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Asymmetric Price Transmission of Rice in Togo

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Abstract

In this paper, we investigate the extent and the speed of adjustment of six domestic markets of imported rice and the local market of processed rice to rice price changes on the global market and how local paddy markets respond to changes in processed rice prices in Togo and we test for asymmetry in the adjustment process using both standard and threshold co-integration analyses. We estimate symmetric and asymmetric error correction models with respect to the linear and threshold co-integration relationships to investigate the short-run price dynamics.

The results indicate that prices of central–local market pairings are co-integrated with relatively low-price transmission elasticities. Threshold co-integration analyses reveal that, in the long run, the local paddy market adjusts asymmetrically to price changes for processed rice and the Cinkasse and Lome domestic markets adjust asymmetrically to price changes on the global market. In the short run, there is asymmetric adjustment only between global and imported rice price dynamics. The results imply that oligopolistic middlemen in rice marketing in Togo are more sensitive to—and react quickly to—rice price changes on the global market that squeeze their margins than to changes that stretch them.

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1. Introduction

The analysis of price transmission has been widely investigated in the literature of agricultural economics. This is because price transmission between geographically separated markets or along the marketing chain drives resource allocation; allows international specialization; and, therefore, has welfare implications (see Amikuzuno and Ogundari, 2012; Bakucs et al, 2013; Fackler and Goodwin, 2001; Meyer and von Cramon-Taubadel, 2004). More critically, asymmetric price transmission analysis is of considerable importance for public policy because asymmetric price transmission alters welfare redistribution through price changes and is associated with welfare losses when it stems from market failure (Meyer and von Cramon-Taubadel, 2004; Wondemu, 2015).

Although these studies are broad, they are relevant. The vulnerability of households in developing countries to food price hikes during the recent global food crisis has illustrated the need for policymakers to better understand how global food price shocks are transmitted to developing countries' local markets. A lack of understanding of these patterns, especially in developing countries, could lead to food insecurity (Barrett and Maxwell, 2006). Unfortunately, the lament of Angus Deaton in 1999—that understanding of commodity prices and the ability to forecast were seriously inadequate, hampering the ability to construct good policy—is still valid today (Dillon and Barrett, 2014).

On the other hand, empirical studies have shown that global to local price transmission patterns vary considerably between developed and developing countries, among developing countries, and across commodities, probably also vary considerably over time, and are context specific (see Abbott, 2009; Baltzer, 2013; DFID, 2014; Huh et al., 2013; Minot, 2010). Most of these studies suffer from methodological limitations, assuming instantaneous pass-through and ignoring threshold effects. There is a need for reliable country-case global to local price transmission analyses to guide country-level evidence-based economic policy away from "one size fits all" policy recommendations.

In Togo, where households are extremely vulnerable to food price shocks (Kamgnia, 2011), cereals are the most-grown and most-consumed food crops. According to a recent agricultural census, cereal production is the main activity of agricultural households in Togo (RNA, 2013) and cereals occupy most of households' per capita food consumption budget (28.73%, compared with roots and tubers (13.72%), vegetables (13%), and fish and seafood (9.84%)). Among cereals, maize, sorghum and rice are the top three cereals in terms of quantity produced and consumed. While the country is more than self-sufficient in maize and sorghum, it relies heavily on rice imports—despite its strong potential for self-sufficiency.

Mostly consumed in urban areas, rice has become part of households' daily food consumption in Togo. With an average annual per capita consumption of 28 Kg, rice ranks third behind maize and sorghum and accounts for 10% of the total dietary energy supply (FAO, 2011). Given the importance of rice to food security in Togo and the pressure of hikes in rice prices on the country's balance of payments, the state authorities' objective is to reduce rice imports—which cost an average of 4 billion CFA francs a year—by boosting local production. Hence, since the recent global food crisis, the government has renewed its support to rice farmers, who are predominantly engaged in small-scale farming subject to rainfall variability, through subsidies of seed and fertilizer purchases and credit facilities.

The government also intervenes in rice marketing in Togo to motivate rice farmers through the national agency for food security (ANSAT), which is in charge of agricultural food commodity price regulation. Rice marketing in Togo has some notable characteristics. First, rice or cereal marketing in general is characterized by high transaction costs due in part to inadequate infrastructure (Koffi-Tessio et al., 2007). Second, rice farmers at the beginning of the marketing chain individually sell their paddy to private processors or to wholesalers, often on the basis of prior informal credits. A survey of 353 rice farmers in the south of Togo revealed that 90% of these farmers sell their production individually and 73% of them sell it without processing (Hodjo and Acharya, 2015). Another survey of 60 wholesalers of local rice at Kovié showed that 25% of wholesalers grant credits to rice farmers (Glé, 2010). This could indicate weak negotiating power of rice farmers in paddy price formation in Togo. Third, using the Africa Rice Center's 2010 consumer preferences survey, Adjognon (2012) has shown that the four biggest rice traders in Togo control more than 50% of the total volume of rice traded weekly, indicating an oligopolistic market structure.

Despite the welfare implications of global to local price transmission in developing food-importing countries—especially the fact that government intervention through price control policies and high transaction costs in rice marketing in Togo on the one hand and the presence of market power in the rice marketing system on the other hand are both likely to cause asymmetric price transmission (see Bakucs et al., 2013; Mayer and von Cramon-Taubadel, 2004)—no study has neither investigated asymmetric price transmission nor determined the extent to which rice price shocks on the global market are transmitted to domestic markets of rice in Togo.

The aim of this paper is to determine the extent and the speed of adjustment of domestic markets of local and imported rice to rice price shocks on the world market and how the local market of paddy responds to the processed rice price variations and to test for asymmetry in the adjustment processes. We use both standard and threshold co-integration analyses and estimate symmetric and asymmetric error correction models with respect to the standard and threshold co-integration relationships between price pairs using monthly retail prices of imported rice in Togo collected on six domestic markets, average monthly retail prices of paddy and processed rice, and monthly prices of Thai rice exports to the world market. The results of Engle and Granger (1987) and Johansen (1988) co-integration tests show that rice prices on the global and domestic markets are co-integrated and the long-run price transmission elasticities are overall relatively low. The results of threshold co-integration reveal asymmetric adjustment of paddy prices to shocks in the processed rice prices and asymmetric adjustment of domestic markets of imported rice of Cinkasse and Lome to price changes on the global market in the long run. In the short run, there is asymmetric adjustment only for the dynamics between the global and domestic markets pairings at Cinkasse and Lome.

The remainder of the paper is organized as follows. Section 2 presents the materials and methods, Section 3 presents and discusses results from the empirical analyses, and the last section concludes.

2. Materials and methods

2.1 Data

Data used in this paper are from the FAO's Global Information and Early Warning System (GIEWS) database, which contains information on monthly retail prices of imported rice in Togo collected on six domestic markets: Cinkasse (an urban market in the northwest of the country), Korbongou (a rural market in the northeast of the country), Kara (an urban market in the center-north of the country), Anie (an urban market in the center-south of the country), Amegnran (a rural market in the southwest of the country), and Lome (the largest urban market along the coast) available from January 2001 to December 2015. We also use monthly retail prices of Thai rice exports to the world market from January 2000 to December 2015. These data are completed by average monthly retail prices of local rice from the board of agricultural statistics, information and documentation in Togo (DSID) available on the period January 2000 to December 2014. All of these series are in FCFA per kilogram.

