INTERCOMMODITY PRICE TRANSMISSION BETWEEN MAIZE AND RICE PRICES IN TANZANIA: EVIDENCE FROM CO-INTEGRATION ANALYSIS AND ERROR CORRECTION MODEL

Muhidini Zungo[1] and Fredy T. M. Kilima[2]

Abstract
This study seeks to investigate whether or not there is a long-term relationship between maize and rice prices in Tanzania. The study used monthly wholesale prices for both commodities over the period of July 1989 through December 2012. The findings indicate that there is strong evidence of long-run equilibrium relation between the two commodities prices. The estimates of the error correction models (ECMs) showed a bidirectional long-run causality between the two commodities in many tests although there were relatively fewer cases that revealed the presence of a unidirectional long-run causality. Certainly, a continued effort by government and key stakeholders in the agricultural sector to improve the transportation infrastructure should ease inter-regional flow of commodities in Tanzania and facilitate the price transmission mechanisms. Similar efforts to improve the dissemination of market information through means such as mobile-phone based market information are ideal in promoting inter-regional trade and stabilizing prices of related tradeable commodities.

Key words: *Maize and rice prices, Error correction model, co-integration; causality, price transmission*

1.0 INTRODUCTION
The staple food basket of many households in developing countries consists of more than one substitutable cereal grains (Rashid, 2011). FAO (2009) indicates that the basket for households in Tanzania includes maize, cassava, rice, wheat, and sorghum. However, maize and rice are the most preferred grains. The marketing of these two commodities involves a wide range of stakeholders. This involvement is the main reason to justify government interventions in maize and rice markets (Ashimogo and Mbiha, 2007). Maize and rice are close substitutes implying that their prices are likely to have a long-run relationship, and price shocks to one commodity are likely to be transmitted to another commodity across space and time, especially when markets are integrated. Therefore, a price transmission study focusing on these crops can potentially draw specific lessons to inform food policy and influence the production, marketing and utilization of maize and rice.

Production and consumption of maize and rice are characterised by seasonal and spatial variation attributable to occurrences of periodic surpluses and deficits in different regions or districts. These differences are the major source of price difference that motivate traders to engage in inter-regional trade, which facilitate price transmission within and between commodities (Zakari, Ying and Song, 2014). Experience shows that when there is maize shortage, the government releases grains from its National Food Reserve Agency (Nyange, 1999). Furthermore, private traders and relief agencies also import maize and rice and these import affect food supply and food prices in Tanzania. The supply and prices of key agricultural commodities in Tanzania during the early 1980s to 90s were also affected by export ban for

[1] *Muhidini Zungo, Tanzania Leaf Tobacco Company, Regional Operations Manager, Chunya, Tanzania. Email:* mzungo@ulitanz.com

[2] *Fredy T. M. Kilima, Associate Professor, Department of Economics and Statistics, Moshi Co-operative University, Moshi, Tanzania. Emails:* ftmkilima@gmail.com

food security purposes (Kilima, Chung and Mbiha, 2008). The combined effect of these factors is not only to affect supply and prices of maize and rice but also inter-commodity substitution as well as spatial and temporal transmission of price within and between commodities.

An understanding of degree of price transmission between maize and rice is crucial for effective design and implementation of food policy in Tanzania. Literature shows that price transmission may affect the speed of traders' response to move food from surplus to deficit areas, especially during emergencies such as drought, floods or pestilence (Nyange, 1999). This paper assesses price transmission between the two substitutable grains to draw key lessons and policy implications.

2.0 LITERATURE REVIEW

2.1 Market integration

The extent to which price changes in one market are associated with price changes in other markets is known as market integration (Gabre-Madhin, 2001 cited by Ashimogo and Mbiha, 2007). This can occur when prices in different markets move together implying that there could be trade between markets (Minot, 2011; Rashid, 2011). In an economy consisting of several regions, trade for a homogeneous commodity between regions will take place if and only if the price in the importing region equals the price in the exporting region plus the per unit transfer cost between the two regions. This happens only if there is free flow of commodities and information through various means of verbal and non-verbal communication and when this occurs, prices across regions are said to be integrated (Sexton *et, al.,* 1991).

Studies on market integration are increasingly becoming important, particularly in developing countries where market failures and government interventions are common leading to price distortions and poor price transmission. These studies have implications on policy aspects such as devising strategies for market intervention (Alexander and Wyeth, 1994), trade facilitation (Barrett, 1996) and enhancing market efficiency (Familow and Benson, 1990).

2.2 Price transmission

Normally price transmission can take place between spatially separated markets (spatial price transmission), along different nodes of the commodity value chain (vertical price transmission) as well as between commodities (inter-commodity price transmission). Price transmission is generally measured in terms of the transmission elasticity, which is defined as the percentage change in the price in one market resulting from one percent change in the price in another market (Minot, 2011). Essentially, price transmission is closely related to market integration. In order for market integration to occur, there must be a transfer of price shocks either between markets, within the supply chain or among related commodities. Price transmission is a mechanism through which price changes in one market, point in the supply chain or related commodities are transmitted to another market, point in the supply chain or related commodity. The flow of commodities between markets is one of the conditions for the occurrence of market integration and is highly influenced by the degree of price transmission.

2.3 Maize and Rice in Tanzania

Maize is the most important staple food in Tanzania. According to the 2002 -2003 National Sample Census of Agriculture (NSCA), 4.5 million farm households representing (about 82% of all Tanzanian farmers) produce maize. It is estimated that about 98% of the maize is produced by smallholder farmers. Its market is dominated by small traders operating in both major production and consumption (urban) areas where some of the surplus production is sold (Nyange and Wobst, 2005). Maize is more likely to be substituted with rice, especially when households' earnings increase. This substitution steams from the fact that many of the consumers are poor and they perceive maize to be inferior to rice because rice tends to be more expensive than maize (Kilima, 2006). Thus, maize has relatively smaller income elasticity than rice.

Rice is also an important staple food in Tanzania. Its per capita consumption is about 16Kg and it contributes about 8% of calorific intake among Tanzanians (Minot, 2010). The largest proportion of rice (99%) is produced by smallholder farmers including those who grow it in large scale irrigation schemes that were formerly state-managed farms (NBS, 2006). Rice is the most commercialized crop and is widely consumed in places such as hotels and restaurants and institutions (Gabagambi, 1998). However, many of the regular consumers of rice in hotels and food vending places are those who are relatively rich to afford its price, which tends to be higher than maize meals. Furthermore, the preference for rice consumption in restaurants and institutions is mainly due to its convenience in terms of catering (Gabagambi, 1998).

2.4 Approaches to Analyze Price Transmission

There are several studies on price transmission which were conceived in a market integration perspective (Appendix 1). These include studies by Ravallion (1986), Gardner and Brooks (1994) and Rapsomanikis *et, al.* (2003). To date these earlier approaches have been significantly advanced to enhance the robustness of parameter estimates. Most of the earlier studies to test the degree of market integration such as Badiane (1997) and Lundahl and Petersson (1983) relied on correlation analysis. However, results from correlation analysis are bound to be affected by a wide range of factors including population growth, seasonality, changes in agricultural policy and general price inflation which can potentially induce significant change in price levels and variability thereby making correlation coefficients unreliable (Badiane, 1997; Kilima, 2006).

