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The impact of the National Food Buffer Stock Company on price transmission in Ghana

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Abstract

Achieving state market policies depends partly on the extent to which changes in commodity prices are transmitted along supply chains. This paper examines the effect of the National Food Buffer Stock Company (NAFCO) on price transmission between white maize wholesale and retail markets in Kumasi, Ghana. The findings suggest that the speed of price transmission elasticity between the market pair is symmetrical pre-NAFCO, asymmetrical post-NAFCO, and asymmetrical over the entire price series. Decreases in prices in the wholesale market are transmitted more quickly to consumers, whilst price increases are passed through sluggishly by retailers. The before- and after-NAFCO regimes show that government intervention through the marketing activities of NAFCO has created an imperfect market environment for maize traders, resulting in asymmetry in the speed of price adjustment in the retail market.

Key words: threshold error correction; asymmetric price transmission; vertical price transmission; white maize market; national food buffer stock company

1. Introduction

Policy makers intervene in the agricultural commodity market by establishing marketing boards, encouraging public-private partnerships, and investing in market infrastructure to facilitate ready market access for farmers. This is to ensure that food price movements along the supply chain are not delayed, especially during the peak season, to prevent traders from exploiting consumers. In addition, minimum prices guaranteed by the state for grains are instituted to prevent traders from exploiting farmers, and thus to protect farmers' income. Such interventions are intended to achieve market integration and developmental objectives such as food security and poverty reduction at both ends of the commodity supply chains. For instance, in the past three to four decades, many developing countries abolished state-owned food marketing corporations to pave the way for the adoption of economic reform programmes that require zero or minimal government intervention in agricultural commodity markets.[1]

[1] Among the countries that adopted the market reforms are Algeria, Benin, Bolivia, Ecuador, Niger, Nigeria, Mexico, Sudan, Uganda, Venezuela, Ghana, Zambia and Tanzania, to name but a few.

The reforms led to an improvement in agricultural commodity markets[2] in some countries, but also had unintended consequences for consumers and farmers. In the early 1990s, Goletti and Babu (1994) found that maize markets in Malawi were symmetrical, and thus the reforms had contributed to ensuring that price information was transmitted more efficiently. Alderman (1993) also confirmed that grain markets in Ghana were efficient, but did not consider the speed of price adjustment. In Tanzania and Ethiopia, however, the reform resulted in an increase in volatility in coffee and maize prices (Gemech & Struthers 2007; Kilima *et al*. 2008), and also price asymmetry in several markets in the African countries that adopted the policy. For instance, a reduction in coffee price in Zambia was passed on to producers more quickly than that of rising world market prices during the reform period (Mofya-Mukuka & Awudu 2013).[3] As a result of these negative, unintended consequences,[4] governments in developing countries have reversed from the economic reform programme to once again actively intervene in the markets.

In 2010, the Government of Ghana, in collaboration with the Ministry of Food and Agriculture, established the National Food Buffer Stock Company (NAFCO). Its mandate is to eliminate surpluses from the markets by purchasing maize and other cereal crops from farmers at a minimum guaranteed farmgate price. These cereals are then released onto the markets during lean seasons, with the objective of stabilising the supply and prices of domestic cereals (NAFCO 2010). As NAFCO's activities in the grain sector are geared toward getting the right price signals for farmers and consumers, it is essential to understand the extent to which changes in wholesale market prices are transmitted to the final consumers. This is because the adjustment of price transmission between wholesale and retail markets is pivotal to NAFCO's impact on grain markets.

In an environment in which marketing agents interfere with price adjustment, this might lead to price asymmetry in agricultural markets. Thus, the existence of asymmetries in price transmission leads to a different distribution of welfare to groups of market actors than would be the case under symmetry when commodity prices rise or fall in the market sector (Meyer & Von Cramon-Taubadel 2004). For this reason, the response to price upturns and downturns by marketing agents continues to be a concern for policy makers due to the exploitation of farmers and consumers. In most cases, both farmers and consumers do not benefit fully and on time from price increases and price reductions. Therefore, the extent to which NAFCO's intervention affects retail-wholesale commodity price transmission is of paramount interest to policy makers.

Despite the fact that empirical evidence for asymmetric price transmission is mixed, asymmetry in the speed of price adjustment is more pronounced in agricultural product markets in developing countries (see Table A1 in the Appendix). In Ghana, Abdulai (2000) examined spatial asymmetric price transmission in three urban maize markets using monthly real prices of wholesale maize. He found that the Accra and Bolgatanga markets reacted more quickly to eliminate negative changes than positive changes in the deviation from the equilibrium triggered by Techiman market price fluctuations to re-establish long-run equilibrium. Acquah and Dadzie (2010) also confirmed asymmetry in price adjustment between the Kumasi wholesale and retail markets for white maize, but did not account for the threshold effect on price transmission. Furthermore, these studies used data that predate the introduction of NAFCO. There is hardly any study that has ascertained the impact of recent government policies on price transmission. It is nevertheless important to understand how this policy intervention changes the dynamics of price transmission. This paper aims to do just that, using the case of Ghanaian white maize markets. Maize is one of the staple food crops that has the