Descriptive statistics show that average prices of the local rice of paddy and processed rice, estimated at 148.05 FCFA/Kg and 288.28 FCFA/Kg, respectively, are above average prices of rice on the world market (see Table 1). But prices of the processed rice represent on average almost the double of paddy prices. This difference between producer and consumer prices of the local rice is consistent with the founding of Koffi-Tessio et al. (2007) that margins are relatively high in cereals marketing in Togo. For imported rice, the highest average price is found in the Amegnran market (423.88 FCFA/Kg), followed by Lome (398.82 FCFA/Kg).

[Table 1 here]

2.2 Methods

Our methodology consists of testing the existence of a stable long-run relationship between price pairs on domestic markets of local and imported rice and the world rice market. If these price pairs are co-integrated, we determine the extent to which world price signals are transmitted to domestic markets in Togo and test whether the adjustment processes are linear or exhibits threshold non-linearity. When the adjustment process is found to be non-linear, we test for asymmetry in the adjustment process.

2.2.1 Standard co-integration and the corresponding error correction model

Classical economic theory assumes that observed data come from stationary process. However, the graphical analysis seems to indicate that our series are not stationary in level but are stationary in first difference (see Figures 1 and 2). Therefore, we have studied the statistical properties of these series following the Augmented Dickey-Fuller (ADF) unit root tests. If the unit root tests reveal that prices are integrated of the same order, then we test for a co-integration relationship between these prices using both Engle and Granger (1987) and Johansen (1988) co-integration tests. Following Engle-Granger's two-stage approach, the long-run relationship between a pair of prices is specified as follows:

$$p_t^d = \alpha + \beta p_t^w + \mu_t \quad (1)$$

where p_t^d and p_t^w represent domestic and the world market prices of rice respectively, α and β are parameters to be estimated, and μ_t is an error term. The parameter β denotes the long-run price transmission elasticity (with the logarithms of p_t^d and p_t^w). It measures the extent to which price shocks on the world market are transmitted to domestic markets of local and imported rice in Togo.

The Engle-Granger co-integration tests consist of determining whether residuals from the long-run relationship are stationary or not, following equation (2):

$$\Delta\mu_t = \rho\mu_{t-1} + \sum_{i=1}\delta_i \Delta\mu_{t-i} + \varepsilon_t \quad (2)$$

where ρ is the speed of convergence, δ_i are other parameters to be estimated, and ε_t is a white noise disturbance term. If the residuals are stationary, the pair of prices involved is co-integrated and assuming that domestic price changes are driven by changes in these prices on the world market, there may exist a corresponding error correction representation following equation (3):

$$\Delta p_t^d = \alpha + \gamma\mu_{t-1} + \sum_{k=1}\eta_k \Delta p_{t-k}^d + \sum_{k=1}\beta_k \Delta p_{t-k}^w + \varepsilon_t \quad (3)$$

where the lagged residual from the long-run relationship is μ_{t-1}, γ is the speed of adjustment, and η_k and β_k are the short-run price transmission elasticities. The number of lags in equation (2) and (3) and further are selected using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), and the Ljung-Box statistics are used in addressing serial correlation problem.

Standard co-integration analysis assumes that there is an instantaneous adjustment process in the short run and implies that the parameters of the error correction model are constants over the sample period (Hassouneh et al., 2012). However, many studies have shown that at least one of these implications of the linearity assumption is not valid (von Cramon-Taubadel, 1998; Hassouneh et al., 2010). Theoretically, there are many reasons invalidating the assumption of linearity (see Hansen, 1999). The most important of these reasons is the presence of “high” transaction costs (Stigler, 2012). In effect, price adjustment occurs only when deviations from the long-run equilibrium are above a certain threshold. A second argument that supports non-linear adjustment process is the presence of market power in the marketing system (see Meyer and von Cramon-Taubadel, 2004). Thus, given the above-mentioned characteristics of the rice marketing system in Togo, threshold co-integration may be useful for a better understanding of domestic rice markets behavior with respect to changes in rice prices on the global market.

2.2.2 Threshold co-integration analysis

In the threshold co-integration introduced by Balke and Fomby (1997), deviations from the long-run equilibrium are adjusted only when they exceed a critical threshold. This allows an inaction or no-arbitrage band to take place in the adjustment process (Goodwin and Piggott, 2001; Stigler, 2012). Following Enders and Granger (1998), the threshold co-integration tests consist of validating a threshold autoregressive (TAR) model or a momentum threshold autoregressive (MTAR) model:

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1-I_t)\rho_2\mu_{t-1} + \sum_{i=2}\theta_i\Delta\mu_{t-i} + \varepsilon_t \quad (4)$$

where μ_t is the residual from the long-run relationship supposed to be independent of the white-noise disturbance term ε_t , ρ_1 and ρ_2 are speeds of adjustment, and θ_i are other parameters to be estimated. I_t is the Heaviside indicator function defined for a zero threshold as follows:

$$I_t = \begin{cases} 1 & si \ \ \mu_{t-1} \geq 0 \\ 0 & si \ \ \mu_{t-1} < 0 \end{cases} \text{ (5a) or } I_t = \begin{cases} 1 & si \ \ \Delta\mu_{t-1} \geq 0 \\ 0 & si \ \ \Delta\mu_{t-1} < 0 \end{cases} \text{ (5b)}$$

Equations (4) and (5a) together define the TAR model and equations (4) and (5b) define the MTAR model (for details on the TAR and MTAR models, see Enders and Granger, 1998).

For a null threshold value, $\mu_{t-1} = 0$ can be considered as the long-run equilibrium. Thus, if $\mu_{t-1} \geq 0$, all other things being equal, rice price decreases on the world market have led to positive deviations from the long-run equilibrium and so the adjustment process is carried out through the regime $\rho_1\mu_{t-1}$. On the other hand, if $\mu_{t-1} < 0$, price increases on the world market have led to negative deviations from the long-run equilibrium and so the adjustment process is carried out through the regime $\rho_2\mu_{t-1}$. Moreover, if $|\rho_1| \leq |\rho_2|$, the transmission of price increases on the world market tends to persist whereas decreases are more quickly adjusted.

Since there is no reason a priori for threshold values to be null, these values are consistently estimated as other parameters in this paper, following the approach developed by Chan (1993). So, for a threshold value τ, the Heaviside indicator function in the TAR and MTAR representations is as follows:

$$I_t = \begin{cases} 1 & si \;\; \mu_{t-1} \geq \tau \\ 0 & si \;\; \mu_{t-1} < \tau \end{cases} \text{ (6a) and } I_t = \begin{cases} 1 & si \;\; \Delta\mu_{t-1} \geq \tau \\ 0 & si \;\; \Delta\mu_{t-1} < \tau \end{cases} \text{ (6b)}$$

In the Enders and Granger (1998) co-integration analysis, two categories of tests allow us to validate the presence of threshold effect and asymmetry. The first category consists of testing the null hypothesis of no-co-integration. For this test, we can use the T-max that corresponds to the largest value of t-statistics of the null hypotheses: $H_0 : \rho_1 = 0$ and $H_0 : \rho_2 = 0$ or the non-standard Fisher statistic (ϕ) for the complementary joint null hypothesis: $H_0 = \rho_1 = \rho_2 = 0$ against the alternative hypotheses of threshold co-integration in both TAR and MTAR specifications. We focus here on the ϕ statistic as it is deemed to be more powerful than the T-max. Critical values of the non-standard F-test are from Enders and Siklos (2001).

