

The fact that estimated proportional transaction costs (measured by thresholds) from both models remain fairly stable over the liberalization period despite improvements in transportation, telecommunication and market infrastructure in the last decade is expected and could imply that improved road quality, means of transportation, information flow and market infrastructure have offset the effects of increased fuel prices on proportional transaction costs.

In sum, based on the empirical results from this study, it can be concluded that, trade liberalization is not clearly revealed to be responsible for the perennial marketing problem faced by fresh tomato producers in Ghana. In fact, when the estimated price adjustment coefficient and thresholds (which practically are non-stationary overtime) are estimated with time trend, then price transmission and market integration between Ghana's fresh tomato markets are observed to have improved following the reduction in import tariffs. Much of this improvement appears to have resulted from improvement in the quality of transportation, marketing and telecommunication facilities in the last decade of the trade liberalization period.

It should be noted that the perishable nature of tomato and the lack of processing and storage facilities as well as impediments to trade flow between the producer markets and consumer markets off the West African highway may be one reason for the problems reported by advocacy studies, namely perennial gluts, volatile and dispersed prices of fresh tomato in Ghana. In addition, high costs of production incurred by farmers and high market margins due the oligopolistic behaviour of wholesalers may impede the competitiveness of tomato markets and the reduction of price volatility and dispersion.

Obviously, other underlying factors in the tomato marketing system namely seasonality, use of market power by wholesalers, road barriers and the high level of risks associated with tomato trade could also imply arbitrage restrictions on optimal, inter-temporal dynamics of price adjustment processes between markets and impede the efficient transmission of price signals between producer and consumer tomato markets in Ghana. Therefore, blaming the uncompetitive prices of fresh tomato solely on liberalization and the consequent import dumping of tomato products on Ghana is not supported by the findings of this chapter.

We recommend that measures of improving price transmission in tomato markets in Ghana should minimize the effects of the factors enumerated above. Policy options encompassing the reduction of the costs of production, contingently curtailing imports of cheap tomato products, and regulating collusive activities of traders' associations may be considered. In addition, encouraging local storage and processing, and improving road linkages between isolated, fresh tomato-deficit markets and the net producer markets will reduce price volatility and improve the competitive urge of fresh tomato over imported tomato products.

Future extensions to this study should explicitly account for the role of the non-price factors noted above. More importantly, developing analytical procedures that explicitly use transaction costs and other trade information in analysing price transmission and market integration will be useful. Such models should seek to address the problem of obtaining unbiased standard errors and confidence intervals often encountered in threshold estimations (Chan 1993 in Van Campenhout, 2006). In contrast to this study, in which the target markets are located along the West African highway, analysing price transmission between net producer and consumer markets poorly connected by road could also be revealing.

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## **CHAPTER SIX**

### **The Influence of Physical Trade flows on the Integration of Tomato Markets in Ghana<sup>9</sup>**

#### **6.1 Introduction**

Most analyses of spatial price transmission rely, explicitly or at least implicitly, on the Enke-Samuleson-Takayama-Judge spatial equilibrium model (Takayama and Judge, 1971). A consequence of this model is the fact that, the prices of a homogenous good in any two spatially separated markets adjust towards long-run equilibrium only when trade physically takes place between the market pair. This means, if deviations of inter-market price margins from their equilibrium value are not large enough to trigger physical trade flows between the markets, then the prices of a homogenous product in them do not converge to achieve long run market equilibrium.

However, Jensen (2007) sheds light on the importance of information flow via mobile phones on price behaviour in spatially separated markets. Stephens et al. (2008), and Fackler and Tastan (2008) also report that mechanisms other than physical trade flows, such as information exchange across markets and trader networks might cause the transmission of price signals between markets even in periods of autarky in inter-market commodity flows. Another possibility is that producers located in space between two or more markets determine where to deliver their produce after examining relative prices in the neighbouring markets. Thus markets may also be integrated by producer commodity-delivery decisions even though no direct trade takes place between them.

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<sup>9</sup> This paper extends an earlier version (in terms of number of observations ), which is co-authored with Rico Ihle and was presented at the 27<sup>th</sup> Conference of the International Association of Agricultural Economists in Beijing, China; 16-22 August, 2009.

Depending on which of the above forces is driving market integration, determining whether other mechanisms, apart from direct trade, cause price transmission is useful for the current policy debate that blames liberalization policy as the sole cause of the perennial marketing problems in Ghana's fresh tomato marketing system. The findings will enrich the empirical results presented in chapter five on the extent of spatial price transmission and market integration in Ghana's fresh tomato markets following trade liberalization.

The determination of alternatives of direct physical trade to market integration is a unique addition to the price transmission literature and a critical issue for further research. A common limitation of most empirical studies of market integration is that they assess the nature and extent of price transmission between markets without investigating the possible underlying factors responsible for market integration or the absence of it (Abdulai, 2007).

The tomato marketing system in Ghana as a target of this study is characterized by seasonal switching in the source of supply, and thus changes in the direction of commodity flow, transfer costs and prices. The markets in the system are always connected by the same single source of commodity supply at any given point in time, but this source switches between the two major producer markets in Ghana from season to season. In this case, no direct physical trade between spatially separated markets may necessarily be observed, but the common supply sources could imply a stable long term relationship between prices in the markets within the system.

In this chapter, we investigate evidence for alternatives to physical trade as an integrating mechanism between markets. This is achieved by examining spatial price adjustment in periods with and without trade in tomato markets in Ghana. The dataset represents a unique set of high frequency data on prices, transfer costs, trade flow and qualitative market information collected twice weekly through market surveys in five tomato markets in Ghana. By using more than just price data, we conduct in Barrett's (1996) terminology, a level II instead of a level I analysis. Analyses using more than price data are commonly conducted in the framework of the Parity Bounds Model (PBM) (Barrett and Li, 2002; Baulch 1997). Nevertheless, this class of models has the drawback of disregarding the time series properties of the data.

The main model applied to analyse our high frequency data is a switching vector error correction model (VECM) similar to that of Stephens et al. (2008); but unlike the latter, we do not assume a switching long-run equilibrium, and focus on prices and trade regimes instead of price margins and transaction costs. The model allows the estimation of regime-dependent adjustment parameters, permitting inferences on the reactions of prices to deviations from long-run equilibrium and enabling the estimation of adjustment coefficients for periods with and without trade between the net producer and net consumer tomato markets in Ghana. In this way, we obtained evidence on the nature of price adjustment in the absence of direct, physical trade flows between market pairs. For comparison purposes, we also estimate a standard VECM that does not differentiate between trade and autarky periods and compares its results to those of the switching VECM (SVECM).

The findings show evidence of market integration in the absence of physical trade flows, thus confirming the findings of Jensen (2007) and Stephens et al. (2008), and suggesting that physical trade may not be the only important mechanism of market integration, but interacts with other factors to determine error correction between the net producer and consumer markets. Therefore, any effect that trade liberalization might produce on inter-market arbitrage processes will have overlaid effects on price transmission and these effects may be modified by other indirect mechanisms of price adjustment. In the next section, the nature of the dataset used for the analysis is presented. In section 6.3, the methodology is reviewed, section 6.4 discusses the results of the analysis, while section 6.5 summarizes and concludes the chapter.

## **6.2 Study Setting and Dataset**

High frequency, semi-weekly data covering five tomato production seasons is used for the analysis in this chapter. For a detail description of this data and how it was collected, see chapter four. The data comprises wholesale level prices, trade flows, transaction costs and other descriptive information on fresh tomato markets in Ghana, but only the price and trade flow variables are used in this analysis. Table 6.1 illustrates some descriptive statistics of the price series over the period covered by the study.

**Table 6.1: Descriptive Statistics of High Frequency Price Series (GH¢/110Kg Crate)**

<i>Statistic</i>	<i>Navrongo</i>	<i>Tamale</i>	<i>Techiman</i>	<i>Kumasi</i>	<i>Accra</i>
<b>Number obs.</b>	243	243	243	243	243
<b>Min</b>	10	12	6	8	10
<b>Max</b>	90	110	120	105	280
<b>Mean</b>	40.38	38.80	38.31	46.58	73.52
<b>Stand. dev.</b>	19.72	18.01	22.36	20.94	48.76
<sup>10</sup> <b>Trade: Navrongo to</b>	-	105	117	103	105
<b>Trade: Techiman to</b>	126	138	-	140	138

Source: Own

It can be seen in Table 6.1 that the minimum, maximum and mean prices of the net consumer markets are not consistently higher than those of the net producer markets as would be expected. This is because of the seasonal switching in the source of tomato supply. The seasonal switching implies changes in the proximity of net consumer (destination) markets to supply sources and consequently changes in trade volumes and transaction costs, a major component of the wholesale price of tomato in Ghana. The Table also shows the number of the periods of trade flow from the net producer markets; Navrongo and Techiman respectively to the net consumer markets in the system.<sup>11</sup> In terms of both trade frequency and volume, Techiman appears to be the most important tomato production market in Ghana.

The motivation for using a high-frequency dataset to analyze the dynamics of commodity prices is that, this form of data helps to estimate the speed of price adjustments more precisely, especially in studies like ours, where the marketing system exhibits a high degree of price volatility with changing supply sources and/or between bumper and lean harvest periods. Low-frequency price data often inaccurately captures the dynamics of price

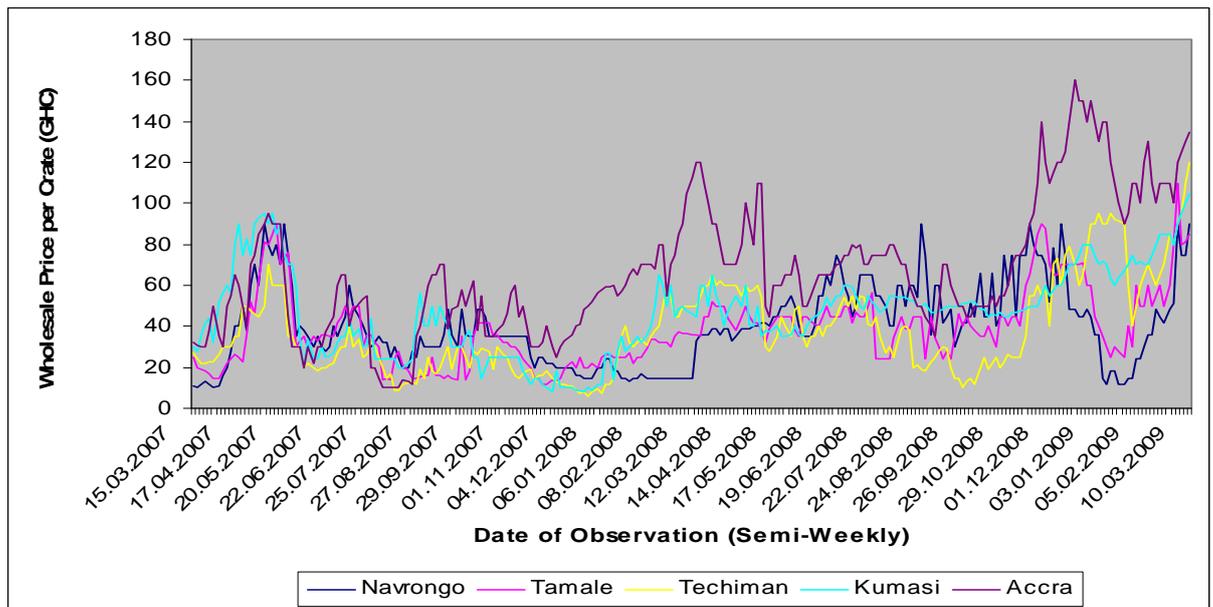
<sup>10</sup> This refers to the frequency of trade from the net producer market to other markets over the period of our surveys.

<sup>11</sup> To a small extent, tomatoes are also imported to Ghana from Burkina-Faso. Because no wholesale price data for this source is available, we treat trade flow Burkina-Faso as trade from Navrongo, and use Navrongo's wholesale prices.

behaviour due to the wide interval between individual observations (Choi, 1992; Choi and Chung, 1995; Lutz et al, 1994).

Though the dataset covers a period of over 26 months, we did not deflate the price series because inflation in Ghana was not significant over much of the period considered. In addition, the periodicity of the primary data is semi-weekly, while consumer price indices (CPI) in Ghana are only measured monthly. Thus, deflating the price data would involve interpolating the CPI deflator, which could create more problems than it solves. All prices are expressed in the new Ghana Cedi, and all the analyses are done using logarithmic transformations of the series. Figure 6.1 below graphically illustrates the dynamic behaviour of the five price series over time.