[2] For instance, reductions in barriers to trade, and an increase in coffee farmers' share of the exported commodity price.
[3] Countries suffering from economic crisis embarked on the reform in the early 1980s and 1990s. To ensure countries' fiscal viability and balance of payments led to greater restrictions: a reduction in state spending, removal of input subsidies, elimination of commodity boards and privatisation of state enterprises aiming to reduce the barriers to trade.
[4] For example, the reform led to an increase in staple food prices, unemployment, abject poverty, depreciation of currencies, and removal of input subsidies in most countries.

potential of alleviating poverty and contributing to improving food security in the country. Per capita maize consumption increased from 43.8 kg/head/year in 2009/2010 to 45.8 kg/head/year in 2013/2014,[5] indicating how heavily Ghanaians demand maize for household consumption. This partly justifies the need to assess NAFCO's impact on the speed of price transmission in white maize markets. This paper contributes to the existing literature by assessing the impact of NAFCO on price transmission in the white maize wholesale and retail markets in Kumasi, Ghana.

Our results confirm asymmetric price transmission in the white maize retail market in Kumasi, Ghana. The nonlinear error correction model results for the entire price series suggest that decreases in white maize wholesale prices are transmitted more quickly, whilst increases in wholesale prices take longer to get through to consumers. This leads to positive asymmetric price transmission, as retailers react more rapidly when their profit margin is squeezed than when it is stretched. The marketing activity of NAFCO in the retail market is a plausible explanation for the asymmetric price adjustment we observed. In the NAFCO intervention period, symmetry in price adjustment has been replaced by positive asymmetric price transmission in the retail market, as an increase in wholesale price appears to be transmitted more quickly and completely to the consumers.

The rest of the paper is structured as follows. In section 2, we present an overview of white maize marketing in Ghana and the potential sources of asymmetric price transmission in Ghanaian maize markets. Section 3 presents the econometric methods, section 4 discusses the results, and section 5 concludes.

2. Background

Maize is one of the important agricultural commodities in Ghana. Its importance in the Ghanaian market can be linked directly to employment creation, poverty reduction, and food security. Maize production contributed 63.82% of the total domestic grain production available for human consumption in 2013/2014 (Ministry of Food and Agriculture [MoFA] 2016). It is an essential grain crop and basic staple food grown by a large number of small-scale farmers, with average land sizes of two hectares (Ragasa *et al*. 2013). Despite the small land size, the production of these small-scale farmers accounts for almost 70% of the total annual production (Angelucci 2012). It is cultivated in all the regions of Ghana due to its ability to thrive well under different agro-ecological conditions. Hence, the country is self-sufficient in white maize, as the total production available for domestic consumption exceeds the estimated net consumption.[6]

In Ghana, maize marketing is predominantly controlled by traders from the urban markets and NAFCO (Figure 1). A total of 71 private maize enterprises in the production regions purchase white maize from the farmers for NAFCO at a minimum guaranteed price. In the absence of contracts, traders sourcing maize from farmers offer price levels above the minimum guaranteed farmgate price. These prices, together with NAFCO's minimum guaranteed farmgate price, protect farmers' income and encourage them to increase production. This, in turn, helps in mitigating food insecurity. The urban traders in the feeder markets also obtain their maize from small-scale farmers, assemblers and commission agents in rural communities. The wholesale traders from maize-deficit urban markets visit the main production markets, especially Techiman, on market days to purchase maize for transport to the consumption regions. This leads to the distribution of maize within the country and spatial arbitrage conditions amongst urban markets as well as rural markets.

[5] This is based on the authors' compilation from the Ministry of Food and Agriculture ([MoFA] 2016).
[6] This is based on the authors' compilation from MoFA (2016).