The second category of tests concerns the standard Fisher test of equality of the coefficients ρ_1 and ρ_2, which allows testing for the null hypothesis of symmetry: $H_0 = \rho_1 = \rho_2$. If the first category of test or both tests are conclusive, an asymmetric error correction model is then estimated to investigate whether price dynamics exhibit non-linearity in the short run or not and to test for asymmetry in the short-run adjustment process.

2.3 Estimation of asymmetric error correction models

We use the asymmetric error correction model developed by Sun (2011). The model allows possible asymmetry in price dynamics and incorporates the effect of threshold co-integration by embodying the Heaviside indicator function. The model is specified as follows (for detailed information about the model, see Sun, 2011):

$$\Delta p_t^d = \alpha + \gamma^+ \mu_{t-1}^+ + \gamma^- \mu_{t-1}^- + \sum_{k=1} \eta_k^+ \Delta^+ p_{t-k}^d + \sum_{k=1} \eta_k^- \Delta^- p_{t-k}^d + \sum_{k=0} \beta_k^+ \Delta^+ p_{t-k}^w + \sum_{k=0} \beta_k^- \Delta^- p_{t-k}^w + \varepsilon_t \quad (7)$$

where α , γ, η and β are parameters to be estimated. Following equation (7), several tests of asymmetry can be performed (see Frey and Manera, 2007). With respect to our objective, we focus on two categories of tests. The first concerns the null hypotheses of symmetry in the cumulative price transmission elasticity for positive and negative deviations $H_{01} : \sum_{k=1} \eta_k^+ = \sum_{k=1} \eta_k^-$ (own lagged price changes) and $H_{02} : \sum_{k=1} \beta_k^+ = \sum_{k=1} \beta_k^-$ (lagged price changes on the central market) for an appropriate selected lag order k. The second concerns the null hypothesis of symmetry in the short-run speed of adjustment $H_{03} : \gamma^+ = \gamma^-$.

2.4 Results of the estimations

Rice price shocks on the world market are transmitted first to domestic markets of imported rice. Changes in domestic markets of imported rice are then transmitted to the local market of processed rice through substitution effect (see Tchabletienne et al., 2010). Along the marketing chain, price changes on the local market of processed rice will affect paddy prices.

2.5 Results of unit root tests

Because the unit root tests are sensitive to deterministic regressors, Enders (2004) recommends the inclusion of the intercept and trend in the estimation of equation (2). The results reported in Table 2 indicate that at 5% significance level, the hypothesis of the presence of unit roots cannot be rejected for all series in level. However, at the same significance level, all of these series are stationary in first difference. The results imply that series are integrated of the same order one and postulate a possible long-run relationship between the domestic prices of local and imported rice and prices on the world market on the one hand and between the prices of paddy and processed rice on the other hand. Therefore, we perform co-integration tests.

[Table 2 here]

2.6 Results of standard and threshold co-integration tests

2.6.1 Results of standard co-integration tests

We perform Engle-Granger and Johansen co-integration tests in this paper. Following the Engle-Granger co-integration tests, the results reported in Table 3 indicate that at the 1% significance level, the null hypothesis of no-co-integration is rejected for all pairs of prices. For Johansen's co-integration, both the trace and the maximum eigenvalue statistics indicate that at the 10% significance level, overall, the null hypothesis of zero co-integrating vector is rejected. Hence, there is a stable long-run relationship between the local prices of paddy and processed rice and between rice prices on domestic markets and on the global market.

[Table 3 here]

Therefore, we estimate the extent to which global rice prices are transmitted to domestic markets taking the logarithms of prices in equation (1). The results reported in Table 4 indicate that—with the exception of the long-run relationship between paddy and processed rice prices and for the long-run relationship between prices in Lome and the global market, where price transmission elasticities are relatively high (0.89 and 0.63, respectively)—price transmission elasticities are found to be on the lower side, ranging from 0.28 in Kara to 0.38 in Cinkasse.

The results are not surprising in the context of cereal price control policies in Togo with the objective of isolating domestic markets from price volatility on the global market. In this respect, Sharma (2003) argues that as long as developing countries have the possibility of protecting producers and consumers from external price shocks, global to local price transmission will remain incomplete. Nevertheless, our results contrast a bit with the synthesis of Baltzer (2013) that governments in developing countries have not succeeded in isolating domestic markets from food price fluctuations on the global market.

[Table 4 here]

2.6.2 Results of threshold co-integration tests

Following equations 5 and 6, we estimate four (4) types of models for threshold co-integration analyses: consistent TAR and MTAR, and TAR and MTAR for a null threshold. We first tried a number of lags of 12 and determined the optimal number of lags included in each model following AIC, BIC and the Ljung-Box statistics so that error terms in the models approximate white noise. We are aware of the demonstration of Eitrhem and Terasvirta (1996) that, in non-linear models, the Ljung-Box statistic does not follow the standard χ^2. So we use the Ljung-Box statistics here with caution. Overall, the consistent estimation of the MTAR model is deemed to be the best fit, following the AIC and BIC criterions. For this reason, we report in Table 5 only the results from the consistent estimation of the MTAR model (the estimates of consistent TAR and TAR and MTAR models for a null threshold are available from the author upon request).

[Table 5 here]

3.2.2.1 Case of local markets of paddy and processed rice

The results reported in Table 5 indicate that for the long-run relationship Processed rice–World, the null hypothesis of no-co-integration is not rejected. In effect, the nonstandard Fisher statistic ϕ for the null hypothesis $\rho_1 = \rho_2 = 0$ estimated to be 3.416 is less than the critical values of the test at the conventional significance levels. However, this hypothesis is rejected for the long-run relationship Paddy–Processed rice. For the latter, the ϕ statistic for the null hypothesis $\rho_1 = \rho_2 = 0$ estimated to be 21.158 is significant at 1% significance level, implying that these prices are co-integrated and the adjustment of paddy prices to processed rice price changes exhibits threshold non-linearity.

Since the adjustment of paddy prices to processed rice price changes exhibits threshold non-linearity, we then test for asymmetry in the long-run adjustment process. The Fisher statistic for the null hypothesis $\rho_1 = \rho_2$, estimated to be 11.643, is greater than the critical value at the 1% significance level. So we reject the null hypothesis of symmetry and conclude that the long-run relationship between paddy and processed rice prices is nonlinear and asymmetric. It means that oligopolistic middlemen in Togo do not transmit processed rice price changes to paddy prices unless changes in deviations from the long-run equilibrium exceed or are in absolute terms equal to 2.208 CFA francs per kilogram and positive deviations from the long-run equilibrium (ρ_1) and negative deviations from the long-run equilibrium (ρ_2) are not resorbed at the same magnitude.

In effect, ρ_1 and ρ_2, the speeds of adjustment towards the long-run equilibrium estimated at –0.315 and –0.734, respectively (all significant at 1% significance level)—are negative and implies convergence, but the speed of adjustment for negative deviations is greater than that of positive deviations. Negative deviations from the long-run equilibrium $\left(\Delta\mu_{t-1} < -2.208\right)$ resulting from periods of processed rice price increases are resorbed at the rate of 73.4% within a month whereas positive deviations from the long-run equilibrium $\left(\Delta\mu_{t-1} \geq -2.208\right)$ are resorbed at the rate of 31.5% within a month. In other words, negative deviations from the long-run equilibrium take less than one and a half months to be totally digested whereas positive deviations from the long-run equilibrium take more than three months to be totally digested. this means, all other things being equal, that oligopolistic middlemen take on average more time to transmit decreases in the prices of processed rice to paddy prices than increases. This could be in general the signal of exercising market power in rice marketing, given the weak negotiating power of rice farmers in paddy price formation in Togo.