Regression models (Monke and Petzel, 1984; Mundlak and Larson, 1992; Gardner and Brooks, 1994) and other time series techniques (Boyd and Brorsen, 1986; Delgado, 1986; Ravallion, 1986 and Trotter, 1992) have also been applied to test for market integration. Essentially, the application of the regression model relies on contemporaneous prices of the commodities between spatially separated markets. When applied, the regression coefficients are used to measure the extent of market integration or co-movement between price series. Nonetheless, there are other limitations surrounding the static nature of this technique as it only considers contemporaneous arbitrage. Occasionally regression analysis can wrongly be used to estimate a spurious regression, especially when non-stationary data are used. This oversight is normally associated with incorrect inferences about the extent and direction of price transmission. Another weakness of the approach is that it ignores the effects of transaction costs and price variation on price transmission and market integration (Kilima, 2006; Onya and Ajutu, 2006).

Techniques such as Granger causality (GC), dynamic regression tests and co-integration analysis are the widely applied models to measure market integration. These models require time series data. Granger causality tests are applied when the intent is to understand the nature of causatility between variables and are conceived and estimated following the vector auto regressive (VAR) process (Granger, 1969). When applied to different commodities it tests the extent of integration among dynamically interconnected prices between commodities in terms of lead and lag relationships (Maro and Mwaijande, 2014). However, the application of GC also suffers from the weaknesses of correlation coefficient and standard regression analyses. In practice GC tests can only indicate whether the relationship between contemporaneous and lagged prices is statistically significant, but it fails to reveal the nature of the relationship (Kilima, 2006).

Dynamic regression techniques pioneered by Ravallion (1986) are the alternative to dynamic standard regressions and GC tests. These techniques have been advanced (Timmer, 1989) to allow computation of the index of market connectedness (IMC). The IMC shows the degree of short-run market integration where smaller values (<1) mean that markets are connected at least in the short-run while larger values (>1) imply that markets are not integrated into the short-run. However, the interpretation of IMC is still ambiguous and its use should be supplemented by prior knowledge of market set-up and the nature of commodity considered. Kilima (2006) argues that two markets may not be integrated due to higher transport costs that are normally excluded when computing the index. Moreover, a low value might indicate that markets are integrated in the short-run but it does not tell the extent to which the markets are connected.

Normally, price series for interconnected markets are expected to be influenced by their own past values as well as previous values of related commodities in other markets. This implies that any past change in prices in one market will be transmitted and induce some changes in the present or future prices in other markets. Literature shows that these co-movements might have inherent long-term relationships (Bulch, 1997; Huyghebaert and Wang, 2010; Natanelov *et al.*, 2011). Thus, researchers have introduced co-integration analysis in order to study long-run linkages between non-stationary sets of prices (Badiane, 1997). Indeed, co-integration between series means that the series may diverge in the short-run but will eventually converge towards a long-run equilibrium (Arshad and Hameed, 2009). This divergence may be attributed to various factors such as policy changes or seasonal price variability (Palaskas, 1995; Enders, 1995). Economic conditions like market forces of demand and supply may force series that drift apart to converge to a common trend in the long-run. However, co-integration techniques do not reveal the dynamic relationships between prices such as the speed of adjustment and the direction of causality. Therefore, an error correction model (ECM) has been proposed and is widely adopted to overcome the weakness of co-integration model and assess better features of dynamic relationships between price series. The short-run and long-run parameters of ECM allow the measurement of speed and degree of price transmission from one price series to another (Prakash, 1999).

The ECM does not consider transfer costs. However, the introduction of parity bound model (PBM) and threshold autoregressive (TAR) model allows analysts to account for the transfer costs incurred in moving commodity between segmented markets. The techniques recognize that prices in such markets may not move together if price differential is less than marketing cost between the markets (Minot, 2010). Normally, spatial price difference between two markets can be equal to marketing costs, less than marketing costs or greater than marketing costs implying that markets are competitive, there is no co-movement of prices or there is temporary disequilibrium due market imperfections, respectively. The PBM is appropriate when estimating the proportion of time at which a pair of markets is in all three conditions (Baulch, 1997). However, the technique is perceived to be biased when applied to bivariate analyses (Fackler and Tostam, 2008). Moreover, results of this model are more likely to be influenced by the distribution of the data that are used (Barrett and Li, 2002) and the technique assumes that shocks are serially independent and hence is inappropriate for modelling dynamic adjustments in time series.

The TAR model approximates the threshold for price margin between markets so as to judge the co-movement of prices and whether trade between such markets is profitable. Thus, if the price margin is greater than the threshold, then co-movement between prices exists and if it is less than the threshold the trade is not profitable and hence co-movement of prices does not exist (Minot, 2010). The threshold can be estimated within the model or using available information. A short summary of the characteristics for some of the techniques discussed here is presented in Appendix 2.

In summary, the extent of price transmission lacks a direct and unambiguous empirical counterpart in the form of single formal testing (Rapsomanikis et al., 2003; Kilima, 2006; Onya and Ajutu, 2006). Therefore, this study employed both Granger-Causality and co-integration tests involving the use error correction model (ECM). Groom and Tak (2015) suggest extending the analysis of ECM to asymmetric error correction model (AECM) so as to assess whether there could be asymmetry in response to deviations from the long run path, depending on whether the variable is above or below the long run path (Prakash et al., 2001). The AECM was not adopted because is beyond the scope of this paper. The PBM and TAR model were not adopted because the models require inclusion of transfer costs which could neither be observed nor sourced from secondary sources.

3.0 METHODOLOGY

3.1 Data and Data Sources

The present study used monthly wholesale prices for both maize and rice over the period of July 1989 through December 2012. The data were sourced from Ministry of Industry, Trade and Marketing in Tanzania and it comprised prices from 10 regional markets that are listed in Table 1. The analysis of price transmission was a step-wise procedure starting with unit root tests to ensure that the models are parsimonious. The second step was to test whether pairs of commodity prices in markets were co-integrated whereas the final step was to examine the underlying causal relationship between maize and rice prices.

3.2 Unit root tests

To overcome the problem of spurious regression, the stationarity (unit root) test was conducted using the Augmented-Dickey Fuller (ADF) test (Dickey and Fuller, 1981). The unit root test was applied to each price series for both crops in all markets at the levels and first differences. To test for unit root in a time series, the ADF test requires the estimation of a regression, which is presented in equation (1):

$$\Delta P_t = \beta + \delta P_{t-1} + \sum_{m=1}^{M} \alpha_m \Delta P_{t-m} + \varepsilon_t \qquad \text{.......(1)}$$

Where:

P_t is either maize or rice price;

Δ is the difference operator;
$\triangle P_{t-1} = P_{t-1} - P_{t-2}$;

$\Delta P_{t-2} = P_{t-2} - P_{t-3}$, which implies that $\Delta P_{t-m} = P_{t-m} - P_{t-m-1}$;

m represents the number of lags included in a model;
β, δ, and α are parameters to be estimated;
ε_t is a white noise error term.

