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Cointegration and spatial price transmission among rice markets in Tanzania: implications for price stabilisation policies

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ABSTRACT

In an effort to increase agricultural production, promote regional specialization and stabilize domestic food prices, the Tanzanian government has implemented several market-enhancing policies. The success of these measures depends, among other factors, on the cointegration and degree of price transmission across spatial markets. This study uses the vector autoregressive procedure of the Toda-Yamamoto causality test, dynamic ordinary least squares cointegration tests, and the asymmetric error correction model to examine the performance of Tanzania's domestic wholesale rice markets (lead-lag price relationship and long-run price adjustment process) during the post-agricultural market liberalization period. In response to changes in the marketing-enhancing policies during the investigation period, the presence of multiple structural breaks in the long-run equation is allowed. The results show that the Dar es Salaam market influences prices in all the rice markets examined, thus acting as a price leader. Furthermore, the price adjustment process results demonstrated the absence of asymmetric price adjustment between the central and regional wholesale rice markets, suggesting improved integration and efficiency of inter-regional rice markets. On the other hand, a central market's presence implies that interventions aimed at the central market can buffer regional markets to withstand adverse price shocks caused by food price spikes and volatility.

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1. Introduction

The study of price transmission, and its corresponding effect on trade margins, is a subject that has aroused great interest among agricultural economists and has motivated various studies in the field (Abdulai 2000; Alemu and Ogundeji 2010; Keho and Camara 2012; Hassanzoy et al. 2017). Prices act as mechanisms to link the different parts of the supply chain; in other words, it "regulates" trade flows. Therefore, the extent to which prices are transmitted provides important information for assessing the efficiency of agricultural commodity markets (Tekgüç 2013; von Cramon-Taubadel 2017). In other words, it is the ability of prices to adapt to changes in supply and demand conditions that enable the market to function effectively (Ongutade and Folayan 2006).

An efficient market is generally characterised by a rapid and symmetrical price reaction to an unexpected shock on one of the chain's links (Dawe 2009). The prices between the different marketing levels reflect the costs associated with the final product's processing and marketing (Brosig et al.

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2011). When markets are efficient, farmers can allocate resources according to their comparative advantage and increase their production (Fafchamps et al. 2005; Panda and Sreekumar 2012). Efficient markets also allow consumers to obtain products at reasonable prices (Panda and Sreekumar 2012). Thus, efficient markets are an important means of increasing farmers' income, consumers' well-being and promoting economic development (Gedara, Ratnasiri, and Bandara 2015). One of the drawbacks that arise is that of asymmetries in the transmission of prices. This phenomenon leads to price increases being transmitted differently from decreases, increasing or decreasing the margin between the price paid by consumers and producers' price. According to Meyer and Von Cramon-Taubadel (2004), asymmetry in price transmission indicates uncompetitive market structures, which can affect the allocation of resources and lead to a loss of economic efficiency.

In Tanzania, efficient food markets can play an important role in bridging the consumption gap caused by a structural deficiency in major grains production. Indeed, efficient markets would improve food distribution from surplus areas to deficit areas. The Tanzanian government has undertaken several necessary reforms to improve the agricultural marketing system's efficiency as part of structural adjustment programmes that began in the mid-1980s and early 1990s. These reforms included removing controls on agricultural product marketing, which aimed to pave the way for private traders' participation in a competitive marketing environment. Previously, the government was involved in the pricing and distribution of staple foods (Cooksey 2003). However, studies have shown that these policies' expected benefits have not been fully realised, especially for food crops (Kadigi 2003; Ashimogo and Mbiha 2007; Kilima et al. 2008). Most agricultural commodity markets remain very volatile, and there is no orderly marketing system for crops (Kaminski, Christiaensen, and Gilbert 2016). On the other hand, there is evidence of unfair pricing by traders and a wide range of food market prices (Kilima et al. 2008; Achandi and Mujawamariya 2016). Additionally, factors such as transaction costs, geographic proximity, inadequate infrastructure, government intervention, information asymmetry, market power, menu costs, and inventory-keeping behaviour may lead to asymmetric price adjustment in the context of Tanzania. The policy reforms aimed at stabilising domestic food prices during and after the global food crises of 2008 and 2011 are also expected to change the properties of rice prices. Therefore, an understanding of the dynamics of price transmission is essential to improve the functioning of rice markets, enable more efficient pricing policies, and respond to market distortions that are at the core of the National Rice Development Strategy (NRDS) and economic development policies of Tanzania.

In this context, this study aims to analyse the spatial efficiency of rice markets in Tanzania. In particular, the lead-lag price relationship and the long-term price adjustment process in the wholesale rice markets during the period after the liberalisation of the agricultural market from January 2005 to December 2019, taking into account the effect of policy reforms during the period of investigation in the form of structural breaks. Not enough empirical evidence has been identified on the country's food markets' spatial integration despite its importance for the agriculture sector development. The rest of the document is structured as follows: Part 2 provides an overview of Tanzania's rice production, consumption, and marketing system. The third part reviews the related literature and presents empirical evidence. Part 4 briefly presents the estimation strategy used in this article. Part 5 illustrates the results. Part 6 offers conclusions and recommendations.

2. An overview of rice production, consumption, and trade in Tanzania

Rice production is a critical area of food security in Tanzania, and food security is a major concern of the Tanzanian government (Wilson and Lewis 2015). Although rice production increases every year, poor transport and communication infrastructure in rural areas, the complexity of marketing channels, insufficient access to low-cost credit, poor access/use of technology, and trade barriers pose serious threats to rice production in Tanzania (Nkuba et al. 2016). Rice is consumed throughout Tanzania, although its main production areas are north, south, and east-central of the country, particularly in Morogoro, Mbeya, and Shinyanga regions. Tanzania ranks second after Madagascar within

Eastern, Central, and Southern Africa in rice production and consumption, with a per capita consumption of 36.9 kg/year (USDA 2019). Rice accounts for nearly 19.5% of the country's annual cereal production (URT 2017a). Smallholder farmers produce around 90 per cent under continuous flooding with average farm size and yield of 1.3 hectares and 2.5tonnes/ha, respectively. More than 1.6 Million operators are engaged in rice production in Tanzania (URT 2017c) (Figure 1).

In terms of trade, rice is the most traded food crop in Tanzania. About 70 per cent of all rice produced is traded on the domestic market, with few exports to neighbouring countries, mainly Burundi, Kenya, Rwanda, and Uganda (Wilson and Lewis 2015). Tanzania has been a net importing country for many years until an import duty of 75% was imposed in early 2006, which reduced imports from 16.5% of domestic production in 2001–2004 to 5.2% in 2005–2010 (Lazaro, Sam, and Thompson 2017). However, levels of protection have declined as the country finally achieved self-sufficiency in 2012, and it seems inevitable that it will continue on the growth path.

Two types of rice marketing systems can be identified in Tanzania (Wilson and Lewis 2015). In the smallholder marketing system, farmers sell their paddy to rural collectors or small and medium-sized millers either on the farm or in formal or informal markets. Local traders and processors assemble the products and sell paddy or processed rice to regional wholesalers. Regional wholesalers supply rice to retailers in regional markets or transport and sell rice to wholesalers in Dar es Salaam and other deficit areas. Dar-es-Salaam (DSM) is the country's marketing hub (given the nature of the transport systems, regional markets are usually linked by DSM) and the largest urban market. While on the other hand, regional markets are usually based in regional and district capitals or urban centres and sell a wide variety of food products. Large commercial farms' marketing system is somewhat different. They prefer to sell their products directly to an end-user (usually in the form of milled rice) through wholesale distributors (Figure 2). However, the majority of rice in Tanzania is grown by smallholder farmers (94 per cent) and large-scale production (6 per cent) (Wilson and Lewis 2015). Thus, rice is mainly marketed under the smallholder marketing system.