2.6.2.1 Case of imported rice: markets in the north of Togo

The results of threshold co-integration tests (see Table 5) for the long-run relationship between prices on the domestic markets of imported rice (Cinkasse, Korbongou, and Kara) and the world market reveal that, at the conventional significance level, the null hypothesis of no-co-integration is not rejected for the pair of prices Kara-World. However, this hypothesis is rejected at the 1% and 10% significance levels for the pairs Cinkasse-World and Korbongou-

World, respectively, implying that these pairs of prices are co-integrated and exhibit threshold nonlinearity. That means rice price changes on the global market are adjusted on the Cinkasse and Korbongou markets only when changes in the deviations from the long-run equilibrium exceed 4.511 CFA francs and 7.42 CFA francs, respectively.

For the test of asymmetry, the Fisher test of equality $\rho_1 = \rho_2$ shows that, for the pair Korbongou-World, at the 10% significance level, the null hypothesis of symmetry is not rejected but it is rejected at the 1% significance level for the pair Cinkasse-World. Thus, while the two pairs exhibit threshold nonlinearity, only the imported rice market of Cinkasse adjusts asymmetrically to rice price changes on the global market. For the latter, the point estimate for $\rho_1 = -0.348$ (significant at the 1% significance level) and for $\rho_2 = 0.080$ (not significant) suggest that positive deviations from the long-run equilibrium $\left(\Delta\mu_{t-1} \geq -4.511\right)$ are digested at the rate of 34.8% within a month but this market doesn't seem to respond to negative deviations from the long-run equilibrium $\left(\Delta\mu_{t-1} < -4.511\right)$.

This means that while the oligopolistic middlemen on the Cinkasse market take a record amount of time to transmit movements of price decreases on the world market, they take more time than necessary to transmit movements of rice price increases on the global market. The fact that the Cinkasse market is the farthest from Lome and exchanges with markets of Burkina Faso (Cinkasse market is located at the border between Togo and Burkina Faso), asymmetric information on transaction costs might have given to the oligopolistic middlemen, (all other things being equal) the opportunity to maintaining rice prices relatively high even when these prices are decreasing on the world market.

2.6.2.2 Case of imported rice: markets in the south of Togo

The results of the estimations of the consistent MTAR models (see Table 5) for markets in the south of Togo (Amegnran, Anie, and Lome) indicate that the null hypothesis of no-co-integration is not rejected for the long-run relationship between prices on Amegnran and the world markets. Indeed, the value of the test estimated to be 3.957 is less than the critical values at conventional significance levels. However, this hypothesis is rejected at the 10% significance level for the pair Anie-World and at the 1% significance level for the pair Lome-World. This means that the imported rice prices on the Anie and Lome markets and rice prices on the global market are co-integrated and exhibit threshold nonlinearity so that prices are adjusted on these markets when changes in deviations from the long-run equilibrium exceed

14.066 CFA francs per kilogram and 27.674 CFA francs per kilogram, respectively. Then, we test for asymmetry in the adjustment process.

Asymmetric tests reveal that the null hypothesis of symmetry $\rho_1 = \rho_2$ is rejected for the pair Anie-World whereas it is not rejected for the pair Lome-World. In fact, the value of the test estimated to be 1.194 on the Anie market is less than the critical values at the conventional significance level whereas the value of the test estimated to be 18.664 on the Lome market is significant at the 1% significance level. So, while the long-run relationship between prices on the domestic markets of imported rice in Anie and Lome and the global market exhibit threshold nonlinearity, only the Lome market adjusts asymmetrically to rice price changes on the world market.

For the latter, the point estimates for $\rho_1 = -0.706$ and $\rho_2 = -0.122$ are all negative and significant implying convergence towards the long-run equilibrium so that positive deviations from the long-run equilibrium $(\Delta\mu_{t-1} \geq 27.674)$ resulting from movements of rice price decreases on the global market are more rapidly adjusted at the rate of 70.6% within a month than negative deviations from the long-run equilibrium $(\Delta\mu_{t-1} < -4.511)$ resulting from movements of rice price increases on the global market adjusted at the rate of 12.2% within a month. In other words, oligopolistic middlemen take on average less than one and a half months to fully transmit movements of rice price decreases on the global market but more than eight months to transmit movements of rice price increases on the world market. All other things being equal, the high demand for imported rice in Lome, the capital of Togo, might have given oligopolistic middlemen the opportunity to exercise market power on this market.

Overall, the results of threshold co-integration are conclusive that, except for the local and central markets pairings Processed rice–World, Kara-World, and Amegnran-World, the other long-run relationships exhibit threshold nonlinearity. Concerning asymmetry tests, we find that for local rice, paddy markets in Togo adjust asymmetrically to price changes in processed rice and for imported rice, only the Cinkasse market, located in the extreme north of the country, and Lome, the largest market in Togo, adjust asymmetrically to rice price changes on the global market. In line with the results of standard and threshold co-integration analyses, we estimate symmetric and asymmetric error correction models to investigate the short-run price dynamics and test for asymmetry for pairings in which the long-run relationships exhibit threshold nonlinearity.

2.7 Results of the estimations of symmetric and asymmetric error correction models

While the fact that Togo is a small country and therefore a price taker could be sufficient reason to assume unidirectional causality for global and local markets pairings, there is no reason a priori to assume the direction of causality for the pairing Processed rice–Paddy. We therefore perform Granger causality tests to ensure the direction of causality. The results reported in Table 6 indicate as expected that rice prices on the world market Granger-cause prices on the domestic markets of local and imported rice whereas prices on the domestic markets of local and imported rice do not Granger-cause prices on the global market. For markets of rice produced locally, prices of processed rice Granger-cause paddy prices and paddy prices also Granger-cause prices of processed rice.

[Table 6 here]

2.7.1 Results of the estimations of symmetric error correction models

We estimate symmetric error correction models for the pairings Processed rice–World, Kara-World, and Amegnran-World and report the results in Table 7. The AIC and BIC together with the Ljung-Box statistics have selected sufficient lag length of two, four, and eight, respectively, for the pairings Kara-World and Amegnran-World. Table 7 indicates that only the error correction term in Kara is significant at the 1% significance level. So, in the short run, prices in Kara adjust so as to resorb 13.6% of deviations from the long-run equilibrium whereas prices in Amegnran and on the processed rice market do not appear to respond to rice price changes on the global market in the very short run.

Nevertheless, price changes on the processed rice market are significantly influenced by both own and global price lagged changes. So, the hypothesis of market segmentation is rejected on the processed rice market. The fact that deviations from the long-run equilibrium are not adjusted in a very short time could suggest that a certain time is necessary for consumers to switch between processed rice and imported rice with respect to price changes on the global market. For the imported rice market of Amegnran, in the short run price changes on that market are determined only by own lagged changes. Given the isolation of this rural market, while connected to the global market in the long run, its prices seem to move independently from price changes on the global market in the short run.