**Figure 6.1: Semi-Weekly Wholesale Prices of Fresh Tomato in Ghana (in GH¢)**



Source: Own

### 6.3 Methodology

In this section, we specify the two variants of the VECM used to analyze the data. First we present the standard form of the VECM, from which the switching VECM (SVECM) is

derived. In the actual estimation of the SVECM, we first estimate the standard model before proceeding to estimate its extension in the SVECM.

### *The Linear VECM*

We denote the equilibrium relationship between the net consumer prices series  $P_t^c$  and net producer price series  $P_t^s$  as:  $P_t^c - \beta_1 P_t^s - \beta_0 = \varepsilon_t$ . If  $\varepsilon_t$ , the error term, is assumed to follow an autoregressive (AR) process, then  $\varepsilon_t = \alpha \varepsilon_{t-1} + e_t$ . This means the equilibrium relationship between  $P_t^c$  and  $P_t^s$  can be expressed as:

$$P_t^c - \beta_1 P_t^s - \beta_0 = \alpha \varepsilon_{t-1} + e_t \quad (1)$$

The equation (1) implies that the long run relationship or cointegration between  $P_t^c$  and  $P_t^s$  is a function of the autoregressive process  $\varepsilon_{t-1}$ . In the above linear representation,  $\varepsilon_{t-1}$  represents deviations from long run equilibrium, and is called the error correction term (ECT), while  $\alpha$  measures the response of  $P_t^c$  and  $P_t^s$  to deviation from equilibrium following random shocks to the markets.

We derive the standard VECM from equation (1) by specifying changes in each of the contemporaneous prices,  $\Delta P_t^c$  and  $\Delta P_t^s$ , as a function of the lagged short term reactions of both prices,  $\Delta P_{t-k}^c$  and  $\Delta P_{t-k}^s$ , and their deviations from equilibrium at period  $t-1$  (i.e.  $ECT_{t-1}$ ) as follows:

$$\begin{aligned} \Delta P_t^c &= \delta_1 + \alpha^c [ECT_{t-1}] + \sum \beta_k^c \Delta P_{t-k}^c + \sum \beta_k^{cs} \Delta P_{t-1}^s + \varepsilon_t^c \\ \Delta P_t^s &= \delta_2 + \alpha^s [ECT_{t-1}] + \sum \beta_k^{sc} \Delta P_{t-k}^c + \sum \beta_k^s \Delta P_{t-1}^s + \varepsilon_t^s \end{aligned} \quad (2)$$

Where  $\Delta P_t = (\Delta P_t^c \ \Delta P_t^s)'$  is a vector of first differences of prices in the markets  $c$  and  $s$ ; the  $\beta_k$ ,  $k = 1, \dots, n$ , are  $(2 \times 2)$  matrix of coefficients quantifying the intensity of the response of the contemporaneous price differences to their lagged values i.e., they express

the short-run reactions of the matrix of prices  $\mathbf{P}_t$  to random shocks, and  $\varepsilon_t$  is assumed to be a white noise error term. The equation (2) can be reformulated as:

$$\Delta \mathbf{P}_t = \boldsymbol{\alpha}_0 + \boldsymbol{\alpha}_1 \mathbf{ECM}_{t-1} + \sum_{i=1}^k \boldsymbol{\Gamma}_i \Delta \mathbf{P}_{t-1} + \varepsilon_t \quad (3)$$

Where  $\boldsymbol{\Gamma}_i$ ,  $i = 1 \dots k$ , is a  $k \times k$  matrix of short run coefficients which quantify the short term responses of the contemporaneous price differences to their lagged values ( $k = 2$  in our pairwise analysis) and the other variables are as already defined above.

The error correction term,  $ECT_t$ , so named because it depicts deviations from the long run relationship or ‘errors’ that are ‘corrected’ by the price transmission process, is a continuous and linear function of the deviation of  $\mathbf{P}_t$  from the long-run equilibrium relationship following a shock on  $P_t^s$  or  $P_t^c$ ; the  $\delta_1$  and  $\delta_2$  denote long-run inter-market price margins. The coefficients  $\boldsymbol{\alpha}^c$  and  $\boldsymbol{\alpha}^s$ , called the loading or adjustment parameters, are the elasticity of price transmission or the speeds of price adjustment by the net producer and net consumer markets respectively, to deviations from long-run equilibrium where  $\varepsilon_t = 0$ . The closer a value of  $\boldsymbol{\alpha}$  approaches one in absolute terms; the faster deviations from equilibrium become corrected.

### *The Switching VECM*

The SVECM, unlike its linear form above, is a trade-regime-dependent model. This means, the model is specified to distinguish between unique price adjustment behaviour in periods with or without direct trade between producer/consumer market pairs. As stated above, switching between the supply sources of tomato, Navrongo and Techiman, is a seasonal phenomenon in Ghana. The model is therefore used to accomplish the objective three, which seeks to ascertain whether other mechanisms either than direct physical trade flow between markets drive inter-market price transmission and market integration in Ghana. We do this by estimating price adjustment parameters between pairs of producer and consumer markets under trade and no-trade regimes.

We observed in chapter two that the condition of competitive inter-market arbitrage may hold under either competitive tradable equilibrium (the LOP) or the autarkic markets condition that occurs when transfer costs exceed inter-market price differences and there are no gains to trade. Because of this phenomenon, spatial arbitrage is expected to differ between periods of trade and autarky between markets.

Using the information on trade flows contained in our primary dataset, we specify an indicator variable  $I_t^{cs} = \mathbf{I}(q_t^{cs} > 0)$  via the indicator function  $\mathbf{I}(\bullet)$  which equals 1 if the quantity  $q_t^{cs}$  traded between markets  $c$  and  $s$  at time  $t$  exceeds zero and 0 if no trade occurs between  $c$  and  $s$  i.e.  $q_t^{cs} < 0$ . Instead of assuming as does Stephens et al. (2008) a vector error correction model (VECM) in which the long-run equilibrium switches along with the short-run dynamics, we assume a stable long-run equilibrium relationship that distinguishes between trade and no-trade regimes, and estimate the following model:

$$\Delta \mathbf{P}_t = \alpha_1 ECT_{t-1}^{Trade} I_t^{cs} + \alpha_2 ECT_{t-1}^{no Trade} (1 - I_t^{cs}) + \sum_{i=1}^k \Gamma_i \Delta \mathbf{P}_{t-1} + \varepsilon_t \quad (4)$$

Where  $ECT^i$  ( $i = \text{trade or no-trade}$ ) denotes the error correction term,  $\alpha_1$  measures the speed of price adjustment under the trade regime and  $\alpha_2$  measures the speed of price adjustment under the no trade regime. All other notations are as defined under the standard VECM. It can be seen that model (4) is an extension of (3), with the error correction term in (4) specified to behave differently under periods of trade (direct arbitrage) and no-trade (autarky) between the tomato consumer and producer market pairs. This differential behaviour of price adjustment under the two periods constitutes two regimes – the trade and no-trade regimes.

Before presenting the results of the analysis, a note on the difference between the TAR model applied in chapter five and the VECM applied in this chapter may be useful. A proof of cointegration between the markets is a prerequisite for using either of the models. If cointegration between the pairs of market is proved and we assume competitive equilibrium, the TAR model which relates prices to transaction costs or the VECM relating prices to deviations from equilibrium may be used to estimate price adjustment parameters and half-

lives. In the TAR model, price adjustment processes depend on whether the inter-market price difference,  $d_{t-1}^{cs}$  is below or above a threshold value,  $\tau^{cs}$ , whereas price adjustment under VECM depends on deviations arising from random shocks to market equilibrium regardless of their magnitude. Furthermore, the SVECM requires in addition to price data, trade flow information between the market pairs for its estimation, while the TAR model is estimated using only price data.

Having pointed out earlier that transaction costs and trade flow reversal are the two most important determinants of price dynamics in Ghana's tomato markets, models that are capable of accounting for both regime switching and thresholds simultaneously would be the most ideal for analyzing price transmission in the markets. This class of models is still however uncommon in the literature and beyond the present context of our study.

## **6.4 Results**

### ***6.4.1 Results of Unit Roots and Cointegration Tests***

We performed preliminary stationarity checks on each of the price series by testing for unit root behaviour in individual price series and for cointegration between pairs of markets. The graphical plots of the series show no sustained trending behaviour (see Fig. 6.1). Therefore, the models we use for the Augmented Dickey-Fuller (ADF) test for unit root and the Johansen's test for cointegration include an intercept but omit a trend. We confirm the ADF's test results by conducting the KPSS unit root test which verifies the reverse of the ADF's null hypothesis of non-stationarity in the price series. As per the theory of testing for unit root, both an intercept and a trend are excluded in verifying the stationary properties of the price series in their first differences. Table 6.2 presents the results of the unit root tests.

From the Table, the following conclusions can be made about the stationary properties of the price series. First, the null hypothesis of unit roots is typically not rejected at the 1% and 5% significance levels when the ADF test is applied to the price series at their levels. This evidence is consistent with the results of the KPSS test, by which the null hypothesis of

stationarity in the level of the prices is strongly rejected at the 1% and 5% significance levels. Conversely, we reject the null of unit roots under the ADF test but do reject the null of stationarity under the KPSS, at the selected significance levels, when both tests are applied to the first differences of the price series. In sum, the evidence favouring unit roots of the order one in semi-weekly prices of fresh tomato in Ghana is strong.

**Table 6.2: Results of ADF and KPSS Unit Root Tests on Semi-Weekly Price Series**

<i>Series</i>	<i>ADF Test</i>		<i>KPSS Test</i>	
	<b>Levels</b>	<b>First Diff.</b>	<b>Levels</b>	<b>First Diff.</b>
<b>Navrongo</b>	-3.012	-12.789**	1.723**	0.052
<b>Tamale</b>	-2.817	-12.340**	3.362**	0.031
<b>Techiman</b>	-1.882	-11.379**	2.991**	0.075
<b>Kumasi</b>	-1.526	-13.916**	2.234**	0.067
<b>Accra</b>	-1.813	-10.824**	1.467**	0.049

Source: Own

The asterisks \*\* and \* denote rejection of the null hypothesis at the 1% and 5% significance levels. The respective critical values at the 1% and 5% significance levels are -3.43 and -2.86 for the ADF test and 0.347 and 0.463 for the KPSS test at the price levels; and -2.56 and -1.94 for the ADF and 0.347 and 0.463 for the KPSS test at the first differences of the prices.

With the prove that the price series is non-stationary, we proceed to test for cointegration between the series of consumer/producer market pairs using Johansen's maximum likelihood VAR approach (see chapter three). The results of the cointegration test between the market pairs are presented in Table 6.3.

The results of the bivariate tests provide evidence in favour of cointegration, at least at the 10% significance level between the net producer and net consumer market pairs. The null hypothesis of  $r = 0$ , implying an absence of a cointegrating vector between net producer/net consumer market pairs is rejected in five cases at the 5% significance level. For the Navrongo – Kumasi pair, the null hypothesis is rejected at the 10% significance level, while the test statistics between the two net producer markets, Navrongo and Techiman, though low; still allows us to reject the null hypothesis of no cointegrating vector at the borderline of the 10% level. We cannot however reject the null hypothesis of at least one cointegrating vector, i.e.  $r = 1$  in all cases at the selected significance levels.

**Table 6.3: Cointegration Test Statistics and Inter-market Cointegration Relations**

<i>Market Pair</i>	<i>Test Statistic (Trace Test)</i>			<i>Cointegration Relation</i>
	<i>Ho: r = 0</i>	<i>Ho: r = 1</i>		$\hat{\beta}_1$
<b>Navrongo –Accra</b>	20.56**	4.76		0.38
<b>Navrongo - Kumasi</b>	19.55*	5.13		0.56**
<b>Navrongo – Techiman</b>	17.95*	4.57		0.41*
<b>Navrongo - Tamale</b>	24.12**	7.29		.94**
<b>Techiman - Accra</b>	27.36**	3.72		.78 **
<b>Techiman -Kumasi</b>	30.90**	3.43		.98**
<b>Techiman - Tamale</b>	32.06**	3.41		.63**
	<b>r = 0</b>	<b>r = 1</b>	<b>r = 2</b>	<b>r = 3</b>
<b>Techiman - Cons. Markets</b>	96.15**	49.78**	21.60**	3.06
<b>Navrongo - Cons. Markets</b>	82.05**	1.54**	20.50**	3.20

Source: Own

The asterisks (\*\*) and (\*) denote rejection of the null hypothesis of no cointegration relation or significance of the cointegration relation at the 5% and 10% levels respectively. The critical values for  $r = 0$  and  $r = 1$  at the 5% and 10% significance levels are 20.16 and 9.14 and 17.98 and 7.60 respectively. The 5% critical values of the multivariate test of the null hypothesis  $H_0: r = i; i = 0, 1, 2 \text{ \& } 3$  are 53.94, 35.07, 20.16 & 9.14 respectively.