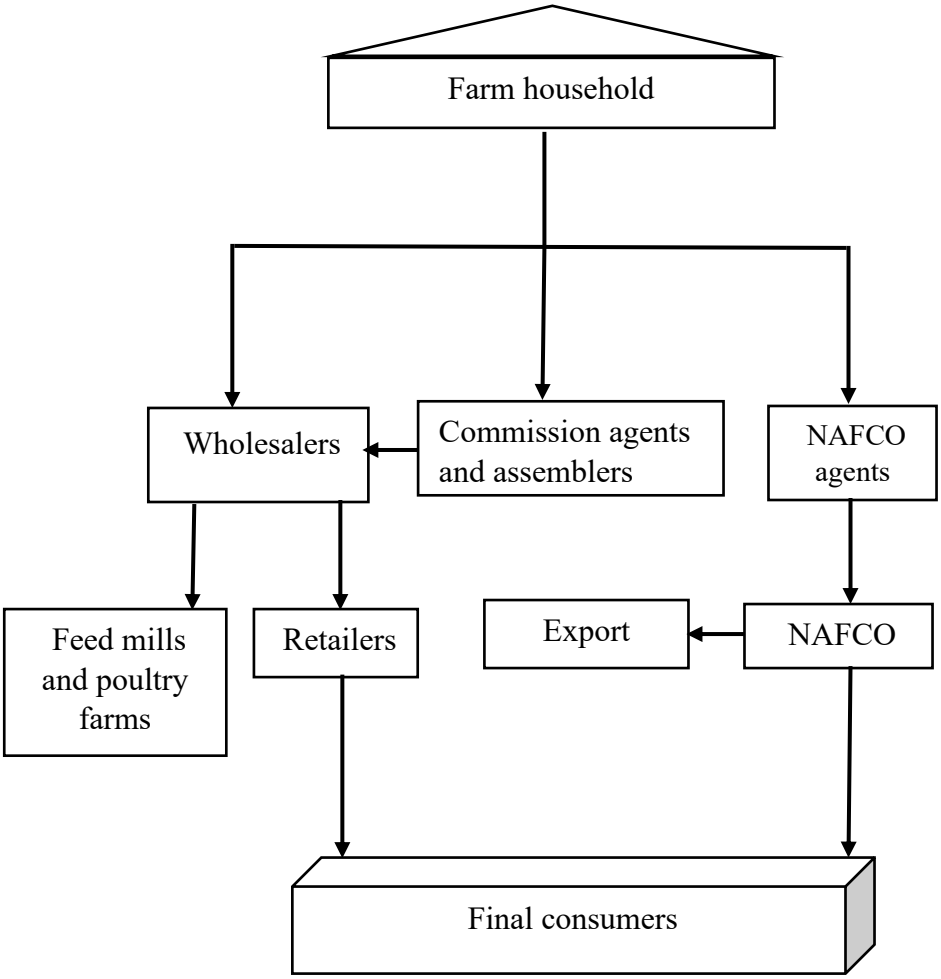

Figure 1: Maize supply chain in Ghana

Sometimes, the prices of white maize are determined by negotiation between the retailers and the urban wholesale traders (Abdulai 2000). NAFCO is the main supplier of maize to public schools and hospitals, and for exports to Burkina Faso, Togo, Mali and the Ivory Coast. The urban maize traders form an association under the headship of "market queens", who have the mandate of searching for favourable market environments for their agricultural products (Langyintuo 2010). According to Langyintuo (2010), maize traders are able to control the volume of stored maize discharged onto the markets. They collude to exercise their market powers in order to influence the conduct of the market so as to maximise their revenues. These traders' associations are strong and popular in urban markets, and often serve as a barrier to entry for non-members. This collusive behaviour is one of the possible reasons that NAFCO does not sell maize to wholesalers, but rather to other actors on the supply chain.

It is often argued that these market traders' associations play a crucial role in achieving efficiency of the marketing chain, for example through the provision of market information on distribution and marketing products and assisting members to work as a team, which can lead to a reduction in transportation cost (Shepherd 2005). In an environment in which these market traders' associations gain market power to influence prices indirectly to generate supernormal profits, the market is rendered imperfectly competitive. Market traders' associations restricting the volume of agricultural products in the market do not always benefit traders. In evidence, Langyintuo (2010) found that the collusive behaviour and imperfect competition induced by maize traders' associations in Ghanaian markets caused a distortion in maize trade flows and reduced traders' profits. He argues that the maize traders' associations exert market power during the marketing process and raise prices by 31% on

average over that of perfect competition. The imbalance in the demand and supply of white maize in urban markets aids these associations to exert market power during the marketing process.

3. Methods and data

3.1 Econometric model specification

We studied the impact of NAFCO marketing activity on price transmission in the white maize market in Kumasi. We considered the price dynamics between retail and wholesale markets. The properties of each price series are important to prevent spurious regression in the analysis of price variables (Granger & Newbold 1974). This underscores the need to determine if each price variable is integrated in the order of one, written as I (1), and implies that the price variable (μ_t) has a unit root and follows a random walk. The first difference of the price variable ($\mu_t - \mu_{t-1}$) is stationary in the order of I (0). To examine the (non-)stationarity of the Kumasi wholesale and retail prices, we estimated the augmented Dickey Fuller (ADF) test (Dickey & Fuller 1979) and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test (Kwiatkowski *et al*. 1992). This ensures that our price variables have the appropriate properties and that the cointegrated price variables are valid.

We then estimated the model proposed by Engle and Granger (1987) for testing the cointegration of price variables for the markets under consideration. The model involved a two-step ordinary least squares (OLS) procedure. In the first step, we estimated an OLS regression of two price variables and saved the estimated residual for the unit root test. In the second step, we applied an ADF test on the estimated residuals to test the null hypothesis of unit root against the alternative hypothesis of no unit root, as in equation (1) below.

$$P_t^M = \gamma + \varphi P_t^X + V_t, \quad (1)$$

where P_t^M and P_t^X are price variables from market M and X respectively, and are integrated in order of I (1). The γ and φ are the parameters to be estimated, and V_t is the estimated residual from the OLS regression. If the estimated residual is I (1), then there is evidence in favour of the null hypothesis of the ADF test of the unit root being equal to one, and hence the markets are not cointegrated. Thus, the OLS regression of the two price variables above is spurious. On the other hand, if the estimated residual is I (0), then there is statistical evidence in support of the alternative hypothesis of the ADF test, namely that the unit root is less than one. Therefore, we reject the null hypothesis of unit root and conclude that the markets are cointegrated in the long run, albeit wandering in the short run.