[Table 7 here]

2.7.2 Results of the estimations of asymmetric error correction models

Asymmetric error correction models are estimated for markets pairings Paddy–Processed rice and Imported rice–World for the Cinkasse, Korbongou, Anie, and Lome markets. One lag is selected for the pairings Paddy–Processed rice and Anie-World, and two and three lags are selected for the pairs Korbongou-World and the rest of pairings, respectively. Results of estimations for the local rice markets pairings reported in Table 8 and for the Imported rice–World markets pairings reported in Table 9 indicate that, overall, the coefficients associated with positive and negative error correction terms are significant at conventional significance levels for market pairings in which there is asymmetry in the long-run price dynamics. For the rest of market pairings for which the long-run price dynamics exhibit threshold nonlinearity but not asymmetric adjustment, these coefficients are not significant. In the short run and for the local rice market pairings (Table 8), a unit positive deviation from the long-run equilibrium resulting from movements of the processed rice price increase is adjusted at the rate of 33.1% and a unit negative deviation resulting from movements of the processed rice price decrease is adjusted at the rate of 44.6%.

[Table 8 here]

For the Imported rice–World price dynamics, Table 9 indicates that a unit positive deviation from the long-run equilibrium is adjusted in the short run at the rate of 30.8% in Cinkasse and 52.2% in Lome. As in the long run, negative deviations are not adjusted on the market of Cinkasse but a unit negative deviation from the long-run equilibrium is adjusted at the rate of 20% in Lome.

Given the difference in the way positive and negative deviations from the long-run equilibrium are adjusted on the imported rice markets in Togo, the null hypothesis of symmetry ($\gamma^{+} = \gamma^{-}$) in the short-run price dynamics is rejected for the Cinkasse-World and Lome-World markets pairings whereas it is not rejected for the pair Paddy–Processed rice. For asymmetry in the distributed lagged changes, Fisher statistics for the null hypothesis of symmetry: $\sum_{k=1} \eta_k^{+} = \sum_{k=1} \eta_k^{-}$ and $\sum_{k=1} \beta_k^{+} = \sum_{k=1} \beta_k^{-}$ indicate that while neither the paddy nor the processed rice markets respond asymmetrically to their own passed price changes, the processed rice market responds asymmetrically to current and passed paddy price changes at the 1% significance level. The imported rice markets of Cinkasse and Lome respond asymmetrically to own, current, and passed global market price changes.

[Table 9 here]

3 Conclusion and discussion

In this paper, we investigate the extent and the speed of adjustment of domestic markets of local and imported rice to price changes on the global market and the response of paddy prices to changes in processed rice prices in Togo, using both standard and threshold co-integration analyses. The results of the Engle-Granger and Johansen co-integration tests show that prices of the central-local markets pairings are co-integrated, implying the existence of a stable long-run relationship between prices in these markets.

Overall, rice price changes on the global market are transmitted to domestic markets of both local and imported rice with relatively low price transmission elasticities. While our results are consistent with the finding of Sharma (2003), they contrast a bit with the synthesis of Baltzer (2013), who points out that African governments' price control policies have not succeeded in isolating domestic markets from the global market price fluctuations. Threshold co-integration analyses reveal the existence of asymmetric adjustment of paddy prices to changes in processed rice prices and asymmetric adjustment of the domestic markets of Cinkasse and Lome to rice price changes on the global market in the long run. But in the short run, there is asymmetric adjustment only in the imported rice markets of Cinkasse and Lome.

Overall, the results imply that oligopolistic middlemen in rice marketing in Togo are more sensitive and react quickly when rice price changes on the global market tend to squeeze their margins than when price changes stretch the margins. The results are consistent with the findings of Adjognon (2012) that the greatest rice marketing margins are found in the Maritime (where the Lome market is located) and Savannah (where the Cinkasse market is located) regions. Results are also consistent with the finding of Koffi-Tessio et al. (2007) that the marketing of cereals' in Togo is concentrated in the hands of a few people accumulating huge profits from their monopoly positions and asymmetric information on market conditions.

The results mean that farmers at the beginning of the marketing chain in Togo (or consumers) do not benefit from periods of price increases (decreases) on the global market. This can lead, rice farmers to subsistence farming while in the long run the goal of the state authorities is to achieve at the national-level self-sufficiency in rice. So, appropriate policy measures are needed to address market inefficiencies in the rice sector in Togo. In particular, there is a need for policy measures that aim at enhancing the market participation of rice farmers in Togo. Moreover, given the net social welfare losses that asymmetric price transmission resulting from market power implies, policy measures that aim at liberalizing or increasing competition in the rice importing sector in Togo are important to ensure an efficient redistribution with respect to price changes on the global market.

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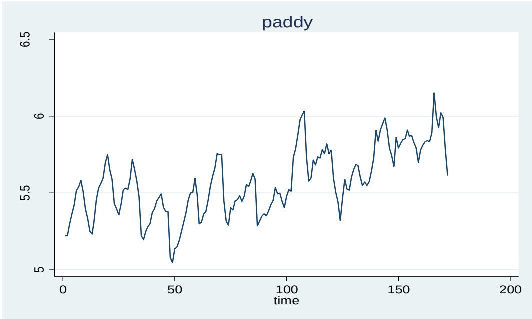
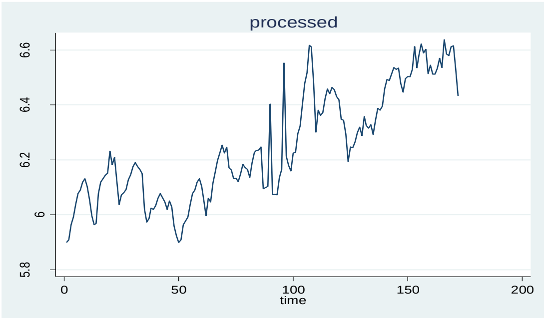
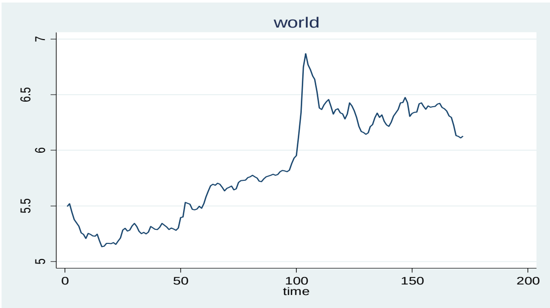
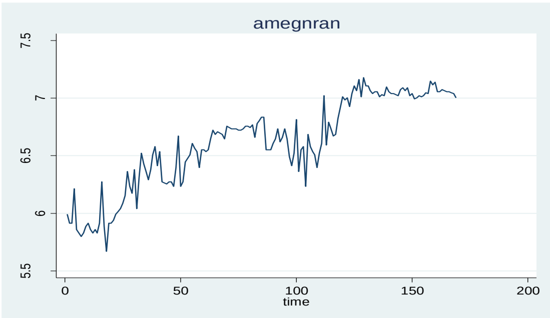
Annex

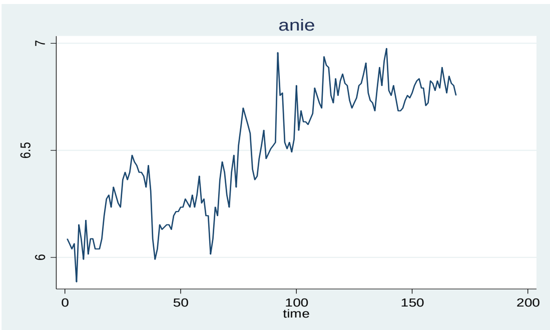
Figure 1: Trends in Prices (series in level)