Note that the null hypothesis is that $\delta = 0$; this means there is a unit root (the price series is non-stationary) and the alternative hypothesis is that $\delta < 0$; that means the price series is stationary.

3.3 Co-integration tests

The next procedure was to test whether each of the proposed pair of commodity prices in markets that were assumed to trade each other were co-integrated. In doing so the ADF unit root test was applied to residuals obtained from the co-integration regression as detailed in equation (2):

$P_{it}^{R} = \alpha + \beta P_{jt}^{M} + \mu_t$ ....(2)

Where:

P_{it}^{M} and P_{jt}^{R} are maize and rice prices for markets *i* and *j* at time *t*, respectively;.

α and β are parameters to be estimated;
μ_t is the error term.

The final step of the test procedure was to examine the underlying causal relationship between maize and rice prices. This study employed Granger (1969) causality test because of its favorable finite sample properties (Guilkey and Salemi, 1982; Geweke et al., 1983). The ECM reflecting the relationship between the commodities under investigation is mathematically given as:

$$\Delta P_t^M = \emptyset + \delta ECT_{t-1} + \sum_{i=1}^{N} \Psi_i \Delta P_{t-i}^R + \sum_{k=1}^{K} \Omega_k \Delta P_{t-k}^M + \gamma_t \text{.......................(5)}$$

Since $ECT_{t-1} = \delta(P_{t-1}^M - \beta P_{t-1}^R)$; then equation (5) becomes:

$$\Delta P_t^M = \emptyset + \delta(P_{t-1}^M - \beta P_{t-1}^R) + \sum_{i=1}^{N} \Psi_i \Delta P_{t-i}^R + \sum_{k=1}^{K} \Omega_k \Delta P_{t-k}^M + \gamma_t \text{..............(6)}$$

Also;

$$\Delta P_t^R = \emptyset' + \delta' ECT_{t-1}' + \sum_{i=1}^{N} \Psi_i' \Delta P_{t-i}^M + \sum_{k=1}^{K} \Omega_k' \Delta P_{t-k}^R + \gamma_t' \text{.......................(7)}$$

Since $\delta' ECT_{t-1}' = \delta'(P_{t-1}^R - \beta' P_{t-1}^M)$; then equation (7) becomes:

$$\Delta P_t^R = \emptyset' + \delta'(P_{t-1}^R - \beta' P_{t-1}^M) + \sum_{i=1}^{N} \Psi_i' \Delta P_{t-i}^M + \sum_{k=1}^{K} \Omega_k' \Delta P_{t-k}^R + \gamma_t' \text{..........(8)}$$

Where:

P_t^M is the natural logarithm of deseasonalised maize price in TZS;
P_t^R Is the natural logarithm of deseasonalised rice prices in TZS;
Δ is the difference operator, i.e. $\Delta P_t^M = P_t^M - P_{t-1}^M$ and $\Delta P_t^R = P_t^R - P_{t-1}^R$;
$\emptyset$ and $\emptyset'$ are intercepts;
Ω and $\emptyset'$ are the autoregressive terms to reveal effects of each change in the maize and rice prices on the change in maize and rice prices in the next period, respectively;
Ψ and Ψ' are the short-run elasticities of the maize and rice prices relative to the rice and maize prices in different markets, respectively;
δ and δ' are the rates reflecting speed of adjustment for maize and rice in the long-run, respectively.
β and β' are the long-run elasticity parameters to be estimated.
γ_t and γ_t' are the normal error terms.

The GC tests the existence of at least unidirectional causality linkages and is an indication of some degree of integration for the series of interest. Unidirectional causality informs about leader-follower relationships in terms of price adjustments for two co-integrated markets. Minimum Akaike Information Criterion (AIC) was used to determine the number of optimal lags to be used to run each ECM. The criterion indicated that a lag length of three months was adequate to detect the presence of short-run price transmission. Therefore, a long-run period is defined as a lag length exceeding three months.

4.0 RESULTS AND DISCUSSION

4.1 Augmented Dickey-Fuller unit root tests for maize and rice prices

Tables 1 and 2 summarize the results of ADF unit root tests for maize and rice price series, respectively. The null hypothesis that suggests the existence of unit root (non-stationarity) could not be rejected when applied to un-differenced prices except for maize price in Songea. This means maize prices in Songea were not stationary (I (0)) at their levels. However, the null hypothesis was rejected when applied to first differences of the prices (p<0.01) implying that the first differences were stationary.

Table 1: ADF test result for deseasonalised maize price series

	Price level			First difference		
Market	**Zero Mean**	**Non-zero Mean**	**Trend**	**Zero Mean**	**Non-zero Mean**	**Trend**
Arusha (AR)	1.249	-0.812 (0.8155)	-3.914 (0.0116)	-8.221	-8.322 (0.0000)	-8.326 (0.0000)
Dar es Salaam (DSM)	1.300	-1.139 (0.6991)	-3.682 (0.0236)	-7.866	-7.987 (0.0000)	-7.980 (0.0000)
Dodoma (DOM)	1.299	-0.776 (0.8261)	-3.867 (0.0135)	-8.615	-8.736 (0.0000)	-8.741 (0.0000)
Iringa (IR)	2.383	-0.658 (0.8575)	-2.848 (0.1799)	-6.120	-6.658 (0.000)	6.638 (0.000)
Songea (SONG)	0.973	-1.717 (0.4223)	-4.720 (0.0006)	-11.107	-11.171 (0.0000)	-11.149 (0.0000)
Mbeya (MBY)	2.685	-0.181 (0.9407)	-2.101 (0.5457)	-4.592	-5.335 (0.0000)	-5.336 (0.0000)
Morogoro (MOR)	1.294	-1.204 (0.6717)	-3.895 (0.0123)	-8.891	-9.013 (0.0000)	-9.002 (0.0000)
Mwanza(MWZ)	1.089	-0.801 (0.8189)	-3.909 (0.0118)	-11.661	-11.729 (0.0000)	-11.739 (0.0000)
Tabora (TBR)	1.147	-0.700 (0.8468)	3.546 (0.0347)	-8.284	-8.373 (0.0000)	-8.397 (0.0000)
Shinyanga (SHY)	1.250	-0.653 (0.8586)	-3.144 (0.0962)	-7.778	-7.875 (0.0000)	-7.889 (0.0000)

Note: Figures in parenthesis represent *p* values; prices are in natural logarithm.