The Granger representation theorem postulates that economic time-series variables that are cointegrated can be represented efficiently by an error-correction model (ECM) to assess the cointegration relationship between price variables (Engle & Granger 1987). The first step estimates an OLS regression of the economic time-series variables to affirm co-integration of the price variables. The co-integration of the price series underscores the need for the second step, in which the estimated residual saved from the long-run equilibrium relationship of the price variables is lagged by one period and incorporated into an ECM. In that regard, we estimated the ECM presented in equation (2) to investigate the dynamics of the price series.

$$\Delta P_t^M = \gamma + \alpha \Delta P_t^X + \sum_{i=1}^{K} \varphi_i \, \Delta P_{t-i+1}^X + \sum_{j=1}^{P} \lambda_j \, \Delta P_{t-j+1}^M + \delta ECT_{t-1} + \varepsilon_t, \quad (2)$$

where $ECT_{t-1} = P_{t-1}^M - \gamma - \varphi P_{t-1}^X$, and δ denotes the speed of adjustment parameter of the error-correction term (ECT_{t-1}). γ, α, φ, λ and δ are parameters to be estimated. The K and P are lagged period for P_{t-i+1}^X and P_{t-j+1}^M respectively, and ε_t is the error term. The error-correction model is an

appropriate tool for examining the speed of the adjustment parameter(s) and the effect of changes of P_{t-i+1}^{X} on P_t^M (Engle & Granger 1987).

Granger and Lee (1989) extend equation (2) by separating the error-correction term (ECT) into positive and negative phases to enable testing for asymmetry in price transmission between cointegrated price variables:

$$\Delta P_t^M = \gamma + \alpha \Delta P_t^X + \sum_{i=1}^{K} \varphi_i \, \Delta P_{t-i+1}^X + \sum_{j=1}^{P} \lambda_j \, \Delta P_{t-j+1}^M + \delta^+ ECT_{t-1}^+ + \delta^- ECT_{t-1}^- + \varepsilon_t \quad (3)$$

Based on equation (3), the null hypothesis of symmetry can be formulated as:

$$H_0 : \delta^+ = \delta^-$$

Since the symmetric model is inserted into the asymmetric error-correction model (AECM), an F-test can be used to test asymmetry in price transmission (Tifaoui & Von Cramon-Taubadel 2016). The rejection of the null hypothesis of symmetry provides statistical evidence in favour of asymmetric price transmission. This model had been applied by several researchers to ascertain the presence of price transmission asymmetry (e.g. Acquah & Dadzie 2010; Acosta 2012).

The specification of the Engle and Granger (1987) cointegration model assumes that price variables always respond immediately to restore long-run equilibrium, irrespective of the magnitude of the deviation. However, the reaction of market price variables to long-run equilibrium might not take place in all period changes due to thresholds that need to be triggered. For instance, retailers may respond quickly to bigger changes because a certain threshold is altered and the cost of changing prices is offset by the additional increment in revenue earnings. The Engle and Granger (1987) cointegration test is mis-specified in the presence of threshold effect in adjustment and/or whenever the process of adjustment towards long-run equilibrium is asymmetric (Enders & Granger 1998; Enders & Siklos 2001).

Enders and Siklos (2001) modelled asymmetric cointegration adjustment that allows deviation from the long-run equilibrium in the form of a threshold autoregressive (TAR), and a momentum threshold autoregressive (M-TAR). Setting the threshold to be equal to zero in the TAR model leads to a very low degree of asymmetry, because it is likely that the threshold is not zero (Enders 2004). Enders (2004) argues that the use of Chan's (1993) grid-search method to search for all possible thresholds limited to the middle 70%[7] to minimise the sum of squared residuals is appropriate for estimating the consistent threshold. The estimated threshold with the smallest sum of squared residuals is the ideal threshold value. Therefore, the M-TAR model is employed to address the setback of symmetric cointegration:

$$\Delta \forall_t = l_t \rho_1 \forall_{t-1} + (1 - l_t) \rho_2 \forall_{t-1} + \sum_{i=1}^{K} \lambda_i \, \Delta \forall_{t-1} + \varepsilon_t, \quad (4)$$

where the momentum Heaviside indicator function (l_t) is formulated as:

$$l_t = \begin{cases} 1 & if \ \Delta \forall_{t-1} \geq \tau \\ 0 & if \ \Delta \forall_{t-1} < \tau \end{cases}, \quad (5)$$

where τ is an unknown threshold value to be estimated. The (l_t) depends on changes in the $\forall_{t-1}$ of the previous period's price spread. The price adjustment is formulated as $\rho_1 \forall_{t-1}$ if $\Delta \forall_{t-1}$ is above the threshold value, and $\rho_2 \forall_{t-1}$ if $\Delta \forall_{t-1}$ is below the threshold value. Equations (4) and (5) are

[7] The threshold values are arranged in an ascending order. The 15% at both ends of the threshold values are not considered when searching for the optimal threshold (Enders 2004).

termed a momentum threshold autoregressive because the $\{\forall_t\}$ displays enormous momentum in one direction rather than in the opposite direction. For instance, if $\|\rho_1\| < \|\rho_2\|$, the M-TAR model displays little adjustment for positive $\Delta\forall_{t-1}$, whilst negative $\Delta\forall_{t-1}$ exhibits substantial decay. This implies that an increase in the M-TAR model tends to be sticky, whilst a decrease tends to return rapidly towards the attractor.