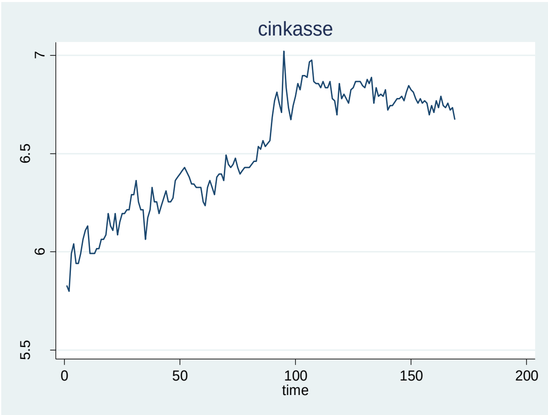


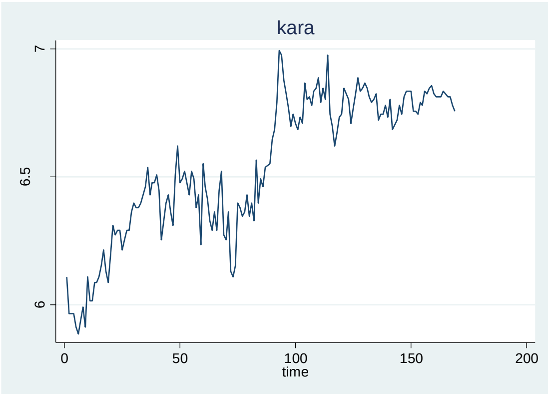


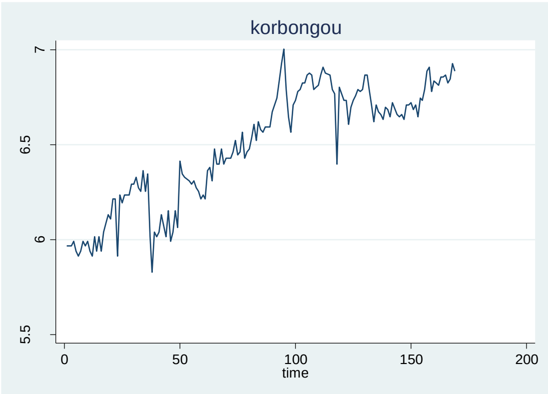












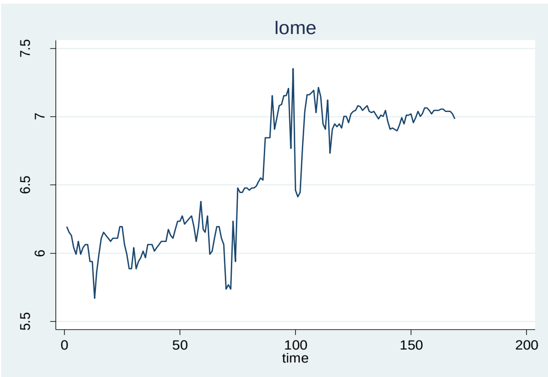
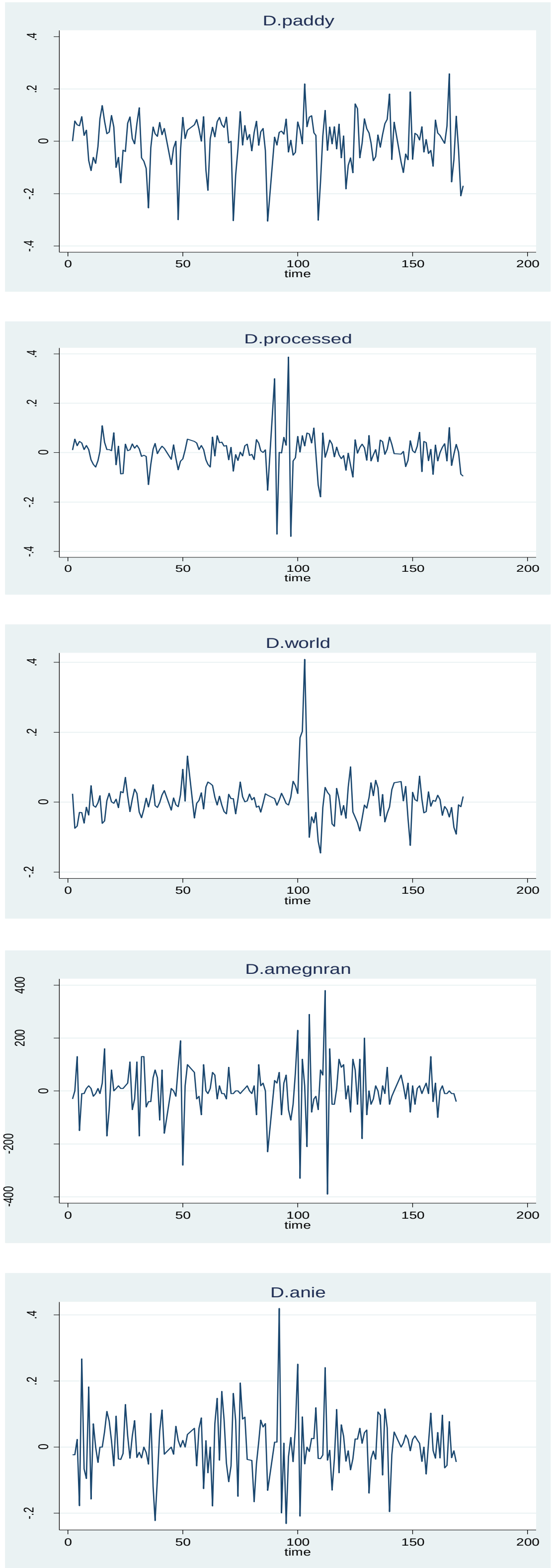
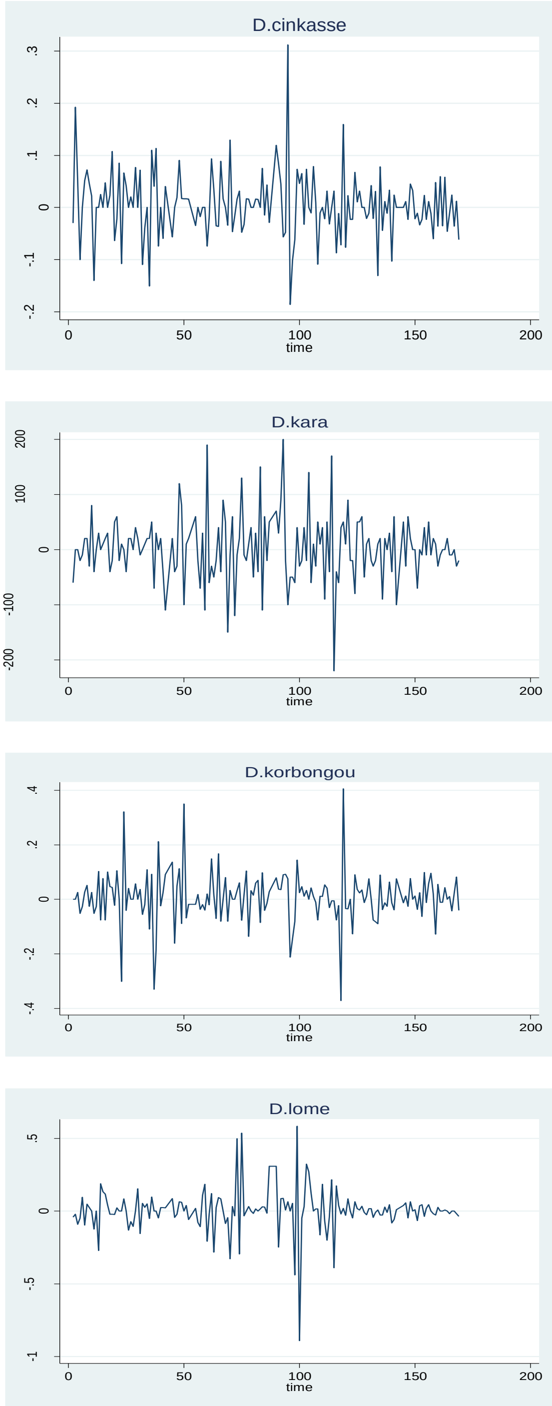


Figure 2: Trends in Prices (first difference)





Source: Author's realizations using the direction of agricultural statistics in Togo (DSID) and the Global Information and Early Warning System (GIEWS) data.