Table 2: ADF results for deseasonalised rice price series

	Price level			First difference		
Market	**Zero Mean**	**Non-zero Mean**	**Trend**	**Zero Mean**	**Non-zero Mean**	**Trend**
ARU	2.913	-0.368 (0.9154)	-2.043 (0.5778)	-8.538	-9.057 (0.0000)	-9.043 (0.0000)
DSM	2.122	-0.547 (0.8824)	-2.761 (0.2115)	-7.763	-8.207 (0.0000)	-8.198 (0.0000)
DOM	1.914	-0.472 (0.8974)	-2.776 (0.2058)	8.593	-8.859 (0.0000)	-8.860 (0.0000)
IR	2.875	0.408 (0.9818)	-1.379 (0.8670)	-3.626	-4.784 (0.000)	-4.843 (0.000)
SONG	1.983	0.026 (0.9606)	-1.941 (0.6332)	-7.226	-7.486 (0.0000)	-7.538 (0.0000)
MBY	2.445	-0.080 (0.9514)	-1.850 (0.6800)	-7.176	-7.548 (0.0000)	-7.574 (0.0000)
MOR	2.280	-0.164 (0.9427)	-2.288 0.4407)	-7.200	-7.681 (0.0000)	-7.694 (0.0000)
MWZ	1.496	-0.754 (0.8323)	-3.011 (0.1291)	-11.455	-11.604 (0.0000)	-11.588 (0.0000)
TBR	1.300	-1.043 (0.7372)	-3.075 (0.1122)	-5.077	-5.334 (0.0000)	-5.332 (0.0000)
SHY	1.421	-0.818 (0.8138)	-3.021 (0.1262)	-10.164	-10.313 (0.0000)	-10.307 (0.0000)

Note: Figures in parenthesis represent *p* values; prices are in natural logarithm.

4.2 Co-integration tests for pairs of markets

In the course of testing for price transmission, all price series for the two crops were tested for co-integration i.e. I (1) using the ADF unit root test, which was applied to the residuals for each of the series (market pair). The bivariate long-run relationship was tested following the specification in Equation 2 to determine whether long-run relationships existed between the maize and rice prices. These relationships were tested within and between markets. Findings show that eleven pairs of maize and rice prices in different markets were not co-integrated (Table 3). Specifically, rice prices in Dodoma, Songea and Shinyanga were not co-integrated with maize prices in other markets such as Iringa, Arusha and Mbeya. This implies that the long-run relationship did not exist between such price series.

Factors such as long distance between markets, inadequate market information among key actors and some of the interventions by the authorities in cereals marketing systems were identified as potential reasons to justify the absence of co-integration in these markets. Usually, long distance between markets tends to increase transportation cost and may reduce the margin from the trade or discourage it. Minot (2009) argues that moving products from southern highlands regions to markets like Dar es Salaam, Shinyanga and Dodoma entails high transportation costs. He also found that these regions were characterised by poor road networks that reduced farmers' access to markets and increased prices for net food buyers in deficit areas. Most of the maize and rice prices in markets labeled with "x" were not co-integrated (Table 3). Incidences of no co-integration were common where markets were far from each other (Table 4). The findings justify the negative effect of long distance on price integration between markets.

Table 3: Results of co-integration test for I (1) price series

		MAIZE								
		AR	DSM	DOM	MOR	MBY	SHY	IR	MWZ	TBR
RICE	Arusha (AR)	C	C	C	C	C	C	C	C	C
	Dar es Salaam (DSM)	C	C	C	C	C	C	C	C	C
	Dodoma (DOM)	C	C	C	C	C	C	X	C	C
	Morogoro (MOR)	C	C	C	C	C	C	C	C	C
	Mbeya (MBY)	C	C	C	C	C	X	C	C	C
	Songea (SONG)	X	C	X	C	X	X	X	X	C
	Shinyanga (SHY)	C	C	C	C	X	X	X	C	C
	Iringa (IR)	C	C	C	C	C	C	C	C	C
	Mwanza (MWZ)	C	C	C	C	C	C	C	C	C
	Tabora (TBR)	C	C	C	C	C	C	C	C	C

Note: C implies co-integrated series; X implies that series are not co-integrated.

Table 4: Distance between markets

	AR	DSM	DOM	IR	SONG	MBY	MOR	MWZ	TBR	SHY
AR		646	425	689	1144	1020	621	787	661	624
DSM	646		451	492	947	822	192	1152	829	989
DOM	425	451		264	720	594	259	701	378	538
IR	689	492	264		455	330	300	965	642	802
SONG	1144	947	720	455		466	755	1420	1033	1257
MBY	1020	822	594	330	466		630	924	567	761
MOR	621	192	259	300	755	630		960	637	797
MWZ	787	1152	701	965	1420	924	960		357	163
TBR	661	829	378	642	1033	567	637	357		194
SHY	624	989	538	802	1257	761	797	163	194	

Source: TANROADS distance chart, March 2017.

4.3 Price transmission

The results for ECM tests (Appendix 3) show that nineteen (19) out of sixty-four (64) tests between the commodities considered failed to reject the presence of short-run transmission of price shocks. Forty-five (45) tests rejected the presence of short-run price transmission between the two commodities at the specified lag length (3). With respect to long-run elasticity of price transmission, fifty-five (55) tests out of 64 failed to reject the presence of long-run price transmission between the two commodities. The discussion on this phenomenon is exemplified by selected cases where price shocks or changes in the price of the two commodities affect each other: The elasticity of price transmission between rice in Shinyanga and maize in Dar es Salaam was found to be 73%. The elasticity of price transmission between rice in Dar es Salaam and maize in Dodoma was 100%. The implication is that over time, 73% of the shocks or changes in rice prices in Shinyanga were transmitted to maize prices in Dar es Salaam. Similarly, all (100%) shocks or changes in rice prices in Dar es Salaam were transmitted to maize prices in Dodoma. The long-run elasticity of price transmission from maize in Shinyanga to rice in Dar es Salaam was 84% while that of maize in Dar es Salaam to rice in Shinyanga was 100%. The implication is that over time, 84% of the shocks or changes in maize prices in Shinyanga were transmitted to rice prices in Dar es Salaam. Similarly, all shocks or changes in maize prices in Dar es Salaam were transmitted to rice prices in Shinyanga.

In general, a period of three months is not long enough for effective transmission of price shocks or changes between maize and rice to occur (Appendix 3). Conversely, findings show that price shocks or changes do pass between the considered commodities in the long-run. Therefore, prices of maize and rice may independently drift apart in the short-run but tend to affect each in the long-run. These findings are consistent with findings from similar studies (Rashid, 2011; Minot, 2011).

The observed markets integration for the considered commodities is presumably a result of the improvements in transportation infrastructure which have occurred over time in Tanzania. These improvements are likely to have promoted the flow of commodities among regions. In addition, availability of market information such as prices for major cereal crops through mobile phones is also perceived to have contributed to the observed price transmission in the long-run period. Information on price differentials between the markets can potentially incentivize traders to venture into inter-regional maize and rice trade where prospects to realize positive margins exist.

4.4 Granger causality

Findings (Appendix 3) show that eight (8) causality tests out of sixty-four (64) suggest a unidirectional causality (leader-follower relationship). In addition, five (5) out of these eight (8) tests indicated that maize prices granger caused rice prices while three (3) tests showed that rice prices granger caused maize prices. The remaining (56) tests suggested presence of bidirectional causality.