We carried out diagnostic checks of the residuals using the Durbin Watson test to determine whether the error term is white noise. To determine the appropriate lag length, we used the Bayesian information criterion. The standard F statistic could be used to test for the null hypothesis of no cointegration and symmetric adjustment. If the symmetric adjustment is rejected and the presence of asymmetric cointegration adjustment towards long-run equilibrium is confirmed in an M-TAR model, then it might be inappropriate to examine short-run adjustments using the Equation (3) error-correction model, in which the underlining process of adjustment is linear (Enders & Siklos 2001). We analysed the short-run adjustments in a non-linear error-correction model that showed different adjustments to positive and negative short-run deviations. The model can be represented as:

$$\Delta P_t^R = \sum_{i=1}^{K} \varphi_i \, \Delta P_{t-i}^W + \sum_{j=1}^{P} \delta_j \, \Delta P_{t-j}^R + \lambda_1 \emptyset\_plus_{t-1} + \lambda_2 \emptyset\_minus_{t-1} + \varepsilon_t, \quad (6)$$

where P_t^R and P_t^W represent retail and wholesale prices respectively. $\emptyset\_plus_{t-1}$ and $\emptyset\_minus_{t-1}$ are positive and negative error correction, defined as:

$$\emptyset\_plus_{t-1} = l_t(P_{t-1}^R - \delta_0 - \delta_1 P_{t-1}^W)$$

$$\emptyset\_minus_{t-1} = (1 - l_t)(P_{t-1}^R - \delta_0 - \delta_1 P_{t-1}^W)$$

3.2 Data

The study used 723 items of weekly wholesale and retail price data on white maize from Kumasi market in Ghana. The price series starts from January 2002 and ends in January 2016. The data obtained from the Ministry of Food and Agriculture was then deflated using the consumer price index from the Ghana Statistical Service. Figure 2 shows the market under study. The Kumasi market was chosen because it is located in the maize consumption region and plays a significant role in agricultural commodity marketing in Ghana.

As an initial exploratory analysis, we illustrate the sample coverage graphically to highlight the movement of the price series over time. This prior knowledge helps in identifying the deterministic variables to use in the regression to ensure that the parameters are properly estimated. Figure 3 shows that the wholesale and retail price series increased intermittently from 2002 to 2016. The evidence of intermittent co-movement of the price series necessitated testing for unit root and co-integration of price variables.

Figure 2: Map of Ghana showing the market under consideration
Source: Authors' own map

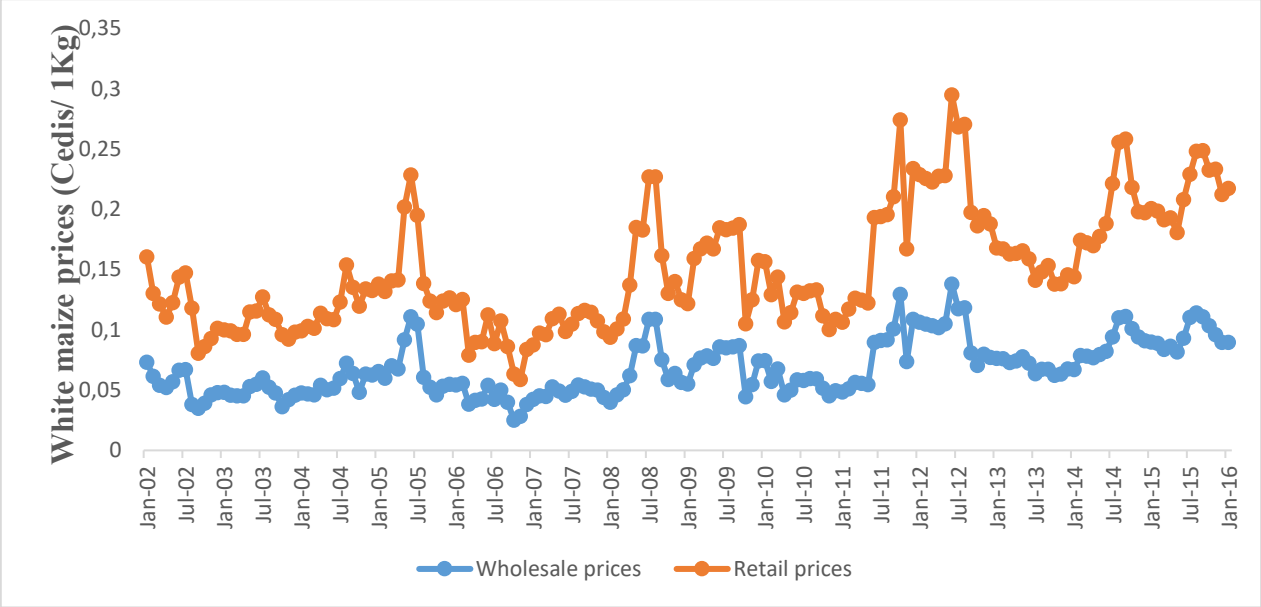

Figure 3: White maize wholesale and retail price series, from January 2002 to January 2016
Source: Author's construct based on data from MoFA (2016)

4. Results and discussion

4.1 Stationarity and the Engle and Granger cointegration tests

Table 1 presents the ADF and KPSS unit root test results of the price series. The selection of the optimal number of lags was based on the Bayesian information criterion. The results suggest that the wholesale and retail price series have a unit root in levels but become stationary at first difference. The first and the second steps of the Engle and Granger (1987) cointegration results are presented in Table 2. The results suggest that the margin between the Kumasi wholesale and retail markets for the entire price series is 0.0952. The cointegration relationship between wholesale and retail markets is 0.9667, implying that a 1% increase in white maize price in the Kumasi wholesale market will result in a 0.9667% increase in the retail market price. The effect is statistically significant at 1%.