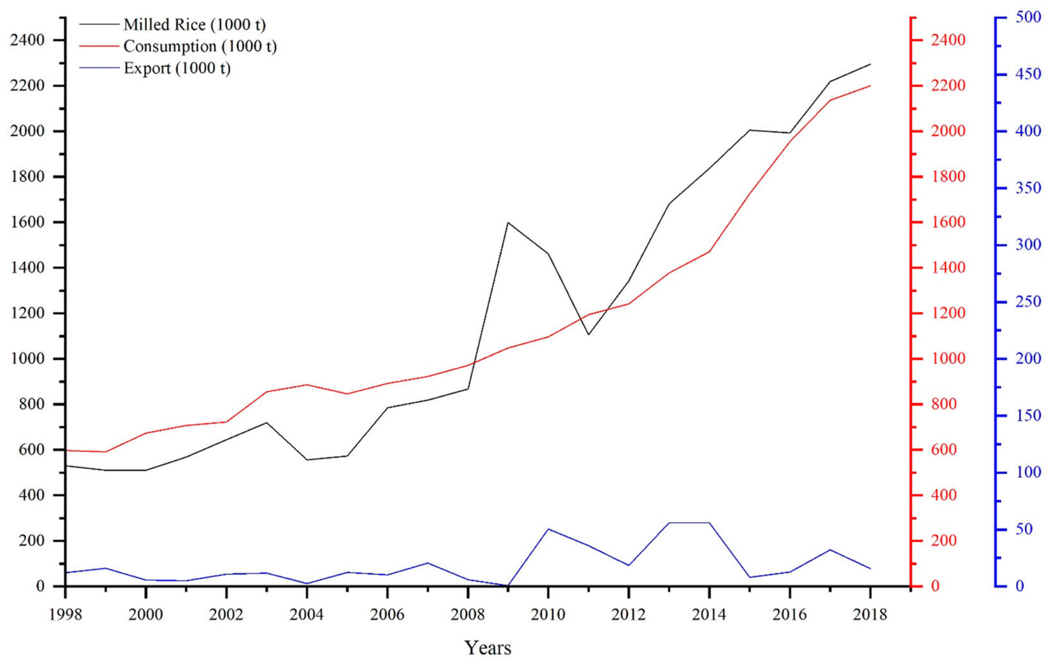

Figure 1. Milled rice production and consumption trend in Tanzania.

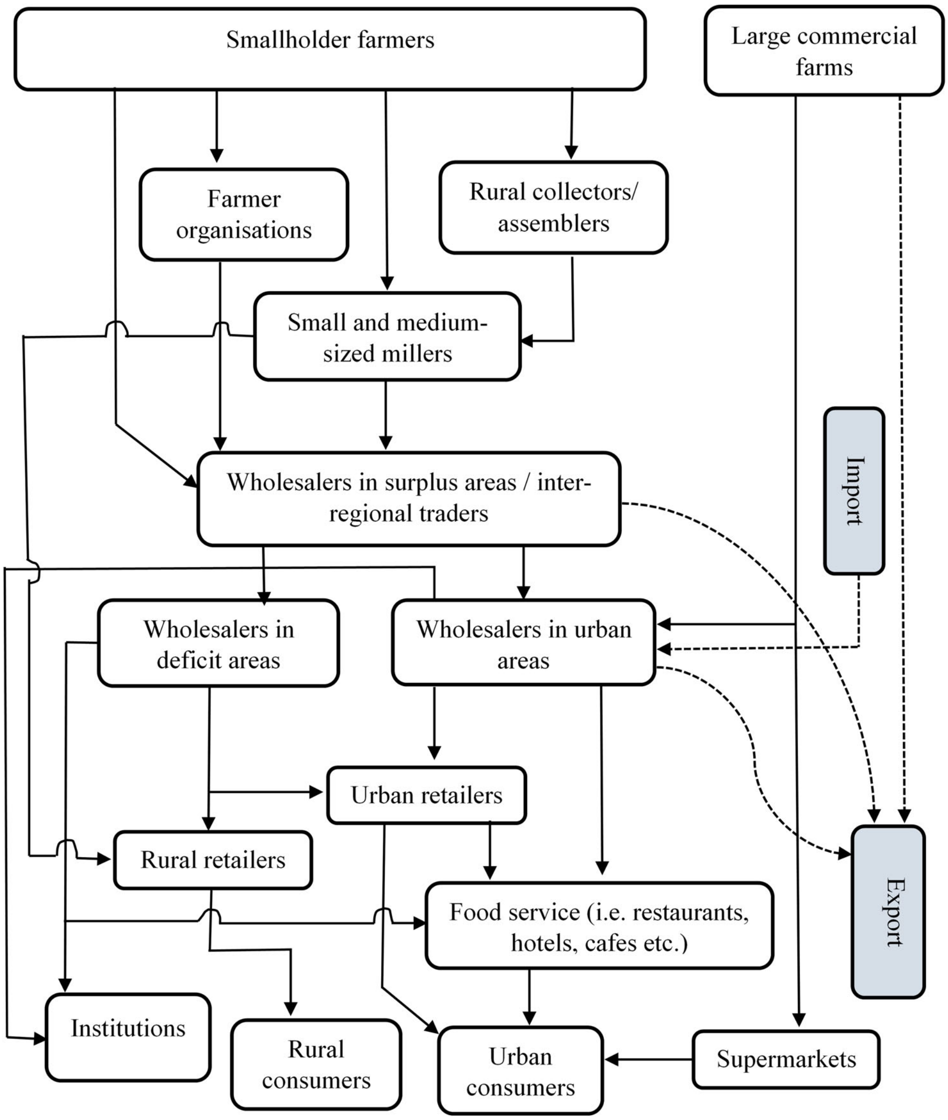

Figure 2. Paddy/rice marketing system in Tanzania.

The choice to study the Tanzanian wholesale rice market was motivated by several factors. First, wholesalers are the main actors in the rice marketing system (see Figure 2). Regional wholesalers in surplus areas supply wholesalers in Dar es Salaam or other deficit areas through brokers or intermediaries. Wholesalers in both surplus and deficit markets ensure that the product reaches the end consumer by selling it directly in open-air markets or through retail outlets in formal and informal markets. The wholesalers are also responsible for distributing rice imports to other cities in the country, which arrive mainly at Dar es Salaam port. Some wholesalers buy rice from farmers and procure a milling service from processors, after which they sell the resulting milled rice to regional wholesalers. Therefore, the pricing practices of wholesalers can affect grain market performance and grain price stabilisation policies.

Second, the Tanzanian rice market is characterised, to some extent, by numerous government regulations, although it was fully liberalised under the Structural Adjustment Programs (SAPs), which began in the mid-1980s (Kadigi 2003; Wilson and Lewis 2015). The main regulation areas are exports (export barn in times of shortage), imports (tariffs), issuance of trade licenses to rice processing industries and rice traders, etc. While some of these interventions are implemented at other market levels, most of them are implemented at the wholesale level. Therefore, understanding wholesale markets' performance is vital for monitoring government interventions' effects on agricultural markets and responding to price distortions.

3. Literature review

In literature, the relationships between markets located in different regions are often related to the integration of spatially separated markets (Barrett and Li 2002; Olipra 2020). An integrated market consists of regions that market the same product and have the same long-term information (Von Cramon-Taubadel 2017). According to Meyer (2004), market integration can be defined as the degree of price transmission between spatially separated markets. Therefore, the greater the degree of market integration, the greater the transmission of prices, encouraging producers to specialise according to the region's comparative advantages.

The literature on asymmetric price responses has mainly focused on two types of price transmission, vertical and horizontal (spatial). The transmission of prices between the different levels of the supply chain is vertical, as well as the transmission of prices from one market to another at the same position in the supply chain is spatial (Listorti and Esposti 2012). Price transmission is said to be asymmetrical if there is a difference in price response between a positive price shock (when there is a price increase) and a negative price shock (when there is a price decline) (Meyer and Von Cramon-Taubadel 2004). Suppose agents react more fully or rapidly to an increase in price than a decrease. In that case, the asymmetry is termed "positive." Correspondingly, "negative" asymmetry denotes a situation in which agents react more fully or rapidly to a decrease in price than an increase (Ghoshray 2002).