To confirm the results of the pair-wise analysis, we use the Johansen’s multivariate test to determine the number of cointegrating vectors between each net producer market and the net consumer markets in the system as a group. The last two rows in Table 6.3 show the results, which point to a cointegrated or common tomato marketing system in Ghana, with at least three cointegrating vectors in each case at the 5% significance level. In conclusion, the evidence proves that there exists at least one stationary cointegrating vector (i.e.  $r = 1$ ) between the pairs of net producer and net consumer price series measured semi-weekly, and between the system of net producer/net consumer markets, there are at least three significant cointegrating vectors (i.e.  $r = 3$ ).

The evidence of at least one cointegrating vector between market pairs has economic meaning if we compute the magnitude of the cointegration relation ( $\hat{\beta}_1$ ) between the pair of markets. The cointegration relation, computed from the long run equilibrium condition:

$ECT_t = P_t^c - \beta_1 P_t^s - \beta_0$ , measures the long run effect of a change in a commodity's price in a given market on its price in another. Therefore, the Navrongo-Kumasi cointegration coefficient, 0.56 implies that a 10% reduction or increase in the price of fresh tomato in Navrongo will cause a 5.6% corresponding change in the price of the commodity in Kumasi. The non-zero cointegrating vectors between the market pairs is confirmed by the statistical significance and relatively high values of the cointegration relations, with the exception of that of Accra-Navrongo.

#### **6.4.2 Results of the Vector Error Correction Models**

The evidence of significant cointegrating vectors between net producer and net consumer tomato market pairs is a necessary condition for using the VECMs to determine the effects of price shocks on price adjustment. In this section, the results of the estimated standard and regime-dependent VECMs are presented and their implications discussed. The results of the pairwise estimation of the standard VECM specification (3) are presented in Table 6.4.

The results show that each of the net producer markets (Techiman or Navrongo) tend to exhibit higher and more rapid significant error correction with the correct sign than do the net consumer markets. The estimated speeds of adjustment (adjustment parameters) measure the rate at which the price per crate of fresh tomato reacts to correct market disequilibrium following price shocks. It can be seen from Table 6.4 that the speeds of adjustment by the net producer markets (denoted  $\hat{\alpha}^s$ ), range from about 0.063 (6.3%) to about 0.128 (12.8%), with an average adjustment speed 0.098 (9.8%)<sup>12</sup>. The net consumer markets, except Tamale, however show almost no significant error correction. Accra and Kumasi, the biggest tomato consumer markets in Ghana are completely weakly exogenous.

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<sup>12</sup> The speeds of adjustment here, which are measured in semi-weeks, are smaller than those estimated by the TAR model which uses monthly observations.

**Table 6.4: Estimated Adjustment Parameters of the standard VECM (1)**

<i>Market pair</i>	$\hat{\alpha}^s$	<i>Half-life</i> ( $\hat{\lambda}^s$ )	$\hat{\alpha}^c$	<i>Half-life</i> ( $\hat{\lambda}^c$ )
<b>Navrongo -Tamale</b>	-0.094*** [-2.97]	7.02	-0.062** [1.97]	10.83
<b>Navrongo -Techiman</b>	-0.098*** [-3.26]	6.72	-0.027 [-0.90]	-
<b>Navrongo -Kumasi</b>	-0.128*** [-3.88]	5.06	-0.084 [-0.98]	-
<b>Navrongo -Accra</b>	-0.114*** [-2.76]	5.73	-0.007 [-0.16]	-
<b>Techiman - Navrongo</b>	-0.079*** [-2.96]	8.42	0.005 [-0.19]	-
<b>Techiman -Tamale</b>	-0.063*** [-2.76]	10.65	0.083*** [3.53]	8.00
<b>Techiman -Kumasi</b>	-0.083** [-2.51]	8.00	-0.032 [-0.99]	-
<b>Techiman - Accra</b>	-0.126*** [-4.63]	5.15	0.038 [1.31]	-

Source: Own

The asterisks \*, \*\* and \*\*\* denote significance at the 10%, 5% and 1% level respectively. Half-lives, measured in semi-weeks, are only computed for significant adjustment parameters

The findings also suggest that an exogenous shock to long-run equilibrium leading to an increase or decrease in the price differential between producer and consumer tomato markets will initiate adjustments ranging from about 6.3% to 12.8% of the prevailing price differential by the producer markets every half week (3 days) towards achieving long run equilibrium. We observe a faster adjustment in the prices of the producer markets than in those of the consumer markets. This observation is confirmed by the results of our test of Granger causality (Appendix II), which reveal that whereas the net consumer markets granger-cause the net producer markets, the reverse is not true. This, in the economic sense, means that the net consumer markets are the price leaders in Ghana's tomato marketing system, leading the producer market prices to adjust to achieve price integration and market

equilibrium, but are themselves not influenced. This implies a weak, long-run exogeneity by the consumer markets (Hendry and Juselius, 2000).

The estimated price adjustment half-lives, the length of time required for half of the deviations from market equilibrium to be eliminated, range from about five semi-weeks (15 days) to about 11 semi-weeks (30 days), averaging about seven semi-weeks (21 days) for the net producer markets. The lowest adjustment parameter of about 0.063, implying the highest half-life of about 11 semi-weeks between Techiman-Tamale is hard to explain. The two markets are separated by a distance of just 270 Km and are connected by a good quality highway. In addition, Tamale is located between the two net producer markets, and is always a transit market that enjoys “wayside” commodity delivery, even when direct trade between it and the net producer markets is absent.

Overall, when no distinction between trade and no-trade regimes is made, the integration between Navrongo and the consumer markets appears to be stronger than that between Techiman and the consumer markets. This is because the average speed of adjustment and half-life between Navrongo and the consumer markets are about 0.109 (10.9%) and six semi-weeks, while those for Techiman and the consumer markets are about 0.088 (8.8%) and eight semi-weeks. Given that Techiman is the largest production region in Ghana, supplying tomato for about 56% (6.7 months) of the time in a year, this revelation is surprising. Techiman is also located in the middle of the country and thus enjoys a higher average proximity<sup>13</sup> to the net consumer markets than Navrongo which supplies tomato for about 44% (5.3 months) of the time in a year and is located at the extreme north of Ghana (see Fig. 4.1).

Since it seems plausible that tomato arbitrage between Techiman and the net consumer markets will be faster, and traders’ network with Techiman from the consumer markets will be well established than with Navrongo, the results are obviously inconsistent with the geographic market structure and the nature of trade flow (trade volume and duration) from the producer to the consumer markets. It appears that trade flow between the producer and

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<sup>13</sup> On average, Techiman is about 200 km closer to the consumer markets than Navrongo.

consumer markets under study and their proximity to each other are not the sole factors driving price transmission between tomato markets in Ghana. If trade flow and distance were the only underlying factor responsible for price transmission, one would expect lower half-lives and more rapid error correction for market pairs involving Techiman than involving Navrongo. Therefore, other factors, possibly seasonality of production, common supply sources of tomato, third market or indirect arbitrage effects<sup>14</sup>, improved road quality, means of transportation and information flow via mobile phones or the internet may be at play.

To elaborate on the seasonal effects, we note that most of Techiman's tomato farms are located in forests areas and its tomatoes are harvested in a rainy season when the quality of roads, especially to the farm gates, is more likely to be poor, making farms difficult to access by traders and trucks. Navrongo's tomato farms are however located in open, savannah farmlands and because its tomatoes are harvested in a dry season, the feeder roads to the farm gates are passable and offer easy access to tomato farms by traders and trucks. Therefore delays in transportation and delivery of fresh tomato from Techiman to the other markets due to bad farm gate roads in the rainy season may cause Techiman's tomato prices to drift apart from the consumer market prices in the short run due to delays in the transmission of price signals.

Rainfall is also noted to reduce the shelve-life of tomato, which in turn increases the marketing risks borne by traders. Perhaps the problem of seasonality and access reduced the price-transmission role of favourable factors such as market size, trade flow and proximity in leading to a higher integration between Techiman and the net consumer markets than that between Navrongo and the consumer markets. This view will be made clearer in the following analysis in which we allow the price transmission coefficients and half-lives to vary with the trade and no-trade regimes.

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<sup>14</sup> Given three markets A, B and C in a system, if A trades with B and B trades with C, but A and C do not trade with each other, prices in A and C may be related due to the common relationship with B.

If a distinction between trade and non-trade periods is made in estimating the speeds of price adjustment and associated half-lives, a clearer implication of direct physical trade between markets for price transmission can be assessed (Table 6.5).

**Table 6.5: Estimated Adjustment Parameters of the Switching VECM**

<i>Market Pair</i>	<i>Trade Regime</i>				<i>Non-Trade Regime</i>		
	$\hat{\alpha}^s$	$\hat{\lambda}^s$	$\hat{\alpha}^c$	$\hat{\lambda}^c$	$\hat{\alpha}^s$	$\hat{\lambda}^s$	$\hat{\alpha}^c$
<b>Navrongo - Tamale</b>	-0.121** [-2.01]	5.37	0.005 [0.09]	-	-0.183*** [-2.91]	3.43	0.064 [1.02]
<b>Navrongo - Techiman</b>	-0.040 [-1.02]	-	0.030 [0.76]	-	-0.154*** [-3.39]	4.14	0.001 [0.02]
<b>Navrongo - Kumasi</b>	-0.091** [-2.15]	7.26	-0.025 [-0.60]	-	-0.203*** [-4.04]	3.05	-0.040 [-0.80]
<b>Navrongo - Accra</b>	-0.069 [-1.23]	-	-0.047 [-0.84]	-	-0.164** [-2.54]	3.87	0.057 [0.88]
<b>Techiman - Navrongo</b>	-0.064 [-1.22]	-	0.011 [0.20]	-	-0.009 [-0.30]	-	0.019 [0.61]
<b>Techiman - Tamale</b>	-0.108** [2.01]	6.06	0.092* [1.71]	7.81	-0.040 [-1.14]	-	0.047 [1.32]
<b>Techiman - Kumasi</b>	-0.121** [-2.54]	5.37	0.058* [1.55]	11.60	-0.074* [-1.80]	9.01	0.017 [0.43]
<b>Techiman - Accra</b>	-0.150* [-1.50]	4.27	0.259** [2.53]	2.31	-0.184*** [-2.78]	3.41	-0.033 [-0.49]

Source: Own

The \*, \*\* and \*\*\* denote significance of the adjustment parameters at the 10%, 5% and 1% level respectively. Half-lives ( $\hat{\lambda}^s$  &  $\hat{\lambda}^c$ ) are only calculated if adjustment parameters are significant at least at the 10% level. The half-lives column for the consumer markets under the no-trade regime is therefore omitted since none of the associated adjustment parameters are significant.

The results show that under the trade regime, error correction (denoted  $\hat{\alpha}^s$ ) by the producer markets (Navrongo or Techiman) to eliminate market disequilibrium are significant between five market pairs, while the adjustments ( $\hat{\alpha}^c$ ) by the consumer markets to eliminate disequilibrium are significant between three market pairs. The significant  $\hat{\alpha}^s$  under the trade

regime range from about 0.091(9.1%) to about 0.121(12.1%), with an average adjustment of 0.118(11.8%), while the significant  $\hat{\alpha}^c$  range from 0.092(9.2%) to 0.295(29.5%), averaging 0.139(13.9%). The respective half-lives of adjustment, under the trade regime, range from about 4.3 to 7.3 semi-weeks for producer markets and 2.3 to 11.6 semi-weeks for consumer markets.

In contrast to the findings of the standard VECM, Navrongo, seems to be more sluggish in eliminating market disequilibrium under the trade regime than Techiman. In addition, we now have three different cases, in the trade regime, in which the net consumer markets exhibit significant speeds of adjustment. These are all the cases involving Techiman. This means by accounting for periods of trade and autarky, Techiman shares more information with the consumer markets in periods of direct trade between it and the net consumer markets, than does Navrongo under the same regime. Though the significant  $\hat{\alpha}^c$  are only three as against five significant  $\hat{\alpha}^s$ , the average adjustment speed by consumer markets, 0.139 (13.9%) is greater than that by the producer markets 0.118 (11.8%). The biggest consumer market, Accra, as expected has the most rapid response, 0.259 (26%), to Techiman, the biggest net producer.

For the regime of no-trade between market pairs, the significant speeds of adjustment by the net producer markets ( $\hat{\alpha}^s$ ) range from 0.074(7.4%) to 0.203(20.3%), averaging 0.160(16%) and implying half-lives from about three to nine semi-weeks. Navrongo as a producer market under the no-trade regime shows more rapid and significant error correction with all the other markets in the system, while Techiman exhibits significant error correction with only Accra and Kumasi, the biggest consumer markets. Under the no-trade regime, none of the consumer markets appears to have significant error correction, confirming their weakly exogenous nature revealed by the results of the standard analysis. This weak exogeneity appears to further decline whenever direct trade flow between the net consumer markets and a particular producer market does not occur. Revelations by the results of the SVECM that Techiman as a producer market tends to have a stronger degree of price transmission with the net consumer markets when direct trade occurs than when there is autarky is expected.