Table 1: ADF and KPSS unit root tests

Wholesale price				
	Lags	**Value**	**P-value**	**KPSS test statistics**
ADF in levels				
2002 – 2016	4	0.9992	0.4702	10.1296
2002 – 2010	4	0.9997	0.6288	1.2337
2011 – 2016	3	0.9999	0.4046	1.0268
ADF in first difference				
2002 – 2016	1	-0.2114	1.4180^{e-041}	0.0223
2002 – 2010	1	-0.1563	1.8630^{e-036}	0.0213
2011 – 2016		-0.2347	1.4100^{-013}	0.0864
Retail price				
ADF in levels				
2002 – 2016	1	0.9925	0.4633	8.9415
2002 – 2010	1	0.9998	0.6385	1.6222
2011 – 2016	3	0.9985	0.3102	1.0268
ADF in first difference				
2002 – 2016	1	-0.3044	1.2200^{e-041}	0.0426
2002 – 2010	1	-0.2356	1.0230^{e-036}	0.0303
2011 – 2016	4	-0.1510	1.1830^{e-010}	0.0864

Notes: The constant critical values for the KPSS test are 0.348, 0.462 and 0.741 at 10%, 5% and 1% respectively

The second stage indicates that the null hypothesis of no cointegration between the two markets can be rejected at the 1% level of statistical significance. Besides, the null hypothesis of no cointegration for market pairs before and after the NAFCO intervention cannot be rejected at the 1% level of significance.

Table 2: The results of the Engle and Granger cointegration test

	First stage		Second stage	
Market pairs	α_0	α_1	ρ_1	R^2
2002 – 2016 $InP_R - InP_W$	0.0952 (0.0642)	0.9667*** (0.0236)	0.7943 (4.613^{e-006})	0.9179
2002 – 2010 $InP_R - InP_W$	0.2305*** (0.0455)	0.8608*** (0.0156)	0.7797 (0.0003)	0.8694
2011 – 2016 $InP_R - InP_W$	0.0880 (0.0729)	0.9499*** (0.0367)	0.8598 (0.0003)	0.8576

The Johansen (1988) maximum likelihood approach has higher power compared to the Engle and Granger two-step OLS method (Abdulai 2000). As a robustness check, we applied the former test to determine the number of rank cointegrating vectors of the market price series to confirm the latter test results. The results[8] indicate that the null hypothesis of zero cointegrating vectors for the market pair can be rejected at the 1% level of significance for trace and maximum-likelihood test statistics. But both test statistics suggest that the null hypothesis of one cointegrating vector linking the wholesale and retail markets cannot be rejected at any level of significance. This confirms the Engle and Granger test results that the two markets are cointegrated and that there is a long-run equilibrium relationship between them, despite drifting apart in the short run. The co-movement of the market pair may imply that marketing agents are abreast of the price information in the urban markets, and have the necessary trading facilities for trade flows and profit opportunities.

4.2 Threshold adjustment in long-run equilibrium

In order to ascertain the presence of a threshold in the long-run equilibrium adjustment between retail and wholesale prices, we employed the Enders and Granger (1998) test. The results of the threshold cointegration tests for the price series are presented in Table 3. Threshold values serve as the optimum price level that prevents marketing agents from reacting continuously to deviations from the long-run equilibrium. For instance, the relevance of the estimated threshold value of 0.050 for the entire price series is that there is no adjustment in retail prices towards long-run equilibrium if the magnitude of the deviation is less than 0.050. An adjustment in retail prices only occurs when the magnitude of deviations from the long-run equilibrium is greater than 0.050. Therefore, the estimated threshold values posit that white maize retailers react to restore long-run equilibrium only when the magnitude of deviation from the long-run equilibrium exceeds the threshold of 0.050, 0.049 and 0.048 for the entire price series, and the pre-NAFCO and post-NAFCO periods respectively.

Table 3: Threshold cointegration test of price series

Sample	τ	ρ_1^a	ρ_2	ω^b	ψ^c
Entire series 2002-2016	-0.050	-0.220*** (5.929)	-0.519*** (7.709)	17.962***	40.158***
Pre-NAFCO 2002-2010	-0.049	-0.302*** (5.730)	-0.491*** (5.832)	4.390	27.870***
Post NAFCO 2011-2016	-0.048	-0.079* (1.656)	-0.641*** (5.892)	25.554***	17.575***

Note: The numbers in parentheses are t-statistic values and are significantly different from zero at the 1% (***), 5% (**) and 10% (*) levels

The consistent threshold critical values are 8.35, 6.29 and 5.39 at the 1%, 5% and 10% levels of significance respectively.