The existence of asymmetric price transmission (APT) in agricultural markets has important implications for the welfare of consumers, producers, and the implementation of agricultural policies (Hassanzoy et al. 2017; Olipra 2020). APT implies a distribution of welfare different from that obtained under symmetry (Gedara, Ratnasiri, and Bandara 2015). In particular, positive asymmetries can disrupt agricultural policies that aim to increase food production and specialisation, as they tend to influence decision-making regarding resource allocation. APT also prevents certain marketing actors from taking full advantage of the price changes in the marketing system while placing others in a position where they derive undue advantage, leading to a redistribution of welfare (Gedara, Ratnasiri, and Bandara 2015). Therefore, examining the presence of asymmetry in price transmission is essential to enable decision-makers to understand the performance of the marketing system and to make informed decisions.

Various studies have attempted to examine the presence of APTs, especially the spatial transmission of prices, with little empirical evidence in African commodity markets. While some examine the level of price transmission between the domestic and international market (Minot 2011; Abidoye and Labuschagne 2014), others focus on transmission between domestic markets (Abdulai 2000; Alemu and Ogundeji 2010; Ifejirika, Arene, and Mkpado 2013; Wondemu 2015; Yami, Meyer, and Hassan 2019), etc. These studies differ in terms of data sources, sampling period, time frequencies, specification of models used, estimation methodology, products analysed, and countries studied. Their estimates of the dynamics of price transmission are not directly comparable. The extent of price transmission is generally different from product to product and varies from country to country. However, most of these studies have shown that price increases are corrected and transmitted more quickly than price decreases (positive APT) except for Wondemu (2015) and Yami, Meyer, and Hassan (2019).

In the Tanzanian grain market context, only a few studies have attempted to address the cereal market's spatial integration (Ashimogo and Mbiha 2007; Kilima et al. 2008; Ihle and Von Cramon-Taubadel 2016; Lwesya 2016). All of these studies provide useful information on the performance of grain markets during the post-liberalisation period. However, none of these studies tested the possible presence of an asymmetric price adjustment that could induced by a particular market structure, nor took into account the effect of structural breaks. Therefore, this study is an improvement of existing knowledge.

4. Data and methods

4.1 Data

Monthly price data (quoted in Tanzanian shillings per 100 kg) from the main wholesale rice markets in Tanzania, collected from the Ministry of Industry and Trade, were used for our empirical analysis. Our data set's time series consists of 180 observations, covering the period from January 2005 to December 2019. The markets were selected based on the leading surplus producers (Mbeya, Morogoro, Shinyanga, Mwanza, and Mpanda) and main deficit markets (Dar es Salaam, Lindi, Mtwara, Dodoma, and Arusha). All price series were deflated by the Consumer Price Index (CPI) to account for inflation. The classification of rice markets as deficit and surplus is based on the FAO's[1] rice production areas and market routes map in Tanzania (Wilson and Lewis 2015) (Figure 3).

The descriptive results of the monthly rice wholesale prices are presented in Table 1. Higher average rice prices were observed in the three deficit rice markets of Lindi, Mtwara, and Arusha, while the lowest was in the surplus market of Mpanda. The coefficient of variation (CV) of rice prices reveals that the main producing markets such as Mbeya, Morogoro, Shinyanga, Mwanza, and Mpanda exhibit more price variations than other rice markets. This variation in rice prices could be attributed to rice production seasonality in the main producing regions. While there are different rice harvest periods in Tanzania, most rice is harvested from May to July. The offseason (November-December) harvest indeed weighs very little in the total harvest. Generally, prices

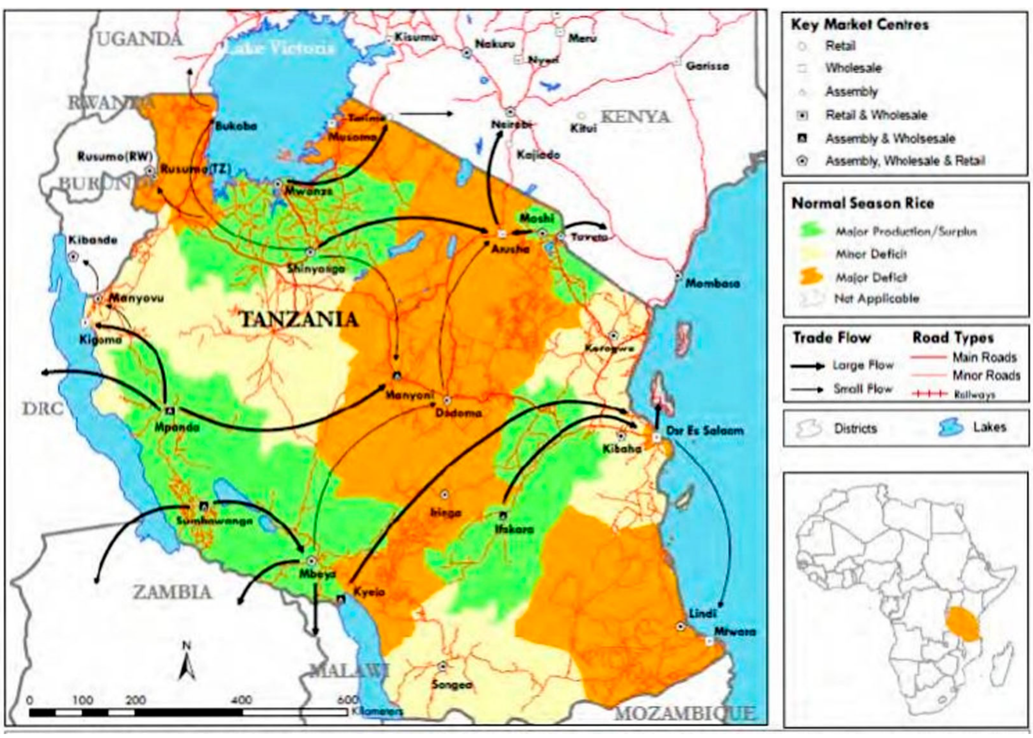

Figure 3. Rice production areas and market routes in Tanzania. Source: Adopted from Wilson and Lewis (2015).

Table 1. Descriptive results of the nominal wholesale rice market prices.[a]

Markets	Mean	Std. Dev.	Min.	Max.	CV	Obs.[b]	Driving distance from Dar[c] (km)	Type of trunk road	Market type
Dar es Salaam	124.47	46.60	46.36	210.00	0.374	180	–	–	Deficit
Mbeya	115.05	44.19	39.46	212.50	0.384	180	833	Paved	Surplus
Morogoro	116.07	43.93	38.75	200.00	0.378	180	193	Paved	Surplus
Shinyanga	109.63	44.66	35.13	191.00	0.407	180	991	Paved	Surplus
Mwanza	111.05	46.16	38.00	197.50	0.416	180	1154	Paved	Surplus
Mpanda	105.11	42.63	34.58	188.13	0.406	180	1383	Paved/unpavved	Surplus
Lindi	133.20	49.50	51.50	230.00	0.372	180	459	Paved	Deficit
Mtwara	134.73	50.03	50.75	225.00	0.371	180	558	Paved	Deficit
Dodoma	123.38	45.80	46.88	200.50	0.371	180	452	Paved	Deficit
Arusha	124.02	44.20	51.42	198.93	0.371	180	616	Paved	Deficit

[a]Price is in (1,000) Tanzanian shillings, [b]Observations, [c]Dar es Salaam.
[d]The types of roads that connect Dar es Salaam market to regional markets.

reach their lowest point during harvest time and start to rise during the lean months before reaching their peak between October and April. The lower price in Mpanda's surplus market can be attributed to long distances and poor infrastructure. Mpanda Market is located in the far west of Tanzania, 1,383 km from Dar es Salaam and between 1,154 km and 1,689 km from other major deficit markets (Table 2), and part of the trunk road that connects it to other areas is unpaved.

The development of road infrastructure has been at the centre of the Tanzanian government's transport development initiatives and has received the largest share of resources from the development budget. Most of the major towns in Tanzania are connected by paved roads, except for some districts and most of the rural areas. In 2019, the entire national road network reached 35,683 km (an increase of 20.1% compared to 28,510 km in 2002), of which 10,293 km were paved, and 25,390 km were unpaved. In contrast, local roads (district, urban and feeder roads) reached 108,947 km in 2017, of which 1,118 km were paved, and 107,829 km were unpaved (URT, 2019). Therefore, the continued development of road infrastructure in Tanzania would play a crucial role in distributing rice and other food crops from surplus production areas to deficit areas.