Given that Techiman has a larger supply volume and longer supply duration than Navrongo, information and trade flow may play a lead, but not the sole role in integrating markets. In the absence of direct trade, price dynamics in smaller markets are more likely to be influenced by information flow and indirect arbitrage in the marketing system than the dynamics of prices in larger markets.

The distinguishing finding in this study is the revelation that mechanisms other than trade flow, drive price transmission and market integration in Ghana's fresh tomato markets. We demonstrate that inter-market price transmission occurs in periods of trade as in periods of market autarky, even though the speeds of adjustment in periods with and without trade differ in magnitude and significance. The existence of significant price adjustment in both periods of trade and autarky is not surprising given the good quality roads linking markets, the ease of information exchange via mobile phones and commonness in the source of tomato supply per season. Therefore the earlier empirical analysis that failed to allow for seasonal patterns of trade flow in price transmission analysis are probably erroneous in the interpretation of their findings. Future studies should endeavour to parse out the importance of trade flow vis-à-vis other underlying factors on the extent of price transmission in agricultural markets (Stephens et al, 2008).

## **6.5 Conclusion and Recommendations**

This paper explores whether other factors, apart from physical, direct trade, drive the integration of fresh tomato markets in Ghana. To this end, a regime-dependent VECM is proposed which allows for the estimation of unique adjustment parameters and half-lives for periods with and without trade. The results are compared with estimates from a standard VECM which allows for no regime regardless of whether or not trade between producer/consumer market pairs takes place.

The results of the standard VECM indicate that market integration between Ghana's tomato markets is generally strong, with the adjustment of prices to eliminate market disequilibrium being rapid and requiring averagely only 12 weeks to be accomplished. It however appears

that the attainment of market equilibrium is mainly ensured by price adjustment (error correction) in the two main producer markets, Navrongo and Techiman. The consumer markets, for the most part are weakly exogenous, and do not error correct.

The findings of the standard VECM are somewhat supported by the results of the regime-dependent VECM, which demonstrate that price transmission occurs both in periods with and without trade, with the net consumer markets significantly reacting to correct disequilibrium in only three cases under both regimes. Unlike the standard VECM results however, those from the regime-dependent model suggest that wholesale prices in Navrongo exhibit more rapid price adjustment under the no-trade than the trade regime, and does not cause corresponding adjustment in the net consumer markets. Techiman, as a producer market however, tends to have a stronger degree of price transmission with the net consumer markets when direct trade occurs than when there is autarky.

The significant speeds of adjustment under both the trade and non-trade regimes are evidence of other mechanisms, beside direct trade, being responsible for price transmission in fresh tomato markets in Ghana. This means, whereas direct trade flow between markets may drive price transmission between them, direct trade flow interacts with other factors in determining the extent of integration among tomato markets in Ghana. These other mechanisms such as a third-market effect due to supply seasonality and commonness in tomato supply sources, improved road and transportation infrastructure as well as information flow play a facilitating role in price transmission and market integration between tomato markets in Ghana.

The results are consistent with the findings of Stephens et al. (2008) for tomato markets in Zimbabwe, and are evidence against the attributing the marketing problem of fresh tomato in Ghana solely to import trade liberalization. This is because if price transmission, as our findings demonstrate, is effective in periods with and without trade, then the effect of the import dumping of cheap tomato products on arbitrage processes between Ghana's fresh tomato markets would not necessarily be negative. Since other factors, in addition to physical trade, jointly determine arbitrage and price transmission, we would expect the effects of cheap imports to be overlaid or offset by the other determinants. It seems therefore

that the problems of perennial gluts, uncompetitive, volatile and dispersed prices in Ghana's fresh tomato markets arise possibly from general impediments to trade flow such as inefficient market structure and competitiveness, poor connectivity between producer markets and consumer markets off the West African highway, trading risks, road barriers and anticompetitive practices of traders.

These findings motivate further research to identify which factors are driving market integration in the absence of trade, and to explain why these factors seem to play an important role for some markets, and not for others. Data on transaction costs between market pairs might cast light on these issues. Estimating threshold adjustment-type models, either over the entire data set or separately for the individual regimes with and without trade, may also prove informative. Further research along these lines is necessary to improve our understanding of market integration processes in developing countries, and to develop more nuanced policy recommendations for improving market integration with a view to increasing the benefit of trade liberalization to Ghanaian farmers.

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## **CHAPTER SEVEN**

### **7.0 Conclusions, Recommendations and Suggestions for further Research**

#### **7.1 Major Conclusions**

One of the key issues of current trade policy debates in most developing countries is the implication of trade liberalization policy for market development, economic growth, food security and poverty alleviation. Particularly contentious is the debate on the effect of the reduction in import tariffs and liberalization of marketing channels on price transmission between agricultural markets in developing countries. It is to provide evidence for current public opinion that blames trade liberalization as the sole cause of perennial gluts, uncompetitive, volatile and dispersed prices in Ghana's fresh tomato markets and to contribute to the debate on the implication of trade liberalization for domestic agricultural markets in Ghana and SSA that this study was conducted.

The main objective of the study is to determine the extent of post-liberalization price transmission and market integration between fresh tomato markets in Ghana. To achieve this objective, we selected five major, fresh tomato markets, consisting of two net producer tomato markets - Navrongo and Techiman and three net consumer markets – Tamale, Kumasi and Accra for the analysis. The supply chain between the producer and consumer markets implies short marketing channels, with relatively high transactions costs in the distribution level of the chain. The dataset comprises monthly and semi-weekly, wholesale level price series and trade flow data from the markets under study. Johansen's cointegration approach, and the threshold autoregressive (TAR) and vector error correction (VEC) models and their extension are applied in analysing the data.

The contribution of the study to the price transmission literature lies on the following issues. For the first time in the price transmission literature on Ghana, we have conducted an analysis that concretely examines the extent of price transmission and market integration using a perishable commodity. All previous price transmission studies in Ghana used grains as the

commodity of interest. We also endeavored to identify whether only trade and/or other mechanisms are responsible for price transmission in the markets considered. The purpose is to gain more insight into the nature of price transmission in Ghana. In this way, we built on previous studies that merely reported the existence of market integration or the lack of it without giving reasons for either case. Lastly, our use of two datasets with monthly and semi-weekly frequencies implicitly addresses the issue of data frequency in price transmission analysis and provides a basis for investigating the issue of data frequency in future price transmission analysis.

In conducting the analysis, we first tested for the existence of cointegration between net producer and net consumer pairs of tomato markets. Then we estimated the speeds of price transmission between the markets under two sub-periods following trade liberalization in Ghana. The first sub-period, the high tariffs period is from 1992 to 2000, while the second, a reduced tariffs period is from 2001-2009. Our task under this analysis is to determine whether price transmission and hence the underlying factors responsible for market integration sufficiently improved over the two sub-periods. Lastly, we examine the importance of direct, inter-market trade flow vis-à-vis other factors in driving price transmission and market integration in the tomato markets. Supposing trade flow is not the sole factor responsible for price transmission, then trade liberalization will have an overlaid effect on arbitrage and hence on the transmission of price signals between markets.

We find evidence for cointegration between tomato markets in Ghana. For the pair-wise cointegration analysis of net producer - net consumer markets using both datasets, there is at least one significant, cointegrating vector between the market pairs, while results of the Johansen's multivariate cointegration approach of testing for cointegration between each producer market and all the net consumer markets as a group demonstrate an integrated tomato marketing system. This implies that a common stochastic process, possibly the effective flow of the commodity and/or trade information, seems to determine price dynamics between markets. As a result, tomato prices between the markets do not drift apart in the long run, but always converge towards long run equilibrium following random, short run price shocks. Estimated, cointegration coefficients (the long run relationships between prices) range from

0.38 to 0.98, averaging 0.67, and appear to support our assertion of a high degree of market integration between fresh tomato markets in Ghana.

The estimated speeds of adjustment using the TAR model reveal that price adjustment under the two sub-periods was swift, while estimated thresholds, a proxy of proportional transaction costs between markets, remained fairly stable over the study period. This is proof of high speeds of price convergence to long run equilibrium, and implies the absence of discontinuities in trade. Whereas a mixed pattern of market performance was discovered between single market pairs, the output of the extended TAR model, the most ideal approach to modelling price adjustment between the markets, reinforced the finding of a lack of compelling evidence to suggest that trade liberalization is responsible for the perennial marketing problem of fresh tomato in Ghana.

The results of the VECM support those of the TAR model; they reveal high speeds of price adjustments, with deviations from equilibrium requiring about 12 weeks to be corrected. Most importantly, we find price adjustment in both periods with and without trade by estimating the semi-weekly data with the switching vector error correction model. This is evidence against the often implicit assumption that trade flow is the main driving force of price transmission and market integration, and is therefore *a contrario* to implicit claims in some of the price transmission literature that assume direct trade between markets as solely necessary for price transmission and market integration.

The findings help us draw the following major conclusions regarding the extent of price transmission and market integration in Ghana's tomato marketing system following trade liberalization:

1. There is no empirical proof that trade liberalization is solely responsible for the perennial marketing problem of Ghana's fresh tomato markets. Even though import trade liberalization opened Ghana's market to the importation of subsidized tomato products, the importation of tomato products alone do not appear to cause the perennial marketing problem of tomatoes mentioned earlier. As we discover, price transmission in the period following liberalization is

swift, a phenomenon that is not only due to trade flow, but also the interaction of trade flow with other factors.

2. The additional underlying factors that seem to influence price transmission and market integration in the markets under study include improved roads and transportation infrastructure, and the efficient flow of market information via mobile phones. These factors might have increased the connectivity of tomato markets, relatively reduced search and inter-market transaction costs, and positively affected the transmission of price signals between the markets under study.
3. It appears however that the improvements in the quality of the above factors failed to have an added benefit in eliminating signals of market failure such as low market competitiveness, supply gluts, price volatility and dispersion in Ghana's tomato markets. This could be due to the fact that oligopolistic pricing and market entry barriers created by wholesalers associations remain a setback to increasing the number of wholesalers and thus market competitiveness at the farm gate, a condition which could ultimately lead to a reduction in price volatility and dispersion between markets. The markets may also be prevented from operating optimally due to transportation difficulties and trade flow impediments such road barriers, toll gates etc.
4. As reported in the descriptive findings in chapter four, wholesalers' bargaining power and anti-competitive behaviour was noted as one of the main causes of the marketing problem of fresh tomato in Ghana during our market survey. Oligopolistic behaviour, anti-competitive pricing strategies and collusion by wholesalers has the potential to cause gluts, and retain price volatility and dispersion between consumer and producer markets. Anti-competitive trader behaviour such as pricing-to-market, misuse of bargaining power, crowding out prospective traders and other strategies that guarantee high profit margins etc. generally tend to create relative scarcity in the consumer markets, while maintaining gluts at the farm gate during peak seasons. This may consequently result in volatile and dispersed prices between markets and reduce price transmission in the short run.
5. It should be noted that the perishable nature of fresh tomato and the lack of inter-temporal arbitrage facilities of storage and processing is one potential cause of gluts and erratic price

dispersion. Being perishable and transported in trucks exposed to the tropical heat and sun, any delays in transportation and commodity delivery may imply high spoilage of the tomatoes and marketing risks for the traders. Such risks for traders discourage the entry of new traders into tomato marketing and truncate the probability distribution of prices. Poor storage and processing facilities may also imply high transaction costs, which can insulate markets from efficient price transmission.

6. One salient, though non-market point to note is that since tomato production in Ghana is not subsidized and costs of inputs like fertilizer and pesticides are high, it is possible that exorbitant production costs render Ghana's local tomato prices in comparison with the price of imported tomato products very high and thus uncompetitive<sup>15</sup>. High production costs are a disincentive to producers in adopting new technology and may cause the problems reported by the advocacy studies such as low income, welfare and profitability of tomato farmers in Ghana. As a point for comparison, the EU policy for tomato includes production and export subsidies, and import tariffs. In 2005 for instance, the production subsidy rate was €39.00, which is about 43% of per unit revenue, while the tariff rate has been 14.4% for processed tomato products since 2001 (Rickard and Sumner, 2006).
  
7. For both proponents and opponents of trade liberalization, we re-emphasize that the added benefits of trade liberalization are contingent on the quality of the complementary policy instruments and market environment a country creates to ensure the trickle-down effect of trade liberalization. Though trade liberalization policies have the potential of promoting marketing efficiency and contributing to price transmission, efficient market infrastructure and opportunities of market competitiveness are necessary to reinforce the positive role of trade liberalization.