Moreover, results indicate that the average long-run elasticity of price transmission from maize to rice and rice to maize are 94.1% and 92.5%, respectively. Therefore, price shocks or changes in either of the two commodities do pass from one another. However, it is important to note that shocks to or changes in maize prices have relatively higher impact on rice prices because the mean value of long-run price transmission from maize to rice (94.1%) is higher than mean value of long-run price transmission from rice to maize (92.5%) implying higher influence of maize prices on rice prices.

The results indicate that eight (8) out of sixty-four (64) tests for the speed of adjustment were insignificant (Appendix 3). It is important to note that for all significant cases, the coefficient of error correction term (ECT) was negative. This suggests that price differential between the substitutable commodities during preceding periods acted as a significant force to make the price series return to their long-run stable conditions whenever they deviated from each other. Specifically, the values of ECT for maize prices as a result of changes in rice prices ranged between 5% and 17%. Similarly, the values of ECT for rice as a result of changes in maize prices ranged between 5% and 20%. Thus, the average speed of adjustment of maize prices as a result of changes in rice prices is 11% while the average speed of adjustment of rice prices as a result of changes in maize prices is 8%. This implies that on average 11% and 8% of the deviation in maize and rice prices are corrected each month, respectively.

5.0 CONCLUSION AND RECOMMENDATIONS

The study found that there was a short-run price integration between rice and maize except where markets were more isolated in terms of travel distance. This situation might also be attributed to interventions such as banning inter-regional or inter-district commodity trade. However, the co-integration tests revealed that prices of the two commodities considered were co-integrated in the long-run.

The findings also revealed that few market pairs experienced short-run price transmission although price shocks between the two commodities in several markets were transmitted to each other in the long-run. The average long-run price transmission rate from rice to maize is 92.5% and from maize to rice is 94.1%. These findings conform with the view that related goods such as substitutes are expected to exhibit significant price transmission if markets are working properly.

Bidirectional causality was mainly observed in many cases than unidirectional. The values for long-run elasticity of price transmission and ECT in many cases were significant suggesting causality between prices of maize and rice. Specifically, ECT bear negative sign in all cases implying that it acted as a force which corrected disequilibria when prices deviated from their long-run equilibria.

Certainly a continued effort by government and key stakeholders in the agricultural sector to improve the transportation infrastructure should ease inter-regional flow of commodities in Tanzania and facilitate the price transmission mechanisms. Similar efforts to improve the dissemination of market information through means such as promoting the adoption and use of mobile-phone and market information are ideal in promoting inter-regional trade and stabilizing prices of related tradeable commodities.

REFERENCES

Abdulai, A. (2007). Spatial and vertical price transmission in food staples market chains in Eastern and Southern Africa: What is the evidence? *Paper Presented at the Trade and Markets Division Workshop on Staple Food Trade and Market Policy Options for Promoting Development in Eastern and Southern Africa*. Rome, 1 – 2 March, 2007. pp. 1 – 33.

Alexander, C. and Wyeth, J. (1994). Co-integration and market integration: An application to the Indonesian rice market. *Journal of Development Studies* 2(30): 303 – 328.

Arshad, F. M. and Hameed, A. A.. (2009). The long run relationship between petroleum and cereals prices. *Global Economy and Finance Journal* 2(2): 91 – 100.

Ashimogo, G. and Mbiha, E. (2007). Impact of market liberalization on integration of grain markets in Tanzania. *Eastern and Southern Africa Journal of Agricultural Economics and Development* 4(2): 114 – 125.

Badiane, O. (1997). *Market Integration and the Long-Run Adjustment of Local Markets to Changes in Trade and Exchange Rate Regimes: Options for Market Reform and Promotion Policies*. Discussion Paper No. 11. International Food Policy Research Institute, Washington DC. 55pp.

Barrett, C. B. (1996). Market analysis methods: Are our enriched toolkits well suited to enlivened markets?" *American Journal of Agricultural Economics* 78: 825 – 829.

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

Baulch, B. (1997). Testing for food market integration revisited. *Journal of Development Studies* 33: 477 – 487.

Boyd, M. and Brorsen, B. W. (1986). Dynamic price relationships for US and EC corn gluten feed related markets. *European Review of Agricultural Economics* 13: 199 – 215.

Chirwa, E. W. (1999). Food marketing Reforms and Integration of maize and rice market in Malawi: Zomba, Malawi. Wadonda Consult.

Chirwa, E. W. (2001). Liberalization of Food Marketing and Market Integration in Malawi, Final Report submitted the African Economic Research Consortium, Nairobi, Kenya.

Conforti, P. (2004). Price transmission in selected agricultural markets. FAO commodity and trade policy research working paper 7.

Delgado, C.L. (1986). A variance components approach to food grain market integration in Northern Nigeria. *American Journal of Agricultural Economics* 68: 970 – 979.

Dickey, D. A. and Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica* 49: 1057 – 1072.

Dercon, S. (1995). On market integration and liberalization: Method and application to Ethiopia. *Journal of Development Studies* 32 (1): 112–143.

Enders, W. (1995). *Applied Econometric Time Series.* John Wiley and Sons Inc., New York. 433pp.

Fackler, P. and Tastan, H. (2008). Estimating the degree of market integration. North Carolina State University. *Journal of Agricultural Economics* 90(1): 69 – 85.

Familow, M. D. and Benson, B. L. (1990).Integration of spatial markets. *American Journal of Agricultural Economics* 72(1): 49 – 62.

FAO (2009). Food balance sheet.[http://faostat.fao.org/site/368/default.aspx#ancor] site visited on 20/6/2017.

Gabagambi, D. M. (1998). Evaluation of agricultural marketing efficiency in Tanzania: A case study of paddy and Cotton in Ulanga District. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 136pp.

Gardner, B. and Brooks, K. M. (1994). Food prices and market integration in Russia. *American Journal of Agricultural Economics* 76: 641 – 646.

Getnet, K., Verbeke, W. and Viaene, J. (2005). Modeling spatial price transmission in the grain markets of Ethiopia with an application of ARDL approach to white teff. *Agricultural Economics* 33: 491-502.

Goletti, F. and Babu, S. (1994). Market liberalization and integration of maize markets in Malawi. Agricultural Economics 11, (2-3), 311-324.

Guvheya, G., Mabaya, E. and Christy, D. R. (1998)."Horticultural marketing in Zimbabwe": margins, price transmission and spatial market integration. Staff Paper. New York, Ithaca, U.S.A: Department of Agricultural, Resource, and Managerial Economics, Cornell University.

Groom, B. and Tak, M. (2015). Welfare analysis of changing food prices: a nonparametric examination of rice policies in India. *Food Security*, 7 (1), 121-141.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37: 424 – 438.

Huyghebaert, N and Wang, L. (2010). The co-movement of stock markets in East Asia: Did the 1997–1998 Asian financial crisis really strengthen stock market integration? *China Economic Review* 21 (1): 98-112.