4.2 Methods

One of the first steps of a time series analysis is to check the stationarity of the series. A series is said to be stationary, denoted I(0) if its stochastic characteristics remain constant over time. In the literature, there are several traditional tests of stationarity. In this case, we applied the Augmented Dickey-Fuller (ADF) (1979), Kwiatkowski-PhillipsSchmidt-Shin (KPSS) (1992), and Phillips and Perron (PP) (1988). However, it should be noted that the results of these tests are not always conclusive. The presence of structural breaks or any other type of non-linearity can distort the reliability of conventional unit root and cointegration tests (Phillips 1986).

Table 2. Driving distance between regional wholesale rice markets in Tanzania.

Distance (Km)	Dar[a]	Arusha	Dodoma	Lindi	Mbeya	Moro[b]	Mpanda	Mtwara	Mwanza	Shinyanga
Dar[a]		616	452	459	833	193	1383	558	1154	991
Arusha	616		424	1075	1173	591	1581	1174	793	630
Dodoma	452	424		911	604	259	1154	1010	702	539
Lindi	459	1075	911		1076	652	1626	99	1613	1450
Mbeya	833	1173	604	1076		640	561	1139	899	736
Morogoro[b]	193	591	259	652	640		1190	751	961	798
Mpanda	1383	1581	1154	1626	561	1190		1689	1449	1256
Mtwara	558	1174	1010	99	1139	751	1689		1712	1549
Mwanza	1154	793	702	1613	899	961	1449	1712		163
Shinyanga	991	630	539	1450	736	798	1256	1549	163	

Note: [a]Dar es salaam; [b]Morogoro.

Bai and Perron (1998, 2003) structural break test

To deal with possible structural breaks in the cointegration relation, we applied the procedure proposed by Bai and Perron (1998), modified by using the significant values proposed by Bai and Perron (2003). A group of SupF($l+1|l$) tests were employed to statistically identify the appropriate number of breaks, with m breaks ($m+1$ regimes).

$$P_t^y = \delta_j \hat{\underset{t}{z}} + \beta \hat{\underset{t}{x}} + u_t, \text{ for } t = T_{j-1}+1, \ldots, T_j \tag{1}$$

$$j = 1, \ldots, m+1$$

where y_t is the dependent variable in period t, z_t is a constant term, x_t is the independent variable, β and δ_j are the corresponding coefficients, and u_t is the disturbance at time t. $T_1, \ldots, T_m$ are indices representing the breakpoints, and m is the maximum number of breaks used for the test and is set to five.

Dynamic ordinary least squares (DOLS) analysis

Several tests can be used to examine the cointegration between the price series. The most common are those of Engle and Granger (1987), Johansen (1991), and the Dynamic Ordinary Least Square (DOLS) approach, developed by Stock and Watson (1993). However, to apply the first two tests, it is mandatory that all variables should be integrated of the same order, more precisely I (1), and that the regressors themselves should not be cointegrated. Thus, DOLS is usually preferred to other methods because it takes care of the regressors' simultaneity bias by adding leads and lags of the regressors' first differences (Masih and Masih 1996).

Once the periods of the possible breaks are identified, they are included in the long-run equation using the DOLS approach suggested by Stock and Watson (1993). Hence, the estimation of the long-run relationship between the two series P_t^y and P_t^x has the following general specification:

$$P_t^y = \alpha_1 + \alpha_2 P_t^x + \sum_{j=-q}^{r} \beta \Delta P_{t-j}^x + u_t \tag{2}$$

Where q and r are the lag and lead of the first differences of the I(1) regressors. P_t^y and P_t^x are prices for the satellite and central rice market.

The Asymmetric Error Correction Model (ECM)

In order to test for asymmetry in price adjustment, the analysis is divided into two parts: first, the long-run equation is estimated, and second the relation between the long-run coefficients is calculated. In this approach, the cointegration model of Engle and Granger (1987) is relaxed by decomposing the error correction term into positive and negative components as proposed by Von Cramon-Taubadel (1998).

First, the long-run equilibrium between any two price series, P^y (regional market price) and P^x (central market price) is estimated using the following equation:

$$P_t^y = \beta_0 + \beta_1 P_t^x + \lambda t + u_t \tag{3}$$

where P_t^y and P_t^x are the wholesale prices of the regional and central rice markets at time t (month) (in log form). β_0 is the constant, β_1 is the cointegrating parameters (elasticity), and u is the random error term that can be contemporaneously correlated. λ represents the transaction cost necessary to move a unit of goods between the two markets. Since transaction costs are difficult to measure, they are found in the error term, and equation (3) is then written as follows:

$$P_t^y = \beta_0 + \beta_1 P_t^x + u_t \tag{4}$$

The estimated long-run residuals ($\hat{u}_t = P_t^y - \beta_0 - \beta_1 P_t^x$) from Equation (4) are tested through the augmented Dickey-Fuller (ADF) test, which is modelled as follows:

$$\Delta u_t = \varphi u_{t-1} + \sum_{i=1}^{l} \lambda_i \Delta u_{t-1} + \gamma_t \tag{5}$$

Where Δ denotes the first difference; φ is the coefficient to be estimated for the ADF test; l is the number of lags that is accounted for by serially correlated residuals; λ is the coefficient related to the lagged estimated residuals, estimated from Equation (1); and γ_t is the white noise term. Optimum lags are chosen using the information criterion (AIC, SBC, and LR). If the null hypothesis of $\varphi = 0$ is rejected, then the Granger theorem suggests that the price series are cointegrated.

Second, the Error Correction Model (ECM) is estimated. For short-run analysis, ECM is specified as follows:

$$\Delta P_t^y = \alpha_y ECT + \sum_{j=1}^{n_x} \Gamma_j^y \Delta P_{t-j}^y + \sum_{i=1}^{n_y} \Gamma_i^x \Delta P_{t-i}^x + \alpha_0 + \varepsilon_t^y \tag{6}$$

Where ECT is defined as the error correction term (u) of the long-run (cointegration) equation described in Equation (3). α_i represents the adjustment of prices on the left-hand side to the deviations from the long-run equilibrium. Γ is the short-run parameters associated with lagged price changes. The lags of P_t^y and P_t^x quantify the short-run dynamics of regional and central prices on price movements of regional rice market prices. Lag length is selected based on the AIC and SBC.

To test for asymmetry in a cointegration framework, Von Cramon-Taubadel (1998) proposed the following form of an error correction model by decomposing the lagged error correction term (u_{t-1}) into positive and negative components:

$$\Delta P_t^y = \sum_{j=1}^{k} (\beta_j^+ D^+ \Delta P_{t-j+1}^x) + \sum_{j=1}^{l} (\beta_j^- D^- \Delta P_{t-j+1}^x) + \varphi^+ ECT_{t-1}^+ + \varphi^- ECT_{t-1}^- + \sum_{j=1}^{p} \Delta P_{t-j}^y + \varepsilon_t \tag{7}$$

where $ECT_{t-1} = u_{t-1} = ECT_{t-1}^+ + ECT_{t-1}^-$

ECT_{t-1}^+ and ECT_{t-1}^- are defined as, if the estimated residuals from Equation (4) are strictly greater than 0, $ECT_{t-1} > 0$, then $ECT_{t-1}^+ = ECT_{t-1}$ and zero otherwise; whereas $ECT_{t-1}^- = ECT_{t-1}$ when $ECT_{t-1} < 0$ and zero otherwise. φ^+ and φ^- are the coefficients to be estimated that measure long-run asymmetry. The presence of asymmetric adjustment in the equilibrium can be detected by inspecting the sign, magnitude, and statistical significance of the coefficients in Equation (7).