The findings from the SVECM, demonstrate the relevance, but not the primacy of trade flow for price transmission and market integration. Since our findings demonstrate that the error correction mechanism is effective both under periods of trade and autarky, it can be concluded that:

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<sup>15</sup> The market share of locally produced tomato has been on the decline since the lifting of import restrictions; falling from 92% at 215 000MT to 57% at 200 000MT in 2003. See Table 4.1 for details.

1. In contrast to implicit assumptions in the literature suggesting that direct trade between markets is solely necessary for price transmission and market integration, we find that price transmission occurs in periods with and without trade. This means that the error correction process is influenced by other indirect mechanisms apart from direct trade, and is evidence of the facilitating role of other mechanisms interacting with trade flow to ensure price transmission and market integration. Obviously, trade flow is a necessary, but not a sufficient condition for price transmission.
2. Given the role of other under-lying factors influencing price transmission, the importation of tomato paste, an excellent substitute for locally produced tomato, may affect the volume of arbitrage of fresh tomato across markets, but this is not expected to significantly affect price transmission because of the role of the indirect arbitrage mechanisms. It also means the problems of tomato marketing arising in the post liberalization period are not due solely to the negative effects of trade liberalization on arbitrage.
3. The underlying factors that seem to partly drive price transmission between markets in Ghana appears to include a third-market or indirect arbitrage effect due to supply seasonality and commonness in tomato supply sources, improved road network and transportation systems linking the major tomato markets, and efficient exchange of market information between traders in the consumer markets and their counterparts at the farm gates via mobile phones.
4. The results of the VECM also show that the net consumer markets are more weakly endogenous than the net producer markets. These results are reinforced by the Granger causality test which reveals a unidirectional causality whereby consumer market prices granger cause producer market prices or lead price adjustment in the marketing system. This may imply that price changes at the farm gate are transmitted to the wholesale level more rapidly than are price changes in the consumer markets to the farm gate, and this may be attributed to the use of bargaining power by the wholesalers.

In the overall, lessons from the study show that the perennial marketing problem in Ghana's fresh tomato may be caused by factors that are difficult to explain by the empirical findings of this

study. What is obvious is that this problem is neither caused by sluggishness in the transmission of price signals between domestic markets nor due solely to the importation of subsidized tomato products into Ghana. In fact, market reforms have enhanced price transmission between markets although this improvement failed to eliminate the signals of low market competitiveness and the other marketing problems that we noted earlier. Perhaps more investments are needed to reduce demand and supply disparities, promote inter-temporal supply and distribution, and minimize risks in the marketing of fresh tomato in Ghana. We elaborate on these measures below.

## **7.2 Recommendations for Policy and Further Research**

Based on the evidence provided by the study, we suggest in this section a roster of complementary policy and structural measures that should be implemented to maximize the added benefits of trade liberalization to tomato producers in Ghana. Policy options aimed at reducing costs of tomato production, curtailing imports of cheap tomato products, minimizing the use of traders' market power, encouraging local storage and processing, and improving road linkages between isolated, fresh tomato-deficit markets and surplus producer markets are recommended. We also offer suggestions for future research into price transmission analysis.

Since tomato production in Ghana represents an important source of income, food and employment for many households in the producing areas and given the evolving concerns regarding food security, poverty alleviation and climate change, it is necessary for government to intervene during peak tomato seasons and when the prices are volatile and highly dispersed. Interventions in the short run may involve government buying fresh tomato in large quantities for storage or distribution to public institutions, a policy already practiced in rice markets.

In the long run, policy measures would also be necessary to address the low competitiveness situation of fresh tomato in Ghana. This requires some degree of regulation of the collusive behaviour of wholesalers and the removal of the entry barriers created by wholesalers associations. We recommend that whenever trader margins are excessively above the trigger threshold value (transaction costs), a threshold at which traders enjoy excess profits, government should intervene to reduce margins by encouraging an increase in the number of market participants through the provision of credit to potential traders and advocating price increases at

the farm gate. Providing credit to wholesalers would also increase competition in the marketing chain. In addition, providing input subsidies, improved seed and credit to producers will boost production and lower the price of locally produced tomato, thus increasing its competitiveness against that of imported fresh tomato from Burkina-Faso and tomato products from the EU<sup>16</sup>.

Appropriate investments should also be done in road, marketing and transport infrastructure to improve the connection and reduce transaction costs between farm gates and net consumer markets, and between surplus producing areas and deficit consumer markets that are off the West African highway. This measure together with the provision of storage and processing infrastructure will promote inter-temporal arbitrage processes, reduce marketing risks for traders and consequently promote arbitrage and price transmission between markets. Measures such as these will also increase the bargaining power of producers and lead to pricing efficiency.

One issue that the study failed to explain is the nature and extent to which trade flow as opposed to other underlying mechanisms influence price transmission and market integration. To offer relevant policy recommendations, there is the need to identify the exact mechanisms of price transmission and document the reasons why the improved transmission of price signals fails to correct the market inefficiencies of gluts, volatile and dispersed prices. Future research should therefore identify exactly the importance of trade flow as well as other factors in driving price transmission and market integration, and especially document the effects of import surges of tomato products on the prices of fresh tomato.

A priori unknown in previous research is the multivariate nature of price dynamics. For this reason, this study and others only conduct bivariate analysis. Since our findings reveal the importance of a third market or indirect arbitrage effect in driving price transmission between markets, they provide an ideal basis for designing appropriate multivariate framework to price transmission analysis in future studies. Such approaches should be able to make use of price and trade flow data as well as real transfer costs data in estimating price adjustment parameters.

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<sup>16</sup> One of the well known causes of fresh tomato gluts during peak harvest seasons is often the preference of wholesalers in Ghana to import fresh tomato from Burkina-Faso instead of buying locally produced tomato, which traders claim has a low quality and storability.

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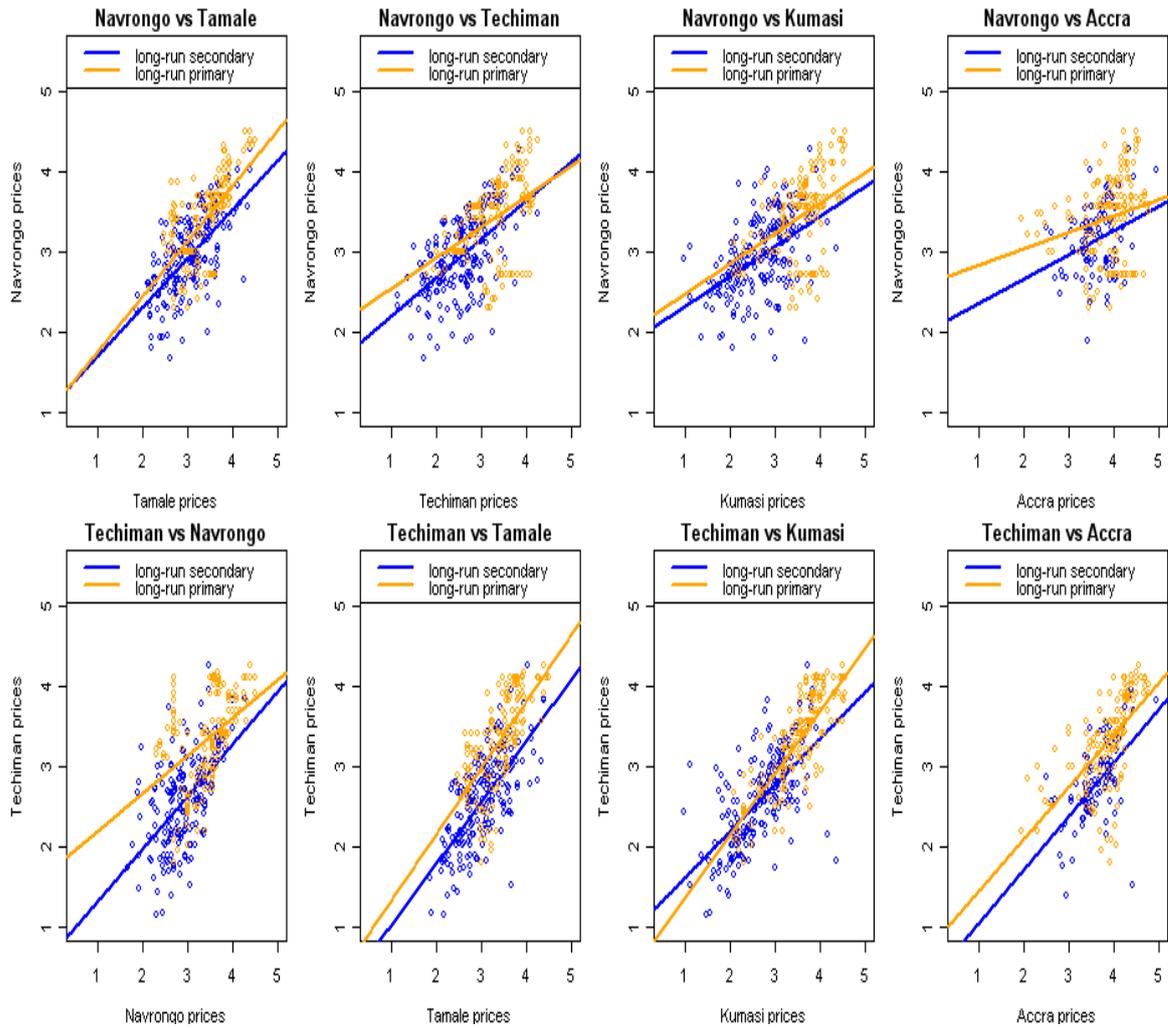
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## Appendix I

Figure 1: Logarithmized primary and secondary data and the respective estimated long-run equilibria of each of the market pairs



## Appendix II

### Causality Tests between net Consumer-net Producer pairs of Markets

<i>Market Pair</i>	<i>Causality</i>	
	$\alpha_1 = 0$	$\alpha_2 = 0$
Accra-Navrongo	2.75* (0.065)	1.08 (0.340)
Kumasi-Navrongo	3.99* (0.019)	1.52 (0.221)
Tamale-Navrongo	6.29** (0.002)	0.78 (0.460)
Techiman-Navrongo	0.366 (0.694)	0.312 (0.733)
Accra-Techiman	14.73** (0.000)	0.198 (0.820)
Kumasi-Techiman	6.47** (0.002)	0.49 (0.614)
Tamale-Techiman	3.52* (0.030)	3.07* (0.047)

It can be seen that in all cases except between the two producer markets Techiman-Navrongo, we reject the null hypothesis of  $\alpha_1 = 0$ , indicating that the first market of a pair does not granger-cause the second. This means that the net consumer markets granger-cause the net producer markets. On the contrary, we do not reject the null hypothesis of  $\alpha_2 = 0$ , i.e. the second market do not granger-cause the first, except between the Techiman-Tamale market pair. Therefore tomato fresh in the consumer markets generally lead price adjustment in the producer markets. The reverse is not generally true.

**Appendix III**  
**Market Integration Questionnaire**

Name of Enumerator..... Date of Survey.....  
Time..... Reference Marketing<sup>17</sup> .....

1. What is the price per crate of tomato in this market?.....

2. Indicate the level of supply of tomato in the market using the following definitions:  
(Not at all available = 0; Available but scarce = 1; Adequately available = 2, Peak supply but not glut = 3; and Glut = 4)  
Briefly explain the selected supply level.....

3. What is the current price of :  
a. Petrol (GH¢/Litre)  
b. Diesel (GH¢//Litre)  
c.

4. Fill in the Table below the indicated information about tomato coming from other markets into the reference market.

Source Market	Navrongo	Tamale	Techiman	Kumasi	Accra
a. Source of produce					
b. Distance to source (Km)					
c. Means of transport <sup>18</sup>					
d. Weight per Crate					
e. Type of arbitrage <sup>19</sup>					
f. Loading cost/unit (GH¢/)					
g. Transportation cost/unit (GH¢/)					
h. Offloading cost/unit(GH¢/)					
i. Toll duties/unit(GH¢/)					

<sup>17</sup> The reference market is the market in which the data is collected.

<sup>18</sup> This is the means by which tomato is transported from the source to the reference market (Truck = 1; Bus = 2; Other (specify) = 3)

<sup>19</sup> Market arrangement through which tomato is transferred from the source to the reference market (Farmer with own transport = 1; Farmer using transporter = 2; Wholesaler with own transport = 3, Wholesaler using transporter = 4; other (specify) = 5.....)

j. Other costs/unit (GH¢/)					
k. Price/crate at source					

5. Are there other tomato source markets apart from those listed in the Table above (specify names and distance from reference market)?.....