Kaminski, J., Christiaensen, L and Gilbert, C. L. (2016). Seasonality in local food markets and consumption: evidence from Tanzania. *Oxford Economic Papers* 68 (3): 736-757.

Kilima, F. T. M. (2006). *Are Prices in The World Market Transmitted to Markets in Less Developed Countries? A Case Study of Sugar, Cotton, Wheat, and Rice in Tanzania*. Discussion Paper No. 160. Institute for International Integration, Dublin. 34pp.

Kilima, F. T., Chung, C., Kenkel, P and Mbiha, E. R. (2008). Impacts of market reform on spatial volatility of maize prices in Tanzania. *Journal of Agricultural Economics*, 59 (2), 257-270.

Lundahl, M. and Petersson, E. (1983). Price series correlation and market integration: Some evidence from Haiti. *Nordic Journal of Latin American Studies*, 13 (1): 61-76.

Loy, J and Wichern, R. (2000). Integration of Zambian Maize Markets. Quarterly, *Journal of International Agriculture*. 39. 173-198.

Minot, N. (2010). Staple food prices in Tanzania. *A Paper Presented at the COMESA Policy Seminar on Variation in Staple Food Prices: Causes, Consequences, and Policy Options*. Maputo, Mozambique, 25 – 26 January, 2010. pp. 1 – 15.

Minten, B. and Kyle, S. (1999). The effect of distance on road quality and food collection, marketing margins and traders' wages: evidence from the former Zaire. *Journal of Development Economics* 60: 467 – 495.

Minot, N. (2011). *Transmission of World Food Price Changes to Markets in Sub-Saharan Africa*. Discussion Paper No. 1059. International Food Policy Research Institute, Washington DC. 44pp.

Maro, F. and Mwaijande, F. (2014). Food Price Trend Analysis: Lessons for strengthening food policy in Tanzania. *African crop science Journal* 22 (s 4): 929-937.

Monke, E. and Petzel, T. (1984). Market Integration: An Application to International Trade in Cotton. *American Journal of Agricultural Economics* 66: 481 – 487.

Moser, C., Barrett, C. and Minten, B., (2009). Spatial integration at multiple scales: rice markets in Madagascar. *The Journal of International Association of Agricultural Economists* 40 (3): 281-294.

Mundlak, Y. and Larson, D. F. (1992). On the transmission of world agricultural prices. *World Bank Economic Review* 6: 399 – 422.

Natanelov, V., Alam, M. J., McKenzie, A. M and Van Huylenbroeck, G. (2011). Is there co-movement of agricultural commodities futures prices and crude oil. *Energy Policy 39* (9), 4971-4984.

Negassa, A. and Jayne, S. (1998). Vertical and spatial integration of grain markets in Ethiopia. Implications for grain market and food security policies.

Negassa, A. and Meyers, R. (2007). "Estimating Policy Effects on Spatial Market Efficiency: An Extension of the Parity Bound Model". *American Journal of Agricultural Economics* 89(2): 380-352.

NBS (2006). *Results of the 2002-03 National Agricultural Sample Census: National Bureau of Statistics.* Ministry of Agriculture and Food Security, Ministry of Cooperatives and Marketing, and Ministry of Livestock, Zanzibar. 371pp.

Nyange, D. A. (1999). Estimation of Inter-regional Maize Market Integration in Tanzania and its Determinants. *Journal of Rural Problem,s* 135: 59 – 71.

Nyange, D. and Wobst, P. (2005). Effects of strategic grain reserve, trade and regional production on maize price volatility in Tanzania. [http://www.pasad.uni-bonn.de] site visited on 10/7/2017.

Onya, R. and Ajutu, E. (2006). Modelling International commodity price transmission to domestic prices of commodities exported by Uganda. [http://www.ubos .org/publications/agriculture] site visited on 20/10/2016.

Palaskas, T. B. (1995). Statistical analysis of price transmission in the European Union. *Journal of Agricultural Economics*46: 60 – 69.

Prakash, A. B. (1999). The transmission of signals in a decentralised commodity marketing system: The Case of the UK Pork Market. Thesis for Award of PhD Degree at Wye College, University of London, 189pp.

Prakash, A., Oliver, E and Balcombe K. (2001). Does Building Roads Really Create Traffic: Some New Evidence. *Applied Economics* 33: 1579-85.

Rapsomanikis, G., Hallam, D. and Conforti, P. (2003). *Market Integration and Price Transmission in Selected Food and Cash Crop Markets in Developing Countries: Review and Applications.* Commodity Market Review No. 04. Food and Agriculture Organization, Rome. 120pp.

Rashid, S. (2004). Spatial Integration of Maize Markets in Post-Liberalized Uganda. *Journal of African Economies* 13. 102-133.

Rashid, S. (2011). Intercommodity Price Transmission and Food Price Policies: An Analysis of Ethiopian Cereal Markets. Discussion Paper No. 1079. International Food Policy Research Institute, Washington DC.17pp.

Ravallion, M. (1986). Testing market integration. *American Journal of Agricultural Economics* 68: 102 – 109.

Sexton, R. J., Kling, C.L. and Carman, H. F. (1991). Market integration, efficiency of arbitrage, and imperfect competition: Methodology and Application to US. Celery. *American Journal of Agricultural Economics* 73(3): 568 – 580.

Timmer, C. P. (1989). *Agricultural Prices and Stabilization Policy*. Discussion Paper No. 290. Harvard Institute for International Development, Cambridge, USA. 38pp.

Tostão, E. and Brorsen, W., (2005). Spatial Efficiency in Mozambique's Post-Reform Maize Markets. *Agricultural Economics* 33. 205-214.

Traub, L. and Jayne, T. (2006). The Effects of Market Reform on Maize Marketing Margins in South Africa: An Empirical Study.

Trotter, B. (1992). *Applying Price Analysis to Marketing Systems: Methods and Examples from the Indonesian Rice Market.* Marketing Series No. 3. Natural Resources Institute, Chatham. 60pp.

Wenban-Smith, H., Fasse, A and Grote, U. (2016). Food security in Tanzania: the challenge of rapid urbanisation. *Food security*, 8 (5): 973-984.

Zakari, S., Ying, L and Song, B. (2014). Market integration and spatial price transmission in Niger grain markets. *African Development Review* 26 (2): 264-273.