[a] ρ_1 *and* ρ_2 are threshold cointegration coefficients

[b] ω and F-statistic values for the null hypothesis of symmetric cointegration

[c] ψ and F-statistic values for the null hypothesis of no cointegration

***, **, and * represent rejection of the null hypothesis at the 1%, 5%, and 10% levels respectively

[8] These results are available on request from the authors.

The results reveal that the null hypothesis of no cointegration ($\rho_1 = \rho_2 = 0$) between retail and wholesale prices cannot be rejected at any level of significance in all cases. In addition, the null hypothesis of linear cointegration ($\rho_1 = \rho_2$) can be rejected, with the exception of in the pre-NAFCO period. The estimates indicate that negative deviations from the long-run equilibrium as a result of reductions in wholesale prices are transmitted more rapidly, whilst positive deviations caused by an increase in wholesale prices are passed on sluggishly to consumers. All the estimated coefficients for deviations below the threshold (ρ_2) are higher than those of the estimated coefficients for deviations above the threshold (ρ_1). This shows that there is a faster speed of adjustment to restore long-run equilibrium when the deviation is below the equilibrium. For the entire price series, 22% of a positive deviation from the long-run equilibrium is eliminated, whereas approximately 52% of negative deviation is eliminated within a week. More importantly, the estimated parameters for the pre-NAFCO period suggest that 30% of positive deviations are eliminated, whilst 49% of negative deviations are eliminated within a week. In the post-NAFCO period, only 8% of positive discrepancies are eliminated, whilst 64% of negative discrepancies are eliminated within a week.

The Enders and Granger test confirmed the linear cointegration relationship between retail and wholesale markets for the pre-NAFCO period. We proceeded and estimated equation (2) to examine the long-run relationship between the wholesale and retail market price series in the absence of NAFCO intervention. The significance of the ECT coefficients led us to estimate equation (3) to investigate the speed of price adjustment parameters with respect to an increase and a decrease in white maize prices during the marketing process. The results are presented in Table 4. The estimated coefficient of the ECT has the expected sign and is statistically significant at 1% for the market pair.

Table 4: Results of the symmetric and asymmetric error-correction model

	Before NAFCO	
Independent variable	**ECM**	**AECM**
Constant	-0.0871** (0.038)	-0.0785** (0.039)
$\Delta InP_{W,t}$	0.5873*** (0.029)	0.5867*** (0.029)
$\Delta InP_{W,t-1}$	0.1441*** (0.042)	0.1477*** (0.042)
$\Delta InP_{W,t-2}$	0.0028 (0.047)	0.0050 (0.047)
$\Delta InP_{W,t-3}$	-0.1146** (0.047)	-0.1166** (0.047)
$\Delta InP_{W,t-4}$	0.0094 (0.041)	0.0113 (0.0412)
$\Delta InP_{R,t-2}$	0.1563*** (0.050)	0.1551*** (0.050)
$\Delta InP_{R,t-3}$	0.1051** (0.049)	0.1046** (0.049)
$\Delta InP_{R,t-4}$	0.0377 (0.045)	0.0384 (0.045)
ECT	0.3664*** (0.047)	
ECT_{t-1}^{+}		0.4076*** (0.064)
ECT_{t-1}^{-}		0.2970*** (0.087)
$ECT_{t-1}^{+} = ECT_{t-1}^{-}$ (P-value)		0.3477
R^2	0.9286	0.9288

Note: Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

The observed positive signs indicate that deviation from long-run equilibrium is reinstated with time after shocks. The deviation from the long-run equilibrium level is corrected at 36.64% for the market pair every week. The null hypothesis of symmetry cannot be rejected at any significant level. The empirical findings suggest that the speed of price transmission elasticities between the Kumasi wholesale and retail market pair is symmetric. This means that changes in maize prices are transmitted on time, and thus the market is efficient.

4.3 Short-run price dynamics

The findings of cointegration of the market pair necessitated the estimation of equation (6) to examine the short-run dynamic relationship between the wholesale and retail market price series. To do this, we employed the threshold error-correction model (TECM) estimation for the entire price series, before and after the NAFCO periods. The results of the estimations are presented in Table 5. The Bayesian information criterion was used to determine the appropriate lag length. The estimated coefficients of $\emptyset\_plus$ and $\emptyset\_minus$ describe the speed of adjustments to restore long-run equilibrium when shocks in the wholesale market exceed the threshold. The estimated parameters for the entire sample period suggest that 10% of negative and 9% of positive deviations from long-run equilibrium are eliminated. Similarly, the estimated parameters for the post-NAFCO period indicate that 13% of negative and 12% of positive discrepancies created by changes in wholesale prices are eliminated. Thus, negative deviations from the long-run equilibrium were transmitted more quickly to consumers than positive deviations in the post-NAFCO period.

In the case of the pre-NAFCO period,[9] 27% of positive and negative discrepancies from long-run equilibrium were eliminated. The result suggests that changes in maize prices are transmitted on time, and thus the market was efficient during the pre-NAFCO period. The Durbin Watson (DW) statistic confirmed no evidence of autocorrelation.