However, the model specified in Equation (7) above still suffers from price simultaneity in different spatial markets. The study attempted to solve this problem using the Toda and Yamamoto causality approach (Toda and Yamamoto 1995). This approach can also help test a central market hypothesis or price leadership in the Tanzanian rice markets. The Toda and Yamamoto approach's innovation is that, unlike the conventional Granger Causality test (Granger 1969), it can be applied irrespective of the order of integration and cointegration of the series. Thus avoiding the potential pre-test biases associated with unit roots and cointegration tests (Clarke and Mirza 2006). The only preliminary information needed before performing the Toda-Yamamoto causality test is the maximum order of integration of the variables (d_{max}) included in the VAR system. Once the optimal number of lags (k) is selected for the model, the VAR is specified as a VAR$(k + d_{max})^{th}$. For this purpose, the optimum lag length is selected using the information criterion (AIC, LR, and FPE). The price series selected fulfilled the notion that central market price (P_t^x) is causal of regional market prices (P_t^y) but not on the contrary.

In this study, the T-Y causality test of VAR($k + d_{\max}$), for an example of two rice markets (M and N) can be specified as follows:

$$y_t = a_0 + \sum_{i=1}^{p=k+d_{\max}} \emptyset_i y_{t-i} + u_t \quad (8)$$

where $y_t = \begin{bmatrix} Market\ M_t \\ Market\ N_t \end{bmatrix}$ $a_0 = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}$ $\emptyset_i = \begin{bmatrix} M_{11,i} & M_{12,i} \\ M_{21,i} & M_{22,i} \end{bmatrix}$ $y_{t-i} = \begin{bmatrix} Market\ M_{t-i} \\ Market\ N_{t-i} \end{bmatrix}$ $u_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$ The hypotheses of the Toda-Yamamoto test are as follows:

H_0: $M_{12,1} = M_{12,2} = \ldots = M_{12,k} = 0$ (Market N price does not granger cause market M rice price)

H_0: $M_{21,1} = M_{21,2} = \ldots = M_{21,k} = 0$ (Market M price does not granger cause market N rice price)

H_1: At least one M_{12} or M_{21} is not zero

where $'d'$ denoted first-order difference operator, and y_{t-i} represents the lagged rice prices. The direction of causality can be confirmed by applying the standard Wald test. The results can then be interpreted in the same way as the conventional Granger causal test results.

5. Empirical results

5.1 Testing for the price leadership role

The Toda and Yamamoto (1995) causality test using vector autoregressive procedure (VAR) was conducted to determine lead-lag price relationships among wholesale rice markets in Tanzania. The procedure gives an overview of the price transmission between the central market and other major regional wholesale rice markets. Unlike the conventional Granger causality test, the approach considers both the short and long-run price movements. However, as explained in the methodology section, before performing the Toda-Yamamoto causality test, it is necessary to identify the maximum order of integration of the variables ($d_{\max}$) as well as the optimal lag length (k) of the VAR system. Based on the AIC, LR, and FPE information criterion, the optimal lag length of the VAR system is selected as eight, the maximum order of integration is selected as 1, and hence the VAR (9) model[2] is specified.

The Toda and Yamamoto Wald causality test results among the regional rice wholesale markets in Tanzania are shown in Table 3. The results show that the Dar es Salaam market prices drive prices in other surplus and deficit markets in a one-way direction, except for the Mbeya market. This suggests that the Dar es Salaam wholesale rice market clearly plays the role of price leader for other domestic markets. Thus, price movements in Dar es Salaam can be used to predict prices in other markets. These findings are understandable since Dar es Salaam region has the highest gross domestic product (GDP) per capita (USD 4,415) compared to the national average of USD 2,915, the highest urban population, and the largest total population in the country (URT 2017b). The region is also the largest marketing hub in the country, which allows it to have many feeder markets that supply or depend on food supply from this market. The region's geographic advantage for imports and exports also contributes to the one-way price influence.

5.2 Asymmetric price transmission (APT) between the pairs of rice markets

Before conducting cointegration analysis, the time series properties of the data are examined. The null hypothesis of the ADF and PP tests is that the variable has a unit root (non-stationary), while the KPSS test is the reverse of the two tests. All tests are conducted with a constant and a trend for the levels and first differences. Based on the frequency of the data (monthly), 12 lags were chosen to whiten the residual. The results for ADF, PP, and KPSS stationarity tests presented in Table 4, suggest that all series are I (1).

Since all the price series are stationary, and I (1), cointegration tests were conducted to investigate the prices' relationships. At first, the Johansen Maximum Likelihood test (Johansen 1991) was carried

Table 3 . Toda-Yamamoto causality tests among wholesale rice markets.[a]

Market	→Dar[b]	→ Mbeya	→ Morogoro	→ Shinyanga	→ Mwanza	→ Mpanda	→ Lindi	→ Mtwara	→ Dodoma	→ Arusha
Dar[b] →	–	8.791**	8.618**	7.587**	11.964***	8.467**	13.988***	14.417***	6.9786**	11.170***
		(0.012)	(0.013)	(0.023)	(0.003)	(0.015)	(0.001)	(0.001)	(0.042)	(0.004)
Mbeya →	4.812*	–	3.356	5.649*	7.721**	2.874	10.055***	6.045**	3.969	4.379
	(0.090)		(0.187)	(0.059)	(0.021)	(0.238)	(0.007)	(0.049)	(0.138)	(0.112)
Morogoro →	2.808	4.712	–	3.849	2.118	1.251	5.339	4.686*	1.546	1.326
	(0.246)	(0.095)*		(0.146)	(0.347)	(0.535)	(0.069)	(0.096)	(0.462)	(0.515)
Shinyanga →	1.511	4.878	3.163	–	5.328*	1.564	5.631*	3.344	0.209	0.759
	(0.469)	(0.087)	(0.206)		(0.069)	0.458	(0.059)	(0.188)	(0.901)	(0.684)
Mwanza →	1.259	0.609	0.254	0.962	–	0.558	0.569	0.907	1.101	0.486
	(0.533)	(0.738)	(0.881)	(0.618)		(0.756)	(0.752)	(0.635)	(0.577)	(0.784)
Mpanda →	1.425	4.537	1.331	4.419	4.174	–	2.529	2.089	4.863	1.731
	(0.491)	(0.104)	(0.514)	(0.109)	(0.124)		(0.282)	(0.352)	(0.088)	(0.421)
Lindi →	1.185	1.898	3.267	3.717	7.269**	5.925*	–	3.679	1.193	1.095
	(0.553)	(0.387)	(0.195)	(0.156)	(0.026)	(0.052)		(0.159)	(0.551)	(0.578)
Mtwara →	3.009	1.178	2.839	2.707	3.766	2.851	3.748	–	1.149	2.726
	(0.222)	(0.555)	(0.242)	(0.258)	(0.152)	(0.240)	(0.154)		(0.563)	(0.256)
Dodoma →	1.926	1.224	2.911	0.483	0.539	0.275	1.041	0.399	–	0.655
	(0.382)	(0.542)	(0.233)	(0.785)	(0.764)	(0.871)	(0.594)	(0.819)		(0.721)
Arusha →	1.038	0.675	1.618	1.049	0.299	0.064	0.501	0.732	1.174	–
	(0.595)	(0.714)	(0.445)	(0.592)	(0.861)	(0.968)	(0.778)	(0.694)	(0.556)	

[a]Null hypothesis of non-causality: $x^2(2)$ statistics; Probability values in parenthesis; ****, ** reject the null hypothesis at 1% and 5% significance levels.
[b]Dar es Salaam.

Table 4. Unit root tests.

Market	Test statistics		
	ADF[b]	PP[b]	KPSS[b]
Level (constant, trend)			
Dar es Salaam	−4.336	−3.463	0.159**
Mbeya	−4.298	−3.772	0.162**
Morogoro	−4.297	−3.530	0.165**
Shinyanga	−4.223	−3.578	0.242***
Mwanza	−4.629	−3.261	0.189**
Mpanda	−4.336	−3.129	0.166**
Lindi	−4.201	−3.531	0.162**
Mtwara	−4.057	−3.522	0.162**
Dodoma	−4.088	−3.176	0.165**
Arusha	−4.224	−3.272	0.151**
First difference (constant, trend)			
Dar es Salaam	−7.887***	−7.932***	0.026
Mbeya	−7.781***	−11.743***	0.025
Morogoro	−7.821***	−9.456***	0.037
Shinyanga	−7.902***	−10.352***	0.027
Mwanza	−7.660***	−10.961***	0.020
Mpanda	−7.538***	−9.172***	0.019
Lindi	−7.721***	−8.430***	0.022
Mtwara	−7.520***	−9.312***	0.026
Dodoma	−7.205***	−9.848***	0.026
Arusha	−7.025***	−9.741***	0.022

Notes: All variables are in natural logs.
[a]***, **, * reject the null hypothesis at 1%, 5%, and 10% significance levels, respectively.
[b]ADF = Augmented Dickey-Fuller unit root test; PP = Phillips-Perron unit root test; KPSS = Kwiatkowski-PhillipsSchmidt-Shin unit root test.

out in a pairwise fashion. All regional rice wholesale markets are paired with the Dar es Salaam rice market. The use of the Dar es Salaam rice market as an exogenous rice market is based on the results of the Toda and Yamamoto causality test (Table 3). The trace and the maximum eigenvalue reported in Table 5 shows that the null hypothesis of no cointegration ($r = 0$) between all market pairs was rejected at a 5% significance level. However, conventional cointegration techniques such as Johansen's (1991) approach may lead to misleading inferences if structural breaks in some of the

Table 5. Johansen cointegration test results between rice market pairs.