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

Vol. 1, Issue 1, 2018 *ISSN 0856-9037*

Appendix 1: Summary of empirical studies on spatial and vertical price transmission in food markets in Eastern and Southern Africa

Transmission	Author	Year	Country	Commodity	Period of time	Approach
	Goletti and Babu	1994	Malawi	Maize	01/1984 to 12/1991	Cointegration/causality
	Dercon	1995	Ethiopia	Teff	07/1987 to 09/1993	Cointegration/causality
	Chirwa	1999	Malawi	Maize and rice	1989 to 1998	Cointegration/VAR
	Chirwa	2001	Malawi	Maize/rice/beans/groundnuts	1989 to 1998	Cointegration/ causality
	Loy and Wichern	2000	Zambia and Malawi	Maize	01/1994 to 06/1998	Cointegration/causality
	Rashid	2004	Uganda	Maize	1993 to 1994 and 1999 to 2001	Cointegration/causality
	Tostao and Brorsen	2005	Mozambique	Maize	1994 to 2001	PBM/causality
	Negassa and Myers	2007	Ethiopia	Maize and wheat	08/1996 to 08/2002	PBM
	Moser et al.	2006	Madagascar	Rice	2000 to 2001	PBM
	Van Campenhout	2007	Tanzania	Maize	1989 to 2000	TAR
	Conforti	2004	Egypt/Ethiopia	Food and cash crops	Egypt: 01/1969- 05/2001 Ethiopia: 09/1993-05/2001	Cointegration/causality
VERTICAL	Guvheya et al.	1998	Zimbabwe	Tomatoes	1996	Causality/Houck
	Negassa	1998	Ethiopia	Grain	08/1996 to 08/1997	Correlation coefficient/causality
	Traub and Jayne	2004	South Africa	Maize	05/1976 to 09/2003	OLS/Generalised Least Squares
	Minten and Kyle	2000	Zaire	Food	1987-1989	SURE/Houck
	Getnet et al.	2005	Ethiopia	White teff	01/1996 to 12/2000	Cointegration/ARDL
ACROSS COUNTRIES	Rapsomanikis et al.	2006	Ethiopia/Rwanda/ Uganda	Coffee	01/1990 to 12/2001	Cointegration/causality
	Baffes and Gardner	2003	Madagascar	Coffee/rice/sugar	1970-1991	Cointegration/error correction
	Kilima	2006	Tanzania	Sugar/cotton/wheat/rice	06/1994 to 06/2005	Cointegration/causality

Note: ARDL refers to autoregressive distributed lag modeling. PBM refers to parity bounds model. SURE is used to denote seemingly unrelated regression estimation.

Source: Abdulai (2007)

Vol. 1, Issue 1, 2018 *ISSN 0856-9037*

Appendix 2: Characteristics of methods for analyzing market integration

	Analytical methods					
Characteristics	**Correlation analysis**	**Regression analysis without lags**	**Regression analysis with lags**	**Co-integration analysis**	**Parity bounds method (PBM)**	**Threshold auto regression (TAR)**
Measures co-movement of prices	Yes, but biased for non-stationary variables	Yes, but biased for non-stationary variables	Yes, but biased for non-stationary variables	Yes	Yes	Yes
Can include more than two markets	No	Yes	Yes	Yes	No	No
Can measure speed of adjustment	No	No	Yes	Yes	Only indirectly	Yes
Takes into account transfer costs	No	No	No	No	Yes	Yes
Can identify market inefficiency and causes	No	No	No	No	No, unless transfer costs are available	No, unless transfer costs are available

Source: Rashid *et al.* (2010)

Vol. 1, Issue 1, 2018 *ISSN 0856-9037*

Appendix 3: Results of price transmission and granger causality (GC) tests based on error correction model (ECM)

Market channel	Dependent variable	Independent variable	Speed of adjustment (%)	Short-run adjustment	Long-run adjustment (%)	Causal reference (Long-run)
MOR-DSM	$\Delta P_t^{Moro(M)}$	$\Delta P_t^{DSM(R)}$	14.7*	N/E	100*	$P_t^{Moro(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Moro(M)}$	7.8*	E*	93.8*	
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Moro(R)}$	14.1*	E*	87.3*	$P_t^{Moro(R)} \rightarrow P_t^{DSM(M)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{DSM(M)}$	5 (NS)	E***	100(NS)	
Iringa-DSM	$\Delta P_t^{Iringa(M)}$	$\Delta P_t^{DSM(R)}$	14.1*	N/E	97.3*	$P_t^{Iringa(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Iringa(M)}$	4.7***	N/E	92.2	
	$\Delta P_t^{Iringa(R)}$	$\Delta P_t^{DSM(M)}$	3.3 (NS)	N/E	100 (NS)	$P_t^{Iringa(R)} \rightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Iringa(R)}$	17.3*	N/E	88.1*	
Mbeya-DSM	$\Delta P_t^{Mbeya(M)}$	$\Delta P_t^{DSM(R)}$	8.8*	N/E	100*	$P_t^{Mbeya(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Mbeya(M)}$	8*	E**	87*	
	$\Delta P_t^{Mbeya(R)}$	$\Delta P_t^{DSM(M)}$	4.6***	E**	100***	$P_t^{Mbeya(R)} \leftrightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Mbeya(R)}$	13.5*	N/E	86.4*	
Arusha-DSM	$\Delta P_t^{Arusha(M)}$	$\Delta P_t^{DSM(R)}$	12.1*	N/E	100*	$P_t^{Arusha(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Arusha(M)}$	7.8*	N/E	89.9*	
	$\Delta P_t^{Arusha(R)}$	$\Delta P_t^{DSM(M)}$	4.1***	N/E	100***	$P_t^{Arusha(R)} \leftrightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Arusha(R)}$	16*	N/E	89.1*	

Appendix 3 continues

Market channel	Dependent variable	Independent variable	Speed of adjustment (%)	Short-run adjustment	Long-run adjustment (%)	Causal reference (Long-run)
Iringa-MOR	$\Delta P_t^{Iringa(M)}$	$\Delta P_t^{Moro(R)}$	11.9*	N/E	92.8*	$P_t^{Iringa(M)} \leftarrow P_t^{Moro(R)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{Iringa(M)}$	3.3 (NS)	E**	94.5*	
	$\Delta P_t^{Iringa(R)}$	$\Delta P_t^{Moro(M)}$	4.6***	N/E	98.7*	$P_t^{Iringa(R)} \leftrightarrow P_t^{Moro(M)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{Iringa(R)}$	15.2*	N/E	96.6*	
Mbeya-MOR	$\Delta P_t^{Mbeya(M)}$	$\Delta P_t^{Moro(R)}$	7.8*	E*	100*	$P_t^{Mbeya(M)} \leftrightarrow P_t^{Moro(R)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{Mbeya(M)}$	7.1*	E*	91.5*	
	$\Delta P_t^{Mbeya(R)}$	$\Delta P_t^{Moro(M)}$	5**	E***	100**	$P_t^{Mbeya(R)} \leftrightarrow P_t^{Moro(M)}$
	$\Delta P_t^{Moro(M)}$	$\Delta P_t^{Mbeya(R)}$	10.9*	N/E	95.7*	
Tabora-MWZ	$\Delta P_t^{Tabora(M)}$	$\Delta P_t^{Mwanza(R)}$	5.7***	N/E	96.4*	$P_t^{Tabora(M)} \leftrightarrow P_t^{Mwanza(R)}$
	$\Delta P_t^{Mwanza(R)}$	$\Delta P_t^{Tabora(M)}$	8.4*	N/E	96.5*	
	$\Delta P_t^{Tabora(R)}$	$\Delta P_t^{Mwanza(M)}$	19.7*	E***	89.9*	$P_t^{Tabora(R)} \leftarrow P_t^{Mwanza(M)}$
	$\Delta P_t^{Mwanza(R)}$	$P_t^{Tabora(R)}$	2.7(NS)	N/E	79.5*	
Arusha-MWZ	$\Delta P_t^{Arusha(M)}$	$\Delta P_t^{Mwanza(R)}$	4.4(NS)	N/E	86.3*	$P_t^{Arusha(M)} \rightarrow P_t^{Mwanza(R)}$
	$\Delta P_t^{Mwanza(R)}$	$\Delta P_t^{Arusha(M)}$	14.4*	N/E	100*	
	$\Delta P_t^{Arusha(R)}$	$\Delta P_t^{Mwanza(M)}$	8.9*	E**	87.8*	$P_t^{Arusha(R)} \leftrightarrow P_t^{Mwanza(M)}$
	$\Delta P_t^{Mwanza(M)}$	$\Delta P_t^{Arusha(R)}$	14.8*	N/E	100*	