6. Are tomato shipped from the source market to other markets not listed in the Table above (specify names and distance from source)?.....

7. What are your personal observations of the market (behaviour of market participants, nature of pricing and other market characteristics)?

#### Appendix IV: A Sample of the Market Survey Data used for the Analysis

Period	Navrongo Series (Net Prod. Market)			Tamale Series (Net Cons. Market)		
	Price	T-fer Costs	Source	Price	T-fer Costs	Source
1-March-1	11	1	Navrongo	25	4.2	Navrongo
1-March-2	10	1	Navrongo	20	4.13	Navrongo
2-March-1	12	1	Navrongo	19	4.5	Navrongo
2-March-2	13	1	Navrongo	18	4.13	Navrongo
01. Apr 01	12	1	Navrongo	17	4.15	Navrongo
01. Apr 02	10	1	Navrongo	15	4.13	Navrongo
02. Apr 01	11	1	Navrongo	15	4.15	Navrongo
02. Apr 02	16	1	Navrongo	18.5	4.27	Navrongo
03. Apr 01	20	1	Navrongo	22	4.42	Navrongo
03. Apr 02	28	1	Navrongo	24	4.5	Navrongo
04. Apr 01	40	1	Navrongo	26	4.5	Navrongo
04. Apr 02	40	1	Navrongo	25	4.5	Navrongo
05. Apr 01	50	1	Navrongo	23	4.3	Navrongo
05. Apr 02	38	1	Navrongo	36	4.3	Navrongo
1-May-01	60	1.05	Navrongo	52	8.8	Navrongo
1-May-02	70	1.05	Navrongo	46	9.8	Navrongo
2-May-01	60	1.05	Navrongo	62	8.8	Navrongo
2-May-02	90	1.05	Navrongo	81	8.1	Navrongo
3-May-01	80	1.05	Navrongo	80	8.1	Navrongo
3-May-02	75	1.05	Navrongo	85	8.45	Navrongo
4-May-01	80	1.05	Navrongo	90	8.8	Navrongo
4-May-02	70	1.05	Navrongo	70	9.2	Navrongo
5-May-01	90	1.05	Navrongo	73	9	Navrongo
5-May-02	75	1.05	Navrongo	76	9	Navrongo
1-June-01	60	7.9	Techiman	52	4	Techiman
1-June-02	35	7.9	Techiman	30	4	Techiman
2-June-01	40	7.9	Techiman	33	4.5	Techiman
2-June-02	38	7.91	Techiman	35	4.1	Techiman
3-June-01	35	7.9	Techiman	30	4.5	Techiman
3-June-02	30	7.92	Techiman	35	4	Techiman
4-June-01	35	7.95	Techiman	33	5.3	Techiman
4-June-02	30	7.98	Techiman	36	4.8	Techiman
5-June-01	28	7.9	Techiman	35.5	5.35	Techiman
5-June-02	30	7.92	Techiman	35.25	5.63	Techiman
1-July-1	40	7.3	Techiman	35	5.91	Techiman
1-July-2	35	7.3	Techiman	42	5.91	Techiman
2-July-1	40	7.3	Techiman	45	5.91	Techiman
2-July-2	45	7.3	Techiman	50	5.91	Techiman
3-July-1	60	7.3	Techiman	45	5.91	Techiman
3-July-2	50	7.3	Techiman	50	5.91	Techiman
4-July-1	45	7.3	Techiman	50	4.23	Techiman
4-July-2	40	7.3	Techiman	30	5.91	Techiman
5-July-1	35	7.3	Techiman	36	4.23	Techiman

The complete dataset and codes for the analysis can be obtained from the author upon request

## Appendix V: The Complete Results of the Estimated Standard and Time-Dependent TAR Models (Analysis with the Stata Software)

### i. Results of the standard TAR Model

#### 1. TARestR2 Itamnav (Tamale-Navrongo)

(1 missing value generated)

(1 missing value generated)

(1 missing value generated)

ESTIMATED THRESHOLD: .1267365217208862

indouttab	Freq.	Percent	Cum.
-1	34	31.78	31.78
0	23	21.50	53.27
1	50	46.73	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	4.763567	1	4.763567	F( 1, 106) = 34.41
Residual	14.674486	106	.138438547	Prob > F = 0.0000
				R-squared = 0.2451
				Adj R-squared = 0.2379
Total	19.438053	107	.181664047	Root MSE = .37207

dependent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
intvarout	-.4911753	.0837334	-5.87	0.000	-.657185 - .3251657

Half Life for adjustment speed of  $\_b[\text{intvarout}]$  is 1.0258941

#### 2. TARestR2 ltechnav (Techiman-Navrongo)

(1 missing value generated)

(1 missing value generated)

(1 missing value generated)

ESTIMATED THRESHOLD: .3001774549484253

indouttab	Freq.	Percent	Cum.
-1	58	54.21	54.21
0	34	31.78	85.98
1	15	14.02	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	6.39258962	1	6.39258962	F( 1, 106) = 25.88
Residual	26.1791942	106	.246973531	Prob > F = 0.0000
				R-squared = 0.1963
				Adj R-squared = 0.1887
Total	32.5717839	107	.304409195	Root MSE = .49696

```

-----
dependent |   Coef.  Std. Err.   t   P>|t|   [95% Conf. Interval]
-----+-----
intvarout | -0.3936137  .0773672  -5.09  0.000  -0.5470018  -0.2402257
-----
Half Life for adjustment speed of _b[intvarout] is 1.3856346

```

### 3. TAREstR2 lkumnav (Kumasi-Navrongo)

(1 missing value generated)  
(1 missing value generated)  
(1 missing value generated)  
ESTIMATED THRESHOLD: .3744365572929382

indouttab	Freq.	Percent	Cum.
-1	57	53.27	53.27
0	38	35.51	88.79
1	12	11.21	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	10.9797086	1	10.9797086	F( 1, 106) = 32.62
Residual	35.6806957	106	.336610336	Prob > F = 0.0000
Total	46.6604043	107	.436078544	R-squared = 0.2353
				Adj R-squared = 0.2281
				Root MSE = .58018

```

-----
dependent |   Coef.  Std. Err.   t   P>|t|   [95% Conf. Interval]
-----+-----
intvarout | -0.5005787  .0876477  -5.71  0.000  -0.6743489  -0.3268086
-----
Half Life for adjustment speed of _b[intvarout] is .99833199

```

### 4. TAREstR2 Itamtech (Tamale-Techiman)

(1 missing value generated)  
(1 missing value generated)  
(1 missing value generated)  
ESTIMATED THRESHOLD: .7021254301071167

indouttab	Freq.	Percent	Cum.
0	81	75.70	75.70
1	26	24.30	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	4.05642291	1	4.05642291	F( 1, 106) = 23.81
				Prob > F = 0.0000

```

Residual | 18.062236 106 .170398453      R-squared   = 0.1834
-----+-----
                        Adj R-squared = 0.1757
Total | 22.1186589 107 .206716439      Root MSE    = .41279

```

```

-----
dependent |   Coef.  Std. Err.   t  P>|t|   [95% Conf. Interval]
-----+-----
intvarout | -0.3778511 .0774429  -4.88  0.000  -0.5313892  -0.2243129

```

Half Life for adjustment speed of  $\_b[\text{intvarout}]$  is 1.4605617

### 5. TARestR2 Ikumtech (Kumasi-Techiman)

(1 missing value generated)

(1 missing value generated)

(1 missing value generated)

ESTIMATED THRESHOLD: .318681001663208

```

indouttab |   Freq.  Percent  Cum.
-----+-----
-1 |      18   16.82   16.82
 0 |      71   66.36   83.18
 1 |      18   16.82  100.00
-----+-----
Total |     107  100.00

```

```

Source |   SS   df   MS       Number of obs = 107
-----+-----
Model | 10.4822332   1 10.4822332       F( 1, 106) = 59.78
Residual | 18.5852296 106 .175332354       Prob > F   = 0.0000
-----+-----
                        Adj R-squared = 0.3546
Total | 29.0674628 107 .271658531       Root MSE   = .41873

```

```

-----
dependent |   Coef.  Std. Err.   t  P>|t|   [95% Conf. Interval]
-----+-----
intvarout | -0.7783382 .1006636  -7.73  0.000  -0.9779136  -0.5787628

```

Half Life for adjustment speed of  $\_b[\text{intvarout}]$  is .46007303

## ii. Results of the Extended TAR Model

### 1. TARestRtrend2inter Itamnav (Tamale-Navrongo)

(1 missing value generated)

(1 missing value generated)

(1 missing value generated)

(108 real changes made)

14.071497 .11778307 .11778307

(108 real changes made)  
 14.068868 .12513041 .12513041  
 (108 real changes made)  
 14.061781 .12513041 .13062906  
 (108 real changes made)  
 14.058002 .13352323 .12513041  
 (108 real changes made)  
 14.055679 .14516807 .20224273  
 ESTIMATED THRESHOLD: .1451680660247803 .2022427320480347

indouttab	Freq.	Percent	Cum.
-1	28	26.17	26.17
0	36	33.64	59.81
1	43	40.19	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	5.38237384	2	2.69118692	F( 2, 105) = 20.10
Residual	14.0556791	105	.133863611	Prob > F = 0.0000
Total	19.438053	107	.181664047	R-squared = 0.2769
				Adj R-squared = 0.2631
				Root MSE = .36587

dependent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
intvarout	-.8455538	.195084	-4.33	0.000	-1.232369 -.4587384
intvaroutt~d	.0049636	.0025408	1.95	0.053	-.0000743 .0100015

Half Life for adjustment speed of  $_b[\text{intvarout}]$  is .37108176

## 2. TARestRtrend2inter ltechnav (Techiman-Navrongo)

(1 missing value generated)  
 (1 missing value generated)  
 (1 missing value generated)  
 (108 real changes made)  
 26.344415 .1613214 .1613214  
 (108 real changes made)  
 26.213165 .1613214 .26934397  
 (108 real changes made)  
 26.11677 .1613214 .30017745  
 (108 real changes made)  
 26.034585 .1613214 .31450105  
 (108 real changes made)  
 25.976168 .1613214 .33643651  
 (108 real changes made)

25.831529 .1613214 .38599503  
 (108 real changes made)  
 25.798084 .1613214 .64572144  
 (108 real changes made)  
 25.748041 .22040296 .47991848  
 (108 real changes made)  
 25.637758 .22040296 .63676113  
 ESTIMATED THRESHOLD: .2204029560089111 .6367611289024353

indouttab	Freq.	Percent	Cum.
-1	49	45.79	45.79
0	49	45.79	91.59
1	9	8.41	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	6.93402635	2	3.46701317	F( 2, 105) = 14.20
Residual	25.6377575	105	.244169119	Prob > F = 0.0000
Total	32.5717839	107	.304409195	R-squared = 0.2129
				Adj R-squared = 0.1979
				Root MSE = .49413

dependent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
intvarout	-.2293687	.1587683	-1.44	0.152	-.544177 .0854395
intvaroutt~d	-.0033155	.0024906	-1.33	0.186	-.0082539 .0016229

Half Life for adjustment speed of  $_b[\text{intvarout}]$  is 2.6603713

### 3. TAREstRtrend2inter Ikumnav (Kumasi-Navrongo)

(1 missing value generated)  
 (1 missing value generated)  
 (1 missing value generated)  
 (108 real changes made)  
 35.940042 .16253209 .16253209  
 (107 real changes made)  
 35.920694 .22344172 .16253209  
 (108 real changes made)  
 35.9049 .25184989 .55562228  
 (108 real changes made)  
 35.764793 .25184989 .56772685  
 (108 real changes made)  
 35.73616 .27021682 .51625359  
 (108 real changes made)  
 35.59476 .27021682 .55562228  
 (108 real changes made)

35.54241 .35616875 .3920083  
 (108 real changes made)  
 35.411811 .35616875 .55219895  
 ESTIMATED THRESHOLD: .3561687469482422 .5521989464759827  
 indouttab | Freq. Percent Cum.