Markets	Trace Test			Max-Eigen Test			Lags
	Null	λ-trace	P-value	Null	λ-max	P-value	
Dar – Mbeya	$r = 0$	21.562***	0.005	$r = 0$	19.119***	0.008	8
	$r \leq 1$	2.443	0.118	$r = 1$	2.443	0.118	
Dar – Morogoro	$r = 0$	32.992***	0.000	$r = 0$	30.249***	0.000	2
	$r \leq 1$	2.742	0.116	$r = 1$	2.742	0.116	
Dar – Shinyanga	$r = 0$	18.816**	0.015	$r = 0$	16.193**	0.025	3
	$r \leq 1$	2.623	0.105	$r = 1$	2.623	0.105	
Dar – Mwanza	$r = 0$	33.880***	0.000	$r = 0$	31.503***	0.000	8
	$r \leq 1$	2.377	0.123	$r = 1$	2.377	0.123	
Dar – Mpanda	$r = 0$	25.186***	0.001	$r = 0$	22.612***	0.002	2
	$r \leq 1$	2.573	0.109	$r = 1$	2.573	0.109	
Dar – Lindi	$r = 0$	23.310***	0.003	$r = 0$	20.893***	0.004	4
	$r \leq 1$	2.418	0.120	$r = 1$	2.418	0.120	
Dar – Mtwara	$r = 0$	25.727***	0.001	$r = 0$	23.019	0.002	2
	$r \leq 1$	2.708	0.109	$r = 1$	2.708	0.109	
Dar – Dodoma	$r = 0$	18.394**	0.018	$r = 0$	15.975**	0.027	3
	$r \leq 1$	2.419	0.120	$r = 1$	2.419	0.120	
Dar – Arusha	$r = 0$	40.253***	0.000	$r = 0$	38.562***	0.000	4
	$r \leq 1$	1.691	0.194	$r = 1$	1.691	0.194	

Note. ** denotes rejection of the hypothesis at the 0.05 level.
The critical values are calculated using the approach in MacKinnon et al. (1999).

deterministic elements that characterise the series are ignored. According to Ndoricimpa (2013), a structural change in a time series occurs when there are instantaneous or permanent and unexpected changes in one or more structural components due to specific events. These events could be policy interventions during the investigation period. Once the periods of the possible breaks are located, they are included in the long-run equation.

In this regard, Bai and Perron (1998, 2003) tests were used to account for possible structural breaks in the wholesale rice market prices. Table 6 shows the distribution of the periods in which the price relations present significant structural breaks. According to the SupF($l+1|l$) test results, 15 breakpoints were identified in Mwanza, Arusha, Shinyanga, Mtwara, Mpanda, Mbeya, Morogoro, and Dodoma wholesale rice markets.

The structural breaks in 2008 and 2011 are probably associated with the Tanzanian government protection policies in the agricultural sector that have been put in place to (i) ensure food security through self-sufficiency and (ii) protect the domestic rice sector against cheap imported rice. For example, in January 2008, the Tanzanian government imposed a grain export ban to stabilise grain availability and prices. However, unofficial exports continued due to higher demand in neighbouring countries, with nominal prices remaining around 80% above the 2004–2007 average in May 2008 (Meijerink, Roza, and van Berkum 2009). Between 2005 and 2012, there were a total of four grain export bans in the country (Stryker and Amin 2012). This may have contributed to the rapid increase in domestic rice prices during this period. Besides, an ad-valorem common external tariff of 75% on rice imposed by member states of the East African Community (EAC) in 2005 to protect local rice farmers from low-cost producers outside EAC could also lead to rapid price increases. However, this percentage was subject to a five-year transition period after 2005, and the agreement provided for an annual reduction of 2% so that the 10% tariff was to be phased out by 2010 (Khorana, Kimbugwe, and Perdikis 2007). In principle, an ad valorem tariff of 75% is expected to reduce rice availability in the market, thereby increasing rice prices. Simultaneously, a tariff on imported rice could trigger an increase in production in response to a rise in market prices. The other breaks in 2009 and 2013 show a dispersion that could be associated with implementing various agricultural support programmes and policies in response to the effects of the global food price crisis of 2008 and 2011. Government interventions have been concentrated on many issues, including providing input subsidies, strengthening the national food agency, improving the rural road network, irrigation, and storage facilities. This has led to an increase in food production and distribution, thus lowering prices.

Afterward, a DOLS by Stock and Watson (1993) was carried out to re-test cointegration by taking into account the Bai and Perron test's structural breaks in the form of dummy variables. The DOLS estimates presented in Table 7 show the long-term equilibrium relationship between all rice market pairs held, even after accounting for the effects of structural breaks. These results imply an improvement in the integration of the Tanzanian cereal markets during the post-liberalisation period.

Table 6. Bai–Perron test of multiple structural changes in the long-run relationship.

Market	Mwanza	Arusha	Shinyanga	Mtwara	Mpanda	Mbeya	Morogoro	Dodoma	Critical Values
Tests	Scaled F-statistics								
sup-F(1|0)	73.099**	17.236**	107.293**	27.056**	47.116**	29.072**	16.391**	16.815**	11.47
sup-F(2|1)	35.976**	22.754**	24.657**	21.085**	10.352	2.699	5.388	12.645	12.95
sup-F(3|2)	21.600**	22.387**	13.464	6.964					14.03
sup-F(4|3)	19.194**	11.366							14.85
sup-F(5|4)	0.000								15.29
	Break dates estimates								
Break dates	2007M05	2008M04	2009M07	2008M06	2013M07	2013M11	2013M10	2008M09	
	2009M08	2008M08	2013M10	2011M12					
	2012M06	2011M07							
	2015M11								

Notes: The critical values are taken from Bai and Perron (1998/2003).
**denotes rejection of the null hypothesis at a 5% significance level.

Table 7. DOLS estimation.

Market pairs	Cointegration test for DOLS (U_t)
Mbeya → Dar es Salaam	−9.860488***
Morogoro → Dar es Salaam	−8.594092***
Shinyanga → Dar es Salaam	−6.679363***
Mwanza → Dar es Salaam	−7.285567***
Mpanda → Dar es Salaam	−6.511638***
Dodoma → Dar es Salaam	−6.793425***
Lindi → Dar es Salaam	−9.020007***
Mtwara → Dar es Salaam	−9.259922***
Arusha → Dar es Salaam	−7.992808***

Notes: U_t is the series obtained by the DOLS cointegration equation. Lead and lags are chosen based on AIC.
*** denotes rejection of the null hypothesis at a 1% significance level.

The results of the APT for the rice market pairs are shown in Table 8. The positive and negative error correction coefficients of all the rice market pairs have the expected signs for convergence, except for the positive adjustment coefficient of the Mpanda – Dar es Salaam market pair. The Wald test suggests that the null hypothesis of symmetry can only be rejected in one of the nine pairs of rice markets. This implies that the majority of rice market pairs adjust symmetrically to deviations from long-term equilibrium. Our results contrast with those of Abdulai (2000), Alemu and Ogundeji (2010), Ankamah-Yeboah (2012), and Ngare et al. (2013), who found evidence of asymmetric price transmission in African food markets.