Table 1: Descriptive statistics of domestic and world rice prices (CFA Francs per kilogram)

Markets	Obs.	Period	Mean	Standard Deviation	Minimum	Maximum	Correlation Coefficient
				Local rice			
Paddy	180	2000. 01 – 2014. 12	148.05	35.19	83.00	250.85	0.91
Processed rice	180	2000. 01 – 2014. 12	288.28	60.53	195.00	407.96	0.80
				Imported rice			
Cinkasse	180	2001. 01 – 2015. 12	368.12	70.50	235.00	493.00	0.86
Korbongou	180	2001. 01 – 2015. 12	365.05	80.58	178.00	500.00	0.70
Kara	180	2001. 01 – 2015. 12	377.34	66.16	230.00	514.00	0.75
Anie	180	2001. 01 – 2015. 12	365.56	72.56	216.00	535.00	0.61
Lome	180	2001. 01 – 2015. 12	398.82	124.24	161.00	750.00	0.80
Amegnran	180	2001. 01 – 2015. 12	423.88	137.82	200.00	650.00	0.54
				World market			
Thai rice	192	2000. 01 – 2015. 12	207.53	70.51	106.76	404.81	-

Source: Author’s calculations using DSID and FAO/GIEWS data.

Table 2: Results of unit root tests

Markets	ADF	ADF (with drift)	ADF (with trend)	ADF	ADF (with drift)	ADF (with trend)
		Series in level			Series in first difference	
			Local rice markets			
Paddy	0.63 [13]	-1.19 [13]	-3.68** [15]	-3.65*** [12]	-3.75** [12]	-3.76** [12]
Processed rice	0.76 [13]	-1.19 [13]	-3.32* [13]	-3.00*** [12]	-3.17** [12]	-3.15* [12]
			Imported rice markets			
Cinkasse	0.48 [2]	-1.61 [2]	-1.79 [2]	-12.69*** [1]	-12.70*** [1]	-12.97*** [1]
Korbongou	1.04 [4]	-0.64 [4]	-2.59 [4]	-9.34*** [3]	-9.43*** [3]	-9.42*** [3]
Kara	0.72 [3]	-1.45 [3]	-2.42 [3]	-11.30*** [2]	-11.34*** [2]	-11.31*** [2]
Anie	0.01 [2]	-2.03 [2]	-3.08 [2]	-12.78*** [1]	-13.72*** [1]	-13.72*** [1]
Amegnran	1.06 [7]	-0.92 [7]	-2.33 [7]	-5.11*** [6]	-5.30*** [6]	-5.28*** [6]
Lome	-0.16 [6]	-1.30 [15]	-1.30 [15]	-8.37*** [5]	-8.35*** [5]	-8.35*** [5]
			Global market			
Thai rice 100% B	-0.24 [9]	-1.98 [9]	-2.25 [9]	-3.92*** [8]	-3.98** [8]	-3.97** [8]

Note: ADF: Augmented Dickey-Fuller. Critical values are –2.66; –1.95 and 1.60 for ADF test without drift and trend; 3.46; 2.88 and 2.57 for ADF test with drift; –3.99; –3.43 and –3.13 for ADF test trend at the 1%, 5%, and 10% significance levels, respectively. Values in square brackets represent the number of lags necessary for error terms to approximate white noise in the ADF test. (***), (**), and (*) represent 1%; 5%, and 10% significance levels, respectively.

Table 3: Results of Engle-Granger (1987) and Johansen (1988) co-integration tests

Markets	ADF	$P.Q_{LB}(4)$	$P.Q_{LB}(8)$	$P.Q_{LB}(12)$	Hypothesis	Trace Statistic	Maximal Eigen Value Statistic
	Engle-Granger test	*Diagnostics (Engle-Granger)*				*Johansen's test*	
			Local rice markets				
Paddy–Processed rice	–7.26*** [28]	0.9927	0.9776	0.1879	None	43.24***	38.74***
	—	—	—	—	At most 1	4.50	4.50
Processed rice–World	–10.56*** [15]	0.8484	0.3508	0.2269	None	24.77***	21.86***
	—	—	—	—	At most 1	290	2.90
			Imported rice markets				
Cinkasse–World	–10.21*** [12]	0.9773	0.9976	0.9986	None	30.24***	26.22***
	—	—	—	—	At most 1	4.02	4.02
Korbongou–World	–9.32*** [11]	0.9889	0.9998	0.5419	None	26.39**	18.01*
	—	—	—	—	At most 1	8.38	8.38
Kara–World	–7.35*** [10]	0.9015	0.9929	0.6824	None	19.01**	15.28**
	—	—	—	—	At most 1	3.82	3.82
Anie-World	–8.48*** [10]	0.9494	0.9944	0.1312	None	14.57	10.75
	—	—	—	—	At most 1	3.82	3.82
Amegnran-World	–7.66*** [11]	0.9969	0.9988	0.9436	None	24.98*	18.34*
	—	—	—	—	At most 1	6.64	6.64
Lome-World	–7.66*** [11]	0.9969	0.9988	0.9436	None	30.73***	28.67***
	—	—	—	—	At most 1	2.07	2.07

Note: Engle-Granger's co-integration test critical values are –2.58, –1.95, and –1.62 at the 1%, 5%, and 10% significance level, respectively (Enders, 2004). Values in square brackets represent the number of lags necessary for error terms to approximate white noise in the ADF test. $P.Q_{LB}$ (4), $P.Q_{LB}$ (8) and $P.Q_{LB}$ (12) represent P-values for the Ljung-Box Q statistics for a lag 4, 8, and 12, respectively. Johansen's co-integration critical values without intercept, with intercept, and with trend at the 5% significance level are, respectively, 17.95, 19.96, and 25.32 for the trace statistic and, respectively, 14.90, 15.67, and 18.96 for the maximum eigenvalue statistic. (***), (**), and (*) represent 1%, 5%, and 10% significance levels, respectively.

Table 4: Long-run relationships for local–central market price pairings

Markets	α	β	Fisher Statistic	P-value
		Local rice markets		
Paddy–Processed rice	–0.0770	0.8946***	72.25	0.0000
	(0.5906)	(0.1053)	—	-
Processed rice–World	3.8656***	0.3406***	35.62	0.0000
	(0.3046)	(0.0571)	—	-
		Imported rice markets		
Cinkasse–World	3.8684***	0.3844***	49.36	0.0000
	(0.2865)	(0.0547)	—	-
Korbongou–World	4.0166***	0.3537***	19.57	0.0000
	(0.4242)	(0.0800)	—	-
Kara–World	4.4263***	0.2833***	20.07	0.0000
	(0.3355)	(0.0632)	—	-
Anie–World	4.3247***	0.2958***	11.62	0.0008
	(0.4610)	(0.0868)	—	-
Amegnran–World	4.2433***	0.3379**	5.67	0.0183
	(0.7619)	(0.1419)	—	-
Lome–World	2.6174***	0.6252***	38.27	0.0000
	(0.5362)	(0.1012)	—	-

Note: Values in brackets are robust standard errors. (***) and (**) represent the 1% and 5% significance levels, respectively.