	Freq.	Percent	Cum.
-1	54	50.47	50.47
0	42	39.25	89.72
1	11	10.28	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	11.2485934	2	5.62429671	F( 2, 105) = 16.68
Residual	35.4118108	105	.337255341	Prob > F = 0.0000
				R-squared = 0.2411
				Adj R-squared = 0.2266
Total	46.6604043	107	.436078544	Root MSE = .58074

dependent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
intvarout	-.5884379	.1887218	-3.12	0.002	-.9626385 -.2142374
intvaroutt~d	.0012042	.0025441	0.47	0.637	-.0038403 .0062487

Half Life for adjustment speed of \_b[intvarout] is .780751

#### 4. TAREstRtrend2inter Itamtech (Tamale-Techiman)

(1 missing value generated)  
 (1 missing value generated)  
 (1 missing value generated)  
 (108 real changes made)  
 18.584668 .17839634 .17839634  
 (108 real changes made)  
 18.533584 .17839634 .18894315  
 (108 real changes made)  
 18.395088 .17839634 .65390229  
 (108 real changes made)  
 18.246009 .17839634 .70212543  
 (108 real changes made)  
 18.20975 .17839634 .72214615  
 (108 real changes made)  
 17.653465 .17839634 .74442089  
 (107 real changes made)  
 17.548853 .18633974 .74442089  
 (107 real changes made)  
 17.409347 .25780463 .74442089  
 ESTIMATED THRESHOLD: .2578046321868897 .7444208860397339

indouttab	Freq.	Percent	Cum.
-1	2	1.87	1.87
0	57	53.27	55.14
1	48	44.86	100.00
Total	107	100.00	

Source	SS	df	MS	Number of obs = 107
Model	4.70931192	2	2.35465596	F( 2, 105) = 14.20
Residual	17.409347	105	.165803305	Prob > F = 0.0000
Total	22.1186589	107	.206716439	R-squared = 0.2129
				Adj R-squared = 0.1979
				Root MSE = .40719

dependent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
intvarout	-.5006423	.1480437	-3.38	0.001	-.7941855 -.207099
intvaroutt~d	.0021269	.0020197	1.05	0.295	-.0018777 .0061315

Half Life for adjustment speed of  $\_b[\text{intvarout}]$  is .99814906

### 5. TARestRtrend2inter Ikumtech (Kumasi-Techiman)

(1 missing value generated)

(1 missing value generated)

(1 missing value generated)

(108 real changes made)

17.467744 .06745327 .06745327

(108 real changes made)

17.467279 .06745327 .08456218

(108 real changes made)

17.441174 .06745327 .08895344

(108 real changes made)

17.423024 .06745327 .10320079

(108 real changes made)

17.408726 .06745327 .11948627

(108 real changes made)

17.362139 .06745327 .13101375

(108 real changes made)

17.35877 .11191574 .31459391

(108 real changes made)

17.295533 .11191574 .31818819

(108 real changes made)

17.245906 .27927274 .08456218

(108 real changes made)

17.231752 .27927274 .0918088

ESTIMATED THRESHOLD: .279272735118866 .0918087959289551

```

indouttab |   Freq.  Percent   Cum.
-----+-----
   -1 |    28   26.17   26.17
    0 |    49   45.79   71.96
    1 |    30   28.04  100.00
-----+-----
 Total |   107  100.00

Source |   SS    df    MS                Number of obs = 107
-----+-----
Model | 11.8357106   2  5.91785531      F( 2, 105) = 36.06
Residual | 17.2317522  105 .164111926      Prob > F   = 0.0000
-----+-----
Total | 29.0674628  107 .271658531      R-squared  = 0.4072
                                           Adj R-squared = 0.3959
                                           Root MSE   = .40511

-----+-----
dependent |   Coef.  Std. Err.   t   P>|t|   [95% Conf. Interval]
-----+-----
intvarout | -1.387316 .2331039   -5.95  0.000   -1.849518  -.9251141
intvaroutt~d | .0090964 .0030312    3.00  0.003    .0030861  .0151066
-----+-----
Half Life for adjustment speed of _b[intvarout] is .

```

### Notes on the Parameter Coefficients of Interest

1. ESTIMATED THRESHOLD: This is denoted  $\tau^{cs}$  in the threshold model and results Tables in Chapter Five. The threshold refers to the minimum proportional differences between inter-market prices that must be exceeded before provoking price adjustment towards equilibrium.
2. intvarout: Denoted  $\rho^{out}$  or  $\rho'$  in the threshold model and results Tables in Chapter Five. This is the estimated speed of price adjustment in the outer regimes i.e. the price adjustment that is produced once the minimum threshold value is exceeded.
3. \_b[intvarout]: Refers to the half-life of price adjustment and denoted  $\lambda^c$  &  $\lambda^s$  in the results Tables in Chapter Five.

## Appendix VI: A Sample of the Output of the Estimated VECM and Switching VECM Models (Analysis with the Gauss Software)

### i. Results of the VECM

#### 1. //Nav-Tam (Navrongo-Tamale)

```

iteration:1.000
ln(det(sigma_U_tilde))8.249
iteration:2.000
ln(det(sigma_U_tilde))8.217
iteration:3.000
ln(det(sigma_U_tilde))8.186
iteration:4.000
ln(det(sigma_U_tilde))8.173
iteration:5.000
ln(det(sigma_U_tilde))8.138
iteration:6.000
ln(det(sigma_U_tilde))8.114
iteration:7.000
ln(det(sigma_U_tilde))8.111

/*****
*****/
//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC
5/28/09 um 20:46:49 Uhr
/*_____*/
// Max # of lags for Model search: 7(# of obs in each search: 235)

// Minimizing number of lags acc. to AIC:6
// Minimizing number of lags acc. to HQ:6
// Minimizing number of lags acc. to SC:6

// # of actual lags: 3
// # of actual obs: 239

/*_____*/
_____*/
//Output of the VECM with the chosen lag length of 3:
Valid cases:          478   Dependent variable:          Y
Missing cases:         0   Deletion method:           None
Total SS:             39938.713   Degrees of freedom:          462
R-squared:            0.153   Rbar-squared:                0.125
Residual SS:         33828.153   Std error of est:            8.557
F(16,462):           5.216   Probability of F:            0.000
Durbin-Watson:       1.992

```

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X01	-0.121463	0.060559	-2.005689	0.045	-0.088893	-0.131671
X02	-0.183083	0.062892	-2.911085	0.004	-0.141702	-0.241966
X03	-0.320835	0.071576	-4.482462	0.000	-0.252751	-0.236804
X04	0.253055	0.079696	3.175232	0.002	0.154634	0.127206
X05	-0.080715	0.071498	-1.128907	0.260	-0.063591	-0.026206
X06	0.082994	0.079863	1.039200	0.299	0.050715	-0.033128
X07	0.087201	0.063369	1.376093	0.169	0.068391	0.107135
X08	0.021741	0.080097	0.271433	0.786	0.012890	0.013352
X09	0.005232	0.060559	0.086401	0.931	0.003829	0.011917
X10	0.064203	0.062892	1.020856	0.308	0.049692	0.060987
X11	-0.030451	0.071576	-0.425438	0.671	-0.023989	-0.057846
X12	-0.096157	0.079696	-1.206539	0.228	-0.058759	-0.069370
X13	0.102163	0.071498	1.428897	0.154	0.080490	0.073222
X14	-0.060824	0.079863	-0.761601	0.447	-0.037168	-0.022579
X15	0.089110	0.063369	1.406220	0.160	0.069888	0.050267
X16	0.052830	0.080097	0.659572	0.510	0.031322	0.068050

/\*  
\_\_\_\_\_\*/

//Est. coefficients for dx and dy:

alphReg1 -0.12146264 0.0052323893  
 alphReg2 -0.18308307 0.064203358  
 gamma\_1x -0.3208345 -0.030450909  
 gamma\_1y 0.25305472 -0.096156868  
 gamma\_2x -0.080714665 0.10216342  
 gamma\_2y 0.082993608 -0.060823758  
 gamma\_3x 0.087201107 0.089110226  
 gamma\_3y 0.021740984 0.052829733  
 1.00000

**2. Tec-Tam (Techiman-Tamale)**

iteration:1.000  
 ln(det(sigma\_U\_tilde))7.749  
 iteration:2.000  
 ln(det(sigma\_U\_tilde))7.741  
 iteration:3.000  
 ln(det(sigma\_U\_tilde))7.717  
 iteration:4.000  
 ln(det(sigma\_U\_tilde))7.710  
 iteration:5.000  
 ln(det(sigma\_U\_tilde))7.698

/\*  
\*\*\*\*\*  
\*\*\*\*\*\*/

//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC  
 5/28/09 um 20:13:13 Uhr

/\* \_\_\_\_\_ \*/  
 // Max # of lags for Model search: 5(# of obs in each search: 237)

// Minimizing number of lags acc. to AIC:5  
 // Minimizing number of lags acc. to HQ:3  
 // Minimizing number of lags acc. to SC:1

// # of actual lags: 4  
 // # of actual obs: 238

/\* \_\_\_\_\_ \*/

//Output of the VECM with the chosen lag length of 4:

Valid cases: 476 Dependent variable: Y  
 Missing cases: 0 Deletion method: None  
 Total SS: 26829.523 Degrees of freedom: 456  
 R-squared: 0.061 Rbar-squared: 0.022  
 Residual SS: 25200.293 Std error of est: 7.434  
 F(20,456): 1.474 Probability of F: 0.085  
 Durbin-Watson: 1.997

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X01	-0.105452	0.054319	-1.941352	0.053	-0.093126	-0.113306
X02	-0.034831	0.036376	-0.957531	0.339	-0.047202	-0.071677
X03	-0.003039	0.073078	-0.041580	0.967	-0.002017	0.001012
X04	0.026003	0.064780	0.401406	0.688	0.019376	0.033112
X05	-0.065118	0.072550	-0.897561	0.370	-0.042807	-0.043155
X06	0.107825	0.064625	1.668473	0.096	0.080345	0.079195
X07	-0.023222	0.071469	-0.324922	0.745	-0.015253	-0.011318
X08	0.107426	0.065849	1.631392	0.103	0.077600	0.065590
X09	-0.007901	0.071298	-0.110810	0.912	-0.005168	0.006190
X10	0.064748	0.067173	0.963894	0.336	0.045289	0.039255
X11	0.095788	0.054319	1.763443	0.078	0.084592	0.094645
X12	0.050305	0.036376	1.382908	0.167	0.068172	0.077216
X13	-0.013186	0.073078	-0.180441	0.857	-0.008752	0.024012
X14	-0.077168	0.064780	-1.191236	0.234	-0.057501	-0.084645
X15	0.095435	0.072550	1.315431	0.189	0.062737	0.089018
X16	-0.006361	0.064625	-0.098434	0.922	-0.004740	-0.027585
X17	-0.036533	0.071469	-0.511178	0.609	-0.023997	-0.018926
X18	0.116387	0.065849	1.767483	0.078	0.084073	0.082800
X19	-0.068416	0.071298	-0.959580	0.338	-0.044757	-0.036258
X20	-0.014793	0.067173	-0.220224	0.826	-0.010347	-0.024094

```

/*
_____*/

//Est. coefficients for dx and dy:
alphReg1  -0.10545224  0.09578837
alphReg2  -0.034831123  0.050304637
gamma_1x  -0.0030385949  -0.013186347
gamma_1y   0.026003023  -0.07716817
gamma_2x  -0.065118113  0.095434608
gamma_2y   0.10782504  -0.0063613136
gamma_3x  -0.023221817  -0.036533415
gamma_3y   0.10742566  0.11638714
gamma_4x  -0.0079005036  -0.068416178
gamma_4y   0.064747625  -0.014793129
1.00000

```

## ii. Results of the Switching VECM

### 1. //Nav-Tam (Navrongo-Tamale)

```

iteration:1.000
ln(det(sigma_U_tilde))8.249
iteration:2.000
ln(det(sigma_U_tilde))8.217
iteration:3.000
ln(det(sigma_U_tilde))8.186
iteration:4.000
ln(det(sigma_U_tilde))8.173
iteration:5.000
ln(det(sigma_U_tilde))8.138
iteration:6.000
ln(det(sigma_U_tilde))8.114
iteration:7.000
ln(det(sigma_U_tilde))8.111

```

```

/*****
*****/

```

//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC

5/28/09 um 20:46:49 Uhr

```

/*
_____*/

```

// Max # of lags for Model search: 7(# of obs in each search: 235)

// Minimizing number of lags acc. to AIC:6

// Minimizing number of lags acc. to HQ:6

// Minimizing number of lags acc. to SC:6

// # of actual lags: 3

// # of actual obs: 239

```

/*
_____*/
//Output of the VECM with the chosen lag length of 3:
Valid cases:      478   Dependent variable:      Y
Missing cases:   0     Deletion method:      None
Total SS:        39938.713   Degrees of freedom:      462
R-squared:       0.153   Rbar-squared:      0.125
Residual SS:    33828.153   Std error of est:      8.557
F(16,462):      5.216   Probability of F:      0.000
Durbin-Watson:  1.992