The symmetrical adjustment between the wholesale rice markets in Tanzania can be attributed to the ongoing market and trade reforms, recent improvements in transport infrastructures, geographic proximity, and the likely lower probability of the existence of marketing power in domestic rice markets (Baffes, Kshirsagar, and Mitchell 2017; Kissoly, Faße, and Grote 2017). On the other hand, a long-standing partnership between traders in regional and central markets that guarantees an adequate supply of rice may also lead to the symmetrical adjustment of regional rice markets to positive and negative deviations from the long-run equilibrium of the central market. Furthermore, the development of foodservice markets, better access to technology (i.e., cell phone, internet), and the

Table 8. Estimates of asymmetric price transmission.[a]

	Asymmetric price transmission[b]			
Market pairs	ECT^{+}_{t-1}	ECT^{-}_{t-1}	Wald test ($ECT^{+}_{t-1} = ECT^{-}_{t-1}$)	LM test[c]
Mbeya → Dar es salaam	−0.827*** (0.000)	−0.469** (0.009)	1.971 (0.160)	0.432
Morogoro → Dar es Salaam	−0.615*** (0.001)	−0.610*** (0.001)	0.0004 (0.985)	0.242
Shinyanga → Dar es Salaam	−0.454* (0.059)	−0.548** (0.044)	0.049 (0.824)	0.537
Mwanza → Dar es Salaam	−0.448* (0.095)	−0.582** (0.024)	0.236 (0.627)	0.799
Mpanda → Dar es Salaam	0.043 (0.812)	−0.287* (0.078)	1.261 (0.262)	0.329
Lindi → Dar es Salaam	−0.634*** (0.000)	−0.586** (0.005)	0.035 (0.852)	0.351
Mtwara → Dar es Salaam	−0.436*** (0.003)	−0.519** (0.008)	0.128 (0.720)	0.362
Dodoma → Dar es Salaam	−0.254* (0.098)	−0.393*** (0.004)	0.428 (0.513)	0.698
Arusha → Dar es Salaam	−0.527*** (0.001)	−0.114 (0.448)	3.199** (0.074)	0.348

[a]Lead and lags are chosen based on information criterion (AIC).
[b]***, **, * denotes significance levels of the error correction terms at 1%, 5%, and 10%.
[c]LM test reports the probability value where the test failed to reject the null hypothesis of no serial correlation in the individual rice equations.

presence of institutional markets, including military, hospitals, and educational institutions, may also have contributed to the absence of asymmetric price transmission as they tend to improve competition and the flow of information in the markets.

In contrast, Arusha wholesale market's asymmetric adjustment to price changes in the Dar es Salaam rice market can be attributed to the fact that Arusha receives a higher proportion of rice from the northern producing regions, which are more close to Arusha than to Dar es Salaam Central Market. Arusha is also the main export market to Kenya, so Nairobi prices can sometimes influence its price. Hence, Arusha rice market adjusts merely to price decrease in Dar es Salaam.

Although the speed of adjustment is generally above 50% for most markets, the distances between the markets may have caused the observed differences in the adjustment coefficients. Brosig et al. (2011) and Keho and Camara (2012) explain that distance (and thus transportation cost) is a factor that helps explain the speed at which prices adjust to shocks in other markets. Slow adjustment speeds mean that the effect of exogenous factors that cause prices to change will continue to be felt in the markets for long periods.

6. Conclusions and policy implications

This study aimed to assess the performance of the wholesale rice markets in Tanzania during the post-agricultural market liberalisation period from January 2005 to December 2019. The central hypothesis tested is the existence of asymmetry in price transmission. This hypothesis assumes that prices in regional surplus and deficit rice markets respond more quickly to increases in central market prices than to decreases. The cointegration and asymmetric error correction models that were estimated revealed that all the major regional rice markets considered in this study are integrated and that the price transmission process is symmetrical. The cointegration of all rice market pairs reflects the strong spatial linkages of the rice market in Tanzania. The presence of long-run symmetry in the studied markets demonstrates the ease of information and product exchange between players in different rice markets.

Furthermore, the study did not find sufficient evidence of a positive APT in regional wholesale rice markets in Tanzania despite the belief that traders tend to pass price increases faster than their decreases and thus contribute to high food prices. In almost all cases, the latter react homogeneously to increases and decreases in price deviations from the central rice market. This could be explained by the ongoing market and trade reforms, improved infrastructure, the development of foodservice markets, improved access and use of telecommunications technologies, and the presence of institutional markets, which are expected to enhance the competitive structure of rice markets.

On the other hand, the cointegration of all the major regional markets with the central market could also suggest that any domestic or global shock will affect the whole country. Therefore, this may require taking precautionary measures such as monitoring rice price changes and maintaining emergency grain reserves. Moreover, a favourable environment for traders, transparent trade policies, reliable market information, and an organised market infrastructure can enhance the efficiency of cereal marketing in Tanzania, thereby increasing the food supply.

Notes

1. Surplus market refers to rice markets in major producing areas and deficit market to rice markets in major consuming areas. It is estimated that around 30 percent of total production is consumed in - or near - the production area and that 70 percent is moved to consumption areas.
2. Model adequacy tests were made using the Breusch-Godfrey (1978) test of serial correlation. The BG (8) test has a *p*-value of 17.52 per cent, so the test failed to reject the null of no serial correlation against the alternative of eight order autocorrelation.

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No potential conflict of interest was reported by the author(s).

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References

Abdulai, A. 2000. Spatial price transmission and asymmetry in the Ghanaian maize market. *Journal of Development Economics* 63: 327–349.

Abidoye, B.O., and M. Labuschagne. 2014. The transmission of world maize price to South African maize market: A threshold cointegration approach. *Agricultural Economics* 45: 501–512.

Achandi, E.L., and G. Mujawamariya. 2016. Market participation by smallholder rice farmers in Tanzania: a double hurdle analysis. *Studies in Agricultural Economics* 118: 112–115.

Alemu, Z.G., and A. Ogundeji. 2010. Price transmission in the South African food market. *Agrekon* 49: 433–445.

Ankamah-Yeboah, I. 2012. *Spatial price transmission in the regional maize markets in Ghana*. MPRA Paper No. 49720. Germany: The Munich University Library.

Ashimogo, G., and E. Mbiha. 2007. Impact of market liberalization on the integration of grain markets in Tanzania. *Eastern and Southern Africa Journal of Agricultural Economics and Development* 4, no. 2: 114–125.

Baffes, J., V. Kshirsagar, and D. Mitchell. 2017. What drives local food prices? Evidence from the Tanzanian maize market. *The World Bank Economic Review* 33, no. 1: 160–184.

Bai, J., and P. Perron. 1998. Estimatingandtestinglinearmodels with multiple structural changes. *Econometrica* 66: 47–68.

Bai, J., and P. Perron. 2003. Computation and analysis of multiple structural change models. *Journal of Applied Econometrics* 18: 1–22.

Barrett, C.B., and J.R. Li. 2002. Distinguishing between equilibrium and integration in spatial price analysis. *American Agricultural Economics* 84, no. 2: 292–307.

Breusch, T.S. 1978. Testing for autocorrelation in dynamic linear models. *Australian Economic Papers* 17: 334–355.

Brosig, S., T. Glauben, L. Götz, E. Weitzel, and A. Bayaner. 2011. The turkish wheat market: spatial price transmission and the impact of transaction costs. *Agribusiness* 27, no. 2: 147–161.

Clarke, J.A. S. and S. Mirza. 2006. A Comparison of some common methods for detecting Granger non-causality. *Journal of Statistical Computation and Simulation* 76, no. 3: 207–231.

Cooksey, B. 2003. Marketing reform? The rise and fall of agricultural liberalization in Tanzania. *Development Policy Review* 21, no. 1: 67–91.

Dawe, D. 2009. Cereal price transmission in several large Asian countries during the global food crisis. *Asian Journal of Agriculture and Development* 6, no. 1: 1–12.

Dickey, D.A. and r, W.A. Fulle. 1979. Distribution of the estimator for autoregressive time series with a unit root. *Journal of American Statistics Association* 74: 427–431.

Engle, R.F., and C.W.J. Granger. 1987. Cointegration and error correction representation, estimation and testing. *Econometrica* 55, no. 2: 251–276.