Vol. 1, Issue 1, 2018 *ISSN 0856-9037*

Appendix 3 continues

Market channel	Dependent variable	Independent variable	Speed of adjustment (%)	Short-run adjustment	Long-run adjustment (%)	Causal reference (Long-run)
Mbeya-MWZ	$\Delta P_t^{Mbeya(M)}$	$\Delta P_t^{Mwanza(R)}$	2.7(NS)	N/E	86.8*	$P_t^{Mbeya(M)} \rightarrow P_t^{Mwanza(R)}$
	$\Delta P_t^{Mwanza(R)}$	$\Delta P_t^{Mbeya(M)}$	9.4*	E**	97.4*	
	$\Delta P_t^{Mbeya(R)}$	$\Delta P_t^{Mwanza(M)}$	9.1*	N/E	93*	$P_t^{Mbeya(R)} \leftrightarrow P_t^{Mwanza(M)}$
	$\Delta P_t^{Mwanza(M)}$	$\Delta P_t^{Mbeya(R)}$	9.7*	N/E	100*	
Mbeya-Tabora	$\Delta P_t^{Mbeya(M)}$	$\Delta P_t^{Tabora(R)}$	2.2 (NS)	N/E	78.5*	$P_t^{Mbeya(M)} \rightarrow P_t^{Tabora(R)}$
	$\Delta P_t^{Tabora(R)}$	$\Delta P_t^{Mbeya(M)}$	11.4*	N/E	92.1*	
	$\Delta P_t^{Mbeya(R)}$	$\Delta P_t^{Tabora(M)}$	5.2**	N/E	96.6*	$P_t^{Mbeya(R)} \leftrightarrow P_t^{Tabora(M)}$
	$\Delta P_t^{Tabora(M)}$	$\Delta P_t^{Mbeya(R)}$	9.1**	N/E	100*	
Tabora-DSM	$\Delta P_t^{Tabora(M)}$	$\Delta P_t^{DSM(R)}$	9.4**	N/E	100*	$P_t^{Tabora(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Tabora(M)}$	5.4**	E***	84.5*	
	$\Delta P_t^{Tabora(R)}$	$\Delta P_t^{DSM(M)}$	11.8*	N/E	100*	$P_t^{Tabora(R)} \leftrightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Tabora(R)}$	7.9*	E**	80.1*	
Tabora-MOR	$\Delta P_t^{Tabora(M)}$	$\Delta P_t^{Moro(R)}$	11.3*	N/E	100*	$P_t^{Tabora(M)} \leftrightarrow P_t^{Moro(R)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{Tabora(M)}$	5.7**	E**	88.7*	
	$\Delta P_t^{Tabora(R)}$	$\Delta P_t^{Moro(M)}$	12.4*	N/E	100*	$P_t^{Tabora(R)} \leftrightarrow P_t^{Moro(M)}$
	$\Delta P_t^{Moro(M)}$	$\Delta P_t^{Tabora(R)}$	5.7***	N/E	86.3*	

Vol. 1, Issue 1, 2018 ISSN 0856-9037

Appendix 3 continues

Market channel	Dependent variable	Independent variable	Speed of adjustment (%)	Short-run adjustment	Long-run adjustment (%)	Causal reference (Long-run)
Dodoma-DSM	$\Delta P_t^{Dodoma(M)}$	$\Delta P_t^{DSM(R)}$	12.5*	N/E	100*	$P_t^{Dodoma(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{Dodoma(M)}$	7.7*	E**	84.5*	
	$\Delta P_t^{Dodoma(R)}$	$\Delta P_t^{DSM(M)}$	4.5***	N/E	100*	$P_t^{Dodoma(R)} \leftrightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{Dodoma(R)}$	12.7*	E*	79.5*	
Dodoma-MOR	$\Delta P_t^{Dodoma(M)}$	$\Delta P_t^{Moro(R)}$	12.6*	N/E	100*	$P_t^{Dodoma(M)} \leftrightarrow P_t^{Moro(R)}$
	$\Delta P_t^{Moro(R)}$	$\Delta P_t^{Dodoma(M)}$	8.3**	N/E	88.3*	
	$\Delta P_t^{Dodoma(R)}$	$\Delta P_t^{Moro(M)}$	7.1*	N/E	100*	$P_t^{Dodoma(R)} \leftrightarrow P_t^{Moro(M)}$
	$\Delta P_t^{Moro(M)}$	$\Delta P_t^{Dodoma(R)}$	9.9**	N/E	86.4*	
Dodoma-Mwz	$\Delta P_t^{Dodoma(M)}$	$\Delta P_t^{Mwanza(R)}$	4.4(NS)	N/E	95.9*	$P_t^{Dodoma(M)} \rightarrow P_t^{Mwanza(R)}$
	$\Delta P_t^{Mwanza(R)}$	$\Delta P_t^{Dodoma(M)}$	10.8*	N/E	94.2*	
	$\Delta P_t^{Dodoma(R)}$	$\Delta P_t^{Mwanza(M)}$	10.6*	N/E	98.6*	$P_t^{Dodoma(R)} \leftrightarrow P_t^{Mwanza(M)}$
	$\Delta P_t^{Mwanza(M)}$	$\Delta P_t^{Dodoma(R)}$	9.2**	E***	98.8*	
SHY-DSM	$\Delta P_t^{SHY(M)}$	$\Delta P_t^{DSM(R)}$	8.7*	E***	100*	$P_t^{SHY(M)} \leftrightarrow P_t^{DSM(R)}$
	$\Delta P_t^{DSM(R)}$	$\Delta P_t^{SHY(M)}$	5.7**	N/E	84.4*	
	$\Delta P_t^{SHY(R)}$	$\Delta P_t^{DSM(M)}$	8*	N/E	100*	$P_t^{SHY(R)} \leftrightarrow P_t^{DSM(M)}$
	$\Delta P_t^{DSM(M)}$	$\Delta P_t^{SHY(R)}$	7.8*	N/E	72.7*	

Note: *, ** and *** implies significant at 1%, 5% and 10% respectively. E implies that short-run adjustment exists, N/E and NS imply that short-run adjustment does not exist and not significant, respectively.