```

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X01	-0.121463	0.060559	-2.005689	0.045	-0.088893	-0.131671
X02	-0.183083	0.062892	-2.911085	0.004	-0.141702	-0.241966
X03	-0.320835	0.071576	-4.482462	0.000	-0.252751	-0.236804
X04	0.253055	0.079696	3.175232	0.002	0.154634	0.127206
X05	-0.080715	0.071498	-1.128907	0.260	-0.063591	-0.026206
X06	0.082994	0.079863	1.039200	0.299	0.050715	-0.033128
X07	0.087201	0.063369	1.376093	0.169	0.068391	0.107135
X08	0.021741	0.080097	0.271433	0.786	0.012890	0.013352
X09	0.005232	0.060559	0.086401	0.931	0.003829	0.011917
X10	0.064203	0.062892	1.020856	0.308	0.049692	0.060987
X11	-0.030451	0.071576	-0.425438	0.671	-0.023989	-0.057846
X12	-0.096157	0.079696	-1.206539	0.228	-0.058759	-0.069370
X13	0.102163	0.071498	1.428897	0.154	0.080490	0.073222
X14	-0.060824	0.079863	-0.761601	0.447	-0.037168	-0.022579
X15	0.089110	0.063369	1.406220	0.160	0.069888	0.050267
X16	0.052830	0.080097	0.659572	0.510	0.031322	0.068050

```

/*
_____*/
//Est. coefficients for dx and dy:
alphReg1  -0.12146264  0.0052323893
alphReg2  -0.18308307  0.064203358
gamma_1x  -0.3208345   -0.030450909
gamma_1y   0.25305472  -0.096156868
gamma_2x  -0.080714665  0.10216342
gamma_2y   0.082993608 -0.060823758
gamma_3x   0.087201107  0.089110226
gamma_3y   0.021740984  0.052829733
1.00000

```

```

//Est. residual covariance matrix:

```

```

76.7505 16.6810
16.6810 51.5080

```

//Model selection criteria (AIC HQ and SC) for the chosen lag length:  
 8.23441 8.25200 8.27805

**2. //Nav-Acc (Navrongo-Accra)**

iteration:1.000  
 ln(det(sigma\_U\_tilde))9.202  
 iteration:2.000  
 ln(det(sigma\_U\_tilde))9.166  
 iteration:3.000  
 ln(det(sigma\_U\_tilde))9.145  
 iteration:4.000  
 ln(det(sigma\_U\_tilde))9.149  
 iteration:5.000  
 ln(det(sigma\_U\_tilde))9.149  
 iteration:6.000  
 ln(det(sigma\_U\_tilde))9.118  
 iteration:7.000  
 ln(det(sigma\_U\_tilde))9.115

/\*  
 \*/

//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC  
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/\* \_\_\_\_\_ \*/

// Max # of lags for Model search: 7(# of obs in each search: 235)

// Minimizing number of lags acc. to AIC:6  
 // Minimizing number of lags acc. to HQ:3  
 // Minimizing number of lags acc. to SC:2

// # of actual lags: 1  
 // # of actual obs: 241

/\*  
 \_\_\_\_\_\*/

//Output of the VECM with the chosen lag length of 1:

Valid cases:	482	Dependent variable:	Y
Missing cases:	0	Deletion method:	None
Total SS:	64020.515	Degrees of freedom:	474
R-squared:	0.066	Rbar-squared:	0.053
Residual SS:	59773.168	Std error of est:	11.230
F(8,474):	4.210	Probability of F:	0.000
Durbin-Watson:	2.033		

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X1	-0.064052	0.053899	-1.188361	0.235	-0.053351	-0.078339

X2	-0.180999	0.061695	-2.933786	0.004	-0.133859	-0.170704
X3	-0.253257	0.075257	-3.365218	0.001	-0.157411	-0.186794
X4	0.074430	0.056965	1.306586	0.192	0.058822	0.036174
X5	-0.026848	0.053899	-0.498114	0.619	-0.022363	-0.027383
X6	0.051142	0.061695	0.828953	0.408	0.037822	0.035026
X7	-0.016164	0.075257	-0.214784	0.830	-0.010047	0.010969
X8	0.121977	0.056965	2.141242	0.033	0.096399	0.095431

```
/*
_____*/
```

```
//Est. coefficients for dx and dy:
```

```
alphReg1 -0.064051767 -0.026847967
alphReg2 -0.18099935 0.051142095
gamma_1x -0.25325738 -0.016164038
gamma_1y 0.074430261 0.12197684
1.00000
```

```
//Est. residual covariance matrix:
```

```
87.1338 20.5750
20.5750 158.528
```

```
//Model selection criteria (AIC HQ and SC) for the chosen lag length:
```

```
9.51055 9.51637 9.52501
```

### 3. //Tec-Nav (Techiman-Navrongo)

```
iteration:1.000
ln(det(sigma_U_tilde))8.280
iteration:2.000
ln(det(sigma_U_tilde))8.219
iteration:3.000
ln(det(sigma_U_tilde))8.187
iteration:4.000
ln(det(sigma_U_tilde))8.183
iteration:5.000
ln(det(sigma_U_tilde))8.170
iteration:6.000
ln(det(sigma_U_tilde))8.142
iteration:7.000
ln(det(sigma_U_tilde))8.137
iteration:8.000
ln(det(sigma_U_tilde))8.122
iteration:9.000
ln(det(sigma_U_tilde))8.115
iteration:10.000
ln(det(sigma_U_tilde))8.100
```

```

/*****
*****/

```

```

//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC
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```

```

/*_____*/
// Max # of lags for Model search: 10(# of obs in each search: 232)

```

```

// Minimizing number of lags acc. to AIC:10
// Minimizing number of lags acc. to HQ:6
// Minimizing number of lags acc. to SC:3

```

```

// # of actual lags: 2
// # of actual obs: 240

```

```

/*_____*/

```

```

//Output of the VECM with the chosen lag length of 2:

```

```

Valid cases:      480   Dependent variable:      Y
Missing cases:    0     Deletion method:      None
Total SS:         36918.092   Degrees of freedom:      468
R-squared:        0.101   Rbar-squared:             0.080
Residual SS:     33177.025   Std error of est:        8.420
F(12,468):       4.398   Probability of F:        0.000
Durbin-Watson:   1.960

```

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X01	-0.065312	0.051813	-1.260536	0.208	-0.056314	-0.065879
X02	-0.011702	0.030985	-0.377677	0.706	-0.017042	-0.025067
X03	-0.010432	0.080855	-0.129021	0.897	-0.005905	0.000863
X04	0.073184	0.057575	1.271102	0.204	0.059951	0.046311
X05	-0.056997	0.080633	-0.706861	0.480	-0.031965	-0.036896
X06	0.093043	0.057093	1.629688	0.104	0.076221	0.052350
X07	-0.006440	0.051813	-0.124292	0.901	-0.005553	0.033406
X08	0.008844	0.030985	0.285429	0.775	0.012879	0.034923
X09	-0.058863	0.080855	-0.728006	0.467	-0.033320	-0.080739
X10	-0.321599	0.057575	-5.585709	0.000	-0.263448	-0.246134
X11	0.238220	0.080633	2.954360	0.003	0.133598	0.147284
X12	-0.149874	0.057093	-2.625098	0.009	-0.122776	-0.027281

```

/*_____*/

```

```

//Est. coefficients for dx and dy:

```

```

alphReg1 -0.06531224 -0.0064399417
alphReg2 -0.011702335 0.0088440193
gamma_1x -0.010431978 -0.058863008
gamma_1y 0.073184211 -0.32159949
gamma_2x -0.05699663 0.23822022

```

gamma\_2y 0.093043089 -0.14987368  
1.00000

//Est. residual covariance matrix:

46.4601 13.9369  
13.9369 89.7300

//Model selection criteria (AIC HQ and SC) for the chosen lag length:  
8.30435 8.31604 8.33336

#### 4. //Tec-Acc (Techiman-Accra)

iteration:1.000  
ln(det(sigma\_U\_tilde))8.600  
iteration:2.000  
ln(det(sigma\_U\_tilde))8.589  
iteration:3.000  
ln(det(sigma\_U\_tilde))8.529  
iteration:4.000  
ln(det(sigma\_U\_tilde))8.531  
iteration:5.000  
ln(det(sigma\_U\_tilde))8.500  
iteration:6.000  
ln(det(sigma\_U\_tilde))8.468

/\*  
\*\*\*\*\*  
\*\*\*\*\*  
\*/

//Results of VECM estimation with automatic model selection acc. to AIC, HQ or SC

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/\* \_\_\_\_\_ \*/

// Max # of lags for Model search: 6(# of obs in each search: 236)

// Minimizing number of lags acc. to AIC:6

// Minimizing number of lags acc. to HQ:6

// Minimizing number of lags acc. to SC:3

// # of actual lags: 5

// # of actual obs: 237

/\*  
\_\_\_\_\_\*/

//Output of the VECM with the chosen lag length of 5:

Valid cases:	474	Dependent variable:	Y
Missing cases:	0	Deletion method:	None
Total SS:	50835.894	Degrees of freedom:	450
R-squared:	0.061	Rbar-squared:	0.013
Residual SS:	47722.902	Std error of est:	10.298
F(24,450):	1.223	Probability of F:	0.215

Durbin-Watson: 2.003

Variable	Estimate	Standard Error	t-value	Prob > t	Standardized Estimate	Cor with Dep Var
X01	-0.065922	0.064756	-1.018015	0.309	-0.048365	-0.056057
X02	-0.012218	0.038579	-0.316694	0.752	-0.015127	-0.021236
X03	-0.041077	0.104206	-0.394193	0.694	-0.019780	0.000734
X04	0.061496	0.054457	1.129266	0.259	0.053804	0.051254
X05	-0.114579	0.104975	-1.091497	0.276	-0.054648	-0.031310
X06	0.021569	0.055278	0.390192	0.697	0.018847	0.022644
X07	-0.097173	0.102563	-0.947443	0.344	-0.046296	-0.008213
X08	0.152751	0.055321	2.761158	0.006	0.132788	0.116687
X09	-0.021691	0.102611	-0.211392	0.833	-0.010293	0.004492
X10	0.013814	0.057269	0.241211	0.810	0.011946	0.019531
X11	-0.103813	0.102425	-1.013554	0.311	-0.049219	-0.037623
X12	0.040266	0.057148	0.704600	0.481	0.034559	0.013826
X13	-0.027239	0.064756	-0.420643	0.674	-0.019984	0.005576
X14	-0.012750	0.038579	-0.330485	0.741	-0.015786	0.009105
X15	0.036031	0.104206	0.345767	0.730	0.017350	0.050396
X16	0.116359	0.054457	2.136713	0.033	0.101804	0.109114
X17	0.053605	0.104975	0.510646	0.610	0.025567	0.012484
X18	0.009519	0.055278	0.172201	0.863	0.008318	0.032955
X19	0.066055	0.102563	0.644045	0.520	0.031471	0.046774
X20	0.102418	0.055321	1.851332	0.065	0.089033	0.109662
X21	0.015615	0.102611	0.152180	0.879	0.007410	0.012553
X22	0.055733	0.057269	0.973178	0.331	0.048198	0.071964
X23	0.188217	0.102425	1.837605	0.067	0.089236	0.060577
X24	-0.124956	0.057148	-2.186548	0.029	-0.107246	-0.063999

/\*  
\_\_\_\_\_\*/

//Est. coefficients for dx and dy:  
 alphReg1 -0.065922181 -0.027239017  
 alphReg2 -0.012217833 -0.012749878  
 gamma\_1x -0.041077208 0.036030989  
 gamma\_1y 0.061496408 0.11635893  
 gamma\_2x -0.11457949 0.053604895  
 gamma\_2y 0.021568908 0.0095188892  
 gamma\_3x -0.097172578 0.066055208  
 gamma\_3y 0.15275055 0.10241788  
 gamma\_4x -0.021691221 0.01561545  
 gamma\_4y 0.013813903 0.05573282  
 gamma\_5x -0.10381345 0.18821702  
 gamma\_5y 0.04026638 -0.12495649  
 1.00000

//Est. residual covariance matrix:

43.2404 20.8780  
20.8780 147.939

//Model selection criteria (AIC HQ and SC) for the chosen lag length:

8.73520 8.76469 8.80836

### **Notes on the Parameter Coefficients of Interest**

1.  $\text{alphReg1}$  and  $\text{alphReg2}$ : These are the long run speeds of price adjustment by the producer market ( $d_x$ ) and consumer market ( $d_y$ ) for the regime 1 ( $\text{alphReg1}$ ) and the regime 2 ( $\text{alphReg2}$ ).
2.  $\text{gamma}_1x$ ,  $\text{gamma}_1y$ ,  $\text{gamma}_2x$ ,  $\text{gamma}_2y$ , etc.: Are estimates of the short run price adjustment processes by the producer market (x) and consumer market (y) respectively
3. The values X01, X02 etc. are a combination of the speeds of price adjustments, the short run adjustment processes and their corresponding standard errors, t-values, p-values, standardized estimates and their correlation with the dependent variable respectively.