Fafchamps, M., E. Gabre-Madhin, and B. Minten. 2005. Increasing returns and market efficiency in agricultural trade. *Journal of Development Economics* 78: 406–442.

Gedara, P.M.K., S. Ratnasiri, and J.S. Bandara. 2015. Does asymmetry in price transmission exist in the rice market in Sri Lanka? *Applied Economics* 48, no. 27: 2491–2505.

Ghoshray, A. 2002. Asymmetric price adjustment and the world wheat market. *Journal of Agricultural Economics* 53, no. 2: 299–317.

Granger, C.W.J. 1969. Investigating causal relations by econometric models and cross-spectral methods. *EconometricA* 37, no. 3: 424–438.

Hassanzoy, N., S. Ito, H. Isoda, and Y. Amekawa. 2017. Spatial market integration and price transmission among high and low-quality rice markets in Afghanistan. *Journal of the Faculty of Agriculture, Kyushu University* 62, no. 1: 263–282.

Ifejirika, C.A., C.J. Arene, and M. Mkpado. 2013. Price transmission and integration of rural and urban rice markets in Nigeria. *Journal of Agriculture and Sustainability* 2, no. 1: 66–85.

Ihle, R., and S. von Cramon-Taubadel. 2016. *Semiparametric insights into price dynamics in Tanzanian maize markets*. 5th International Conference of the African Association of Agricultural Economists, September 23–26, 2016, Addis Ababa, Ethiopia, Agricultural and Applied Economics Association.

Johansen, S. 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica* 59: 1551–80.

Kadigi, J.M.R. 2003. Rice Production Economics at the Local and National Levels. Report ELEBWU3, Sokoine University of Agriculture, Tanzania.

Kaminski, J., L. Christiaensen, and C.L. Gilbert. 2016. Seasonality in local food markets and consumption: evidence from Tanzania. *Oxford Economic Papers* 68, no. 3: 736–757.

Keho, Y., and A.S. Camara. 2012. Vertical price transmission in local rice markets in Côte d'Ivoire: Are consumers really right? *Asian Journal of Agriculture and Rural Development* 2, no. 4: 552–564.

Khorana, S., K. Kimbugwe, and N. Perdikis. 2007. *The Impact of tariff reductions under the East African Community customs union: intra-trade effects on Uganda*. International conference on Policy Modeling' in Sao Paulo, Brazil on 11–13 July 2007.

Kilima, F.T.M., C. Chung, P. Kenkel, and E.R. Mbiha. 2008. Impacts of market reform on spatial volatility of maize prices in Tanzania. *Journal of Agricultural Economics* 59, no. 2: 257–270.

Kissoly, L., A. Faße, and U. Grote. 2017. The integration of smallholders in agricultural value chain activities and food security: evidence from rural Tanzania. *Food Security* 9: 1219–1235.

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin. 1992. Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? *Journal of Econometrics* 54, no. 1-3: 159–178.

Lazaro, E., A.G. Sam, and S.R. Thompson. 2017. Rice demand in Tanzania: an empirical analysis. *Agricultural Economics* 48: 187–196.

Listorti, G., and R. Esposti. 2012. Horizontal price transmission in agricultural markets: fundamental concepts and open empirical issues. *Bio-Based and Applied Economics* 1, no. 1: 81–96.

Lwesya, F. 2016. An assessment of spatial integration for major wholesale rice markets in Tanzania. *Greener Journal of Business and Management Studies* 6, no. 1: 35–49.

MacKinnon, J.G., A.A. Haug, and L. Michelis. 1999. Numerical distribution functions of likelihood ratio tests for cointegration. *Journal of Applied Econometrics* 14, no. 5: 563–577.

Masih, R., and A.M.M. Masih. 1996. Stock-Watson dynamic OLS (DOLS) and error-correction modelling approaches to estimating long- and short-run elasticities in a demand function: new evidence and methodological implications from an application to the demand for coal in mainland China. *Energy Economics* 18, no. 4: 315–334.

Meijerink, G., P. Roza, and S. van Berkum. 2009. East African governments' responses to high cereal prices. LEI Wageningen UR, The Hague, 114 p.

Meyer, J. 2004. Measuring market integration in the presence of transaction costs–a threshold vector error correction approach. *Agricultural Economics* 31, no. 2-3: 327–334.

Meyer, J., and S. Von Cramon-Taubadel. 2004. Asymmetric price transmission: A survey. *Journal of Agricultural Economics* 55, no. 3: 581–611.

Minot, N. 2011. Transmission of world food price changes to markets in Sub-Saharan African, Discussion Paper No. 01059. International Food Policy Research Institute, Washington, DC.

Ndoricimpa, A. 2013. Structural breaks and fiscal deficit Sustainability in EAC countries: empirical evidence. *International Journal of Economics, Finance and Management Sciences* 1, no. 6: 391–399.

Ngare, L. W., S.K. Wambugu, and C. Shisanya. 2013. Asymmetric price transmission in food markets in the highlands of central Kenya. Paper Presented at the 4th International Conference of the African Association of Agricultural Economists, 22–25 September, Hammamet, Tunisia.

Nkuba, J., A. Ndunguru, R. Madulu, D. Lwezaura, G. Kajiru, and A. Babu. 2016. Rice value chain analysis in Tanzania: identification of constraints, opportunities, and upgrading strategies. *African Crop Science Journal* 24: 73–87.

Olipra, J. 2020. Price transmission in (de)regulated agricultural markets. *Agrekon* 59, no. 4: 412–425.

Ongutade, A.E., and J.A. Folayan. 2006. Assessment of efficiency of price information transmission between the central market and source market for cocoa in southwestern Nigeria a cointegration analysis. *Agricultural Journal* 1, no. 4: 198–201.

Panda, R.K., and R. Sreekuma. 2012. Marketing channel choice and marketing efficiency assessment in agribusiness. *Journal of International Food & Agribusiness Marketing* 24: 213–230.

Phillips, P.C.B. 1986. Understanding spurious regressions in econometrics. *Journal of Econometrics* 33: 311–340.

Phillips, P.C.B., and P. Perron. 1988. Testing for a unit root in time series regression. *Biometrika* 75: 335–46.

Stock, J.H., and M. Watson. 1993. A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica* 61: 783–820.

Stryker, D., and M. Amin. 2012. Study of Policy Options for Increasing Tanzanian Exports of Maize and Rice (Draft) – Improving Food Security to 2025. USAID Feed the Future contracted project to AIRD.

Tekgüç, H. 2013. Oligopoly and price transmission in Turkey's fluid milk market. *Agribusiness* 29, no. 3: 293–305.

Toda, H.Y., and T. Yamamoto. 1995. Statistical inference in vector auto-regressions with partially integrated processes. *Journal of Econometrics* 66: 225–250.

URT. 2017a. Agricultural Sector Development Programme Phase II (ASDP): Programme document. The United Republic of Tanzania.

URT. 2017b. National accounts for Tanzania mainland 2007-2016. The United Republic of Tanzania.

URT. 2017c. 2016/17 Annual Agriculture Sample Survey Crop and Livestock Report. The United Republic of Tanzania.

USDA. 2019. 2019/20 Rice Outlook. The United state Department of Agriculture.
Von Cramon-Taubadel, S. 1998. Estimating asymmetric price transmission with the error correction representation: An application to the German pork market. *European Review of Agricultural Economics* 25, no. 1: 1–18.
Von Cramon-Taubadel, S. 2017. The analysis of market integration and price transmission – results and implications in an African context. *Agrekon* 56, no. 2: 83–96.
Wilson, R.T., and I. Lewis. 2015. The rice value chain in Tanzania. A Report from the Southern Highlands Food Systems Programme. The Food and Agriculture Organization of the United Nations (FAO).
Wondemu, K. 2015. Price transmission asymmetry in spatial grain markets in Ethiopia. *African Development Review* 27: 106–116.
Yami, M., F. Meyer, and R. Hassan. 2019. Should traders be blamed for soaring food prices in Ethiopia? Evidence from wholesale maize markets. *International Food and Agribusiness Management Review* 23, no. 1: 19–23.

Appendix 1. Trunk roads network in Tanzania