Table 5: Results of threshold error-correction model

Sample	$\emptyset\_plus$	$\emptyset\_minus$	DW
Entire series 2002 – 2016	-0.090*** (-2.940)	-0.101*** (-3.057)	2.0
Pre-NAFCO 2002 – 2010	0.270*** (-3.944)	-0.270*** (-3.941)	2.0
Post-NAFCO 2011 – 2016	-0.122** (-2.314)	-0.133** (-2.451)	1.98

Note: The numbers in parentheses are t-statistic values and are significantly different from zero at the 1% (***) and 5% (**) levels

The results indicate that retailers in Kumasi market react more quickly and/or completely to decreases than increases in the price of white maize. In other words, when the Kumasi retailers' margin is below its long-run equilibrium, they react faster and to a greater extent than when the margin is above its long-run equilibrium. Hence, Kumasi white maize retailers reacted more quickly when the margin is squeezed than when it is stretched with respect to the entire price series and after the NAFCO intervention period. These results confirm the findings of Acquah and Dadzie (2010), who found that, when the marketing margin is below its long-run equilibrium, the Kumasi retailers react faster and to a greater extent than when it is above its long-run equilibrium. This suggests that retailers respond quickly when their marketing margin is squeezed than when it is stretched. The above findings indicate that the establishment of the NAFCO marketing system might have altered the short-run price-transmission dynamics.

[9] As robustness check, we included pre-NAFCO price series in estimating equation (6) to investigate short-term price asymmetry. The finding confirms the symmetric-error correction of equation (3), and thus there was no price asymmetry present in the marketing of maize in the Ghanaian urban markets pre-NAFCO. Pre-NAFCO and before NAFCO are used synonymously throughout the paper, as are post-NAFCO and after NAFCO.

6. Conclusion

The study examined vertical price transmission in the Kumasi white maize market. We employed the symmetric error-correction and threshold error-correction models to ascertain the impact of NAFCO on price transmission from the wholesale to the retail market, and thus the results are robust. The empirical findings suggest that the speed of price transmission elasticity between the Kumasi wholesale and retail market pair is asymmetric for the entire sample period and the post-NAFCO period. This implies that there is a delay in passing on changes in food prices along the supply, and thus the market is considered inefficient. The results of this study complement the findings of earlier empirical studies on staple food crops markets in Africa, proving that food price changes are not passed on in time along the supply chain (e.g. Abdulai 2000; Mashamite & Moholwa 2005; Minten & Kyle 2000; Usman & Haile 2017).

The positive price asymmetry in the Kumasi retail market is beneficial for consumers. This result is in contrast to that of Abdulai (2000), who found that asymmetry in the Accra and Bolgatanga maize wholesale markets benefited traders. The presence of competition for market share might lead to a squeezed margin being corrected more quickly than a stretched margin in the long run. The evidence of price asymmetry in the Kumasi retail-wholesale market indicates that government intervention (i.e. NAFCO) in the markets has altered the short-term price dynamics. The reason for this is that there is no evidence of asymmetric price transmission in the Kumasi retail-wholesale market before government intervened through NAFCO.

Prior to the NAFCO intervention, the white maize market was efficient. After the NAFCO intervention, the market became inefficient. The difference in impact from before the NAFCO intervention to after the intervention can be attributed to government intervention through NAFCO. This policy has not yielded a mutual benefit for actors in the supply chain. An inclusive supply chain that ensures an equal benefit for all the actors along the chain should be encouraged. This will prevent a group of actors from benefiting at the expense of others. Therefore, there is a need for consultation with stakeholders on ways to ensure that changes in food prices are transmitted along the supply chain without any delay. It is recommended that policy makers pay more attention to the effect of NAFCO marketing activities on Ghanaian maize markets, especially in the main production and consumption cities.

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Appendix

Table A1: Empirical findings of asymmetric price transmission on agricultural commodity markets in Africa

Author	Market	Product	Frequency	Result
Abdulai (2000)	Accra Bolgatanga	Maize	Monthly	Asymmetry Asymmetry
Minten and Kyle (2000)	Zaire (Kinshasa)	Maize flour Maize in grains Peanuts in grains Peanuts in shell Cassava, Bandundu White beans Coloured beans Cassava flour	Weekly ✓ ✓ ✓ ✓ ✓ ✓ ✓	Asymmetry Asymmetry Asymmetry Asymmetry Asymmetry Symmetry Symmetry Symmetry
Mashamite and Moholwa (2005)	South African futures exchange	Wheat Sunflower seed White maize Yellow maize	Daily Weekly ✓ ✓	Asymmetry Symmetry Symmetry Symmetry
Cutts and Kirsten (2006)	South African futures exchange	Maize meal Cooking oil Fresh milk Long-life milk	Monthly ✓ ✓ ✓	Asymmetry Asymmetry Asymmetry Asymmetry
Worako *et al*. (2008)	Sidama, Domestic	Coffee	Monthly	Asymmetry
Acquah and Dadzie (2010)	Kumasi	Maize	Monthly	Asymmetry
Acosta (2012)	Domestic	Maize	Monthly	Asymmetry
Mofya-Mukuka and Abdulai (2013)	Domestic	Coffee	Monthly	Asymmetry
Usman and Haile (2017)	Amhara Oromia ✓ ✓	Teff ✓ Maize Wheat	Monthly ✓ ✓ ✓	Symmetry Symmetry Asymmetry Symmetry