Table 5: Results of consistent MTAR estimations

Markets	Threshold (a)	ρ_1	ρ_2	$\phi(H_0:\rho_1=\rho_2=0)$ (b)	$F(H_0:\rho_1=\rho_2)$ (c)	AIC	BIC	P.Q_{LB}(4)	P.Q_{LB}(8)	P.Q_{LB}(12)
		Coefficients		**Hypothesis tests**			**Diagnostic tests**			
					Local markets					
Paddy–Processed rice	-2.808	-0.315***	-0.734***	21.158***	11.643***	1374.602	1396.756	0.996	0.272	0.284
	[4]	(0.102)	(0.114)	[6.32]	[0.001]	-	-	-	-	-
Processed rice–World	-8.221	-0.127**	0.095	3.416	6.116**	1513.814	1548.373	0.612	0.859	0.569
	[8]	(0.066)	(0.082)	[6.32]	[0.014]	-	-	-	-	-
					Imported rice markets					
Cinkasse–World	-4.511	-0.348***	0.088	20.490***	24.674***	1582.895	1595.622	0.475	0.738	0.266
	[1]	(0.056)	(0.071)	[6.63]	[0.000]	-	-	-	-	-
Korbongou–World	7.42	-0.053	-0.165***	5.770*	1.341	1740.394	1753.121	0.725	0.365	0.553
	[1]	(0.085)	(0.049)	[6.63]	[0.248]	-	-	-	-	-
Kara–World	4.671	0.028	-0.123***	2.581	2.373	1637.635	1659.789	0.973	0.892	0.796
	[4]	(0.089)	(0.056)	[6.32]	[0.125]	-	-	-	-	-
Anie–World	14.066	-0.210***	-0.110***	5.689*	1.194	1735.235	1747.962	0.494	0.274	0.503
	[1]	(0.080)	(0.049)	[6.63]	[0.276)	-	-	-	-	-
Amegnran–World	-2.113	-0.117***	0.036	3.957	6.196**	1810.772	1832.926	0.990	0.406	0.726
	[4]	(0.044)	(0.045)	[6.32]	[0.014]	-	-	-	-	-
Lome–World	27.674	-0.706***	-0.122*	13.309***	18.664***	1894.715	1926.190	0.926	0.694	0.199
	[7]	(0.137)	(0.076)	[6.32]	[0.000]	-	-	-	-	-

Note: Coefficients in parentheses are standard errors. Values in square brackets in column (a) represent the number of sufficient lags for errors terms to approximate white noise in MTAR model estimations. These values in column (b) represent the 5% critical values for the threshold co-integration tests from Enders and Siklos (2001); in column (c), they represent P-values for asymmetry tests. (***), (**) and (*) represent the 1%, 5%, and 10% significance levels., respectively.

Table 6: Results of Granger causality tests

Markets	Null hypothesis	(a) Rice prices on the global market do not Granger cause rice prices on domestic markets in Togo	(b) Rice prices on domestic markets in Togo do not Granger cause rice prices on the global market
		Local rice markets	
Paddy–Processed rice		6.4087*** (a)	15.0263*** (b)
		[0.0021]	[0.000]
Processed rice–World		7.0461***	2.6547
		[0.0010]	[0.0732]
		Imported rice markets	
Cinkasse–World		12.7219***	1.6987
		[0.0000]	[0.1860]
Korbongou–World		3.464**	0.3796
		[0.0336]	[0.6848]
Kara–World		9.8294***	0.2236
		[0.0000]	[0.7999]
Anie–World		9.9869***	2.5031
		[0.0019]	[0.1154]
Amegnran–World		1.7388**	1.0635
		[0.0361]	[0.3967]
Lome–World		24.7539***	3.0656
		[0.0000]	[0.0817]

Note: (a) stands for the null hypothesis: “Processed rice prices do not Granger cause paddy prices.” (b) stands for the null hypothesis “Paddy prices do not Granger cause processed rice prices.” Values in square brackets represent the P-values for the Granger causality test. (***) and (**) represent the 1% and 5% significance levels, respectively.

Table 7: Results of the estimations of symmetric error correction models

Parameters	Processed rice–World	Kara–World	Amegnran–World
	Estimated coefficients		
α	1.880	1.267	4.133
	(1.448)	(1.783)	(3.017)
γ	-0.059	-0.136***	-0.034
	(0.056)	(0.046)	(0.031)
η^1	-0.298***	-0.364***	-0.515***
	(0.090)	(0.077)	(0.078)
η^2	-0.177**	-0.175**	-0.327***
	(0.092)	(0.071)	(0.085)
η^3	-0.180**		-0.209**
	(0.093)		(0.085)
η^4	-0.151**		-0.244***
	(0.087)		(0.075)
η^5	-0.326***		
	(0.084)		
η^6	-0.004		
	(0.083)		
η^7	0.191***		
	(0.079)		
η^8	-0.218***		
	(0.080)		
β^1	-0.073	0.170	0.017
	(0.124)	(0.136)	(0.231)
β^2	0.151	0.216	-0.105
	(0.133)	(0.142)	(0.253)
β^3	0.037		-0.118
	(0.134)		(0.252)
β^4	0.226**		0.135
	(0.131)		(0.230)
β^5	0.159		
	(0.133)		
β^6	0.002		
	(0.133)		
β^7	-0.145		
	(0.129)		
β^8	0.223**		
	(0.119)		
	Diagnostic tests		
AIC	1502.044	1630.187	1794.669
BIC	1561.736	1652.420	1829.482
$P.Q_{LB}(4)$	0.887	0.117	0.979
$P.Q_{LB}(8)$	0.972	0.110	0.451
$P.Q_{LB}(12)$	0.189	0.302	0.743

Note: Values in parentheses are standard errors; (***), (**) and (*) represent the 1%, 5%, and 10% significance level, respectively.

Table 8: Results of the estimations of asymmetric error correction models for local rice market pairings

Parameters	Paddy–Processed rice	Processed rice–Paddy
	Estimated coefficients	
α	2.683**	6.052***
	(1.605)	(2.096)
γ^{+}	–0.331***	–0.186
	(0.107)	(0.140)
γ^{-}	–0.446***	0.128
	(0.128)	(0.168)
η_1^{+}	0.172	0.602***
	(0.156)	(0.204)
η_1^{-}	0.480***	0.501***
	(0.132)	(0.172)
β_1^{+}	–0.153*	–0.774***
	(0.102)	(0.133)
β_1^{-}	0.006	0.019
	(0.086)	(0.112)
	Diagnostic tests	
AIC	1447.183	1523.885
BIC	1497.911	1574.612
$P.Q_{LB}(4)$	0.993	0.950
$P.Q_{LB}(8)$	0.624	0.430
$P.Q_{LB}(12)$	0.225	0.112
	Hypothesis tests	
$H_{01}: \sum_{i=1} \eta_i^{+} = \sum_{i=1} \eta_i^{-}$	1.902	0.119
	[0.170]	[0.731]
$H_{02}: \sum_{i=1} \beta_i^{+} = \sum_{i=1} \beta_i^{-}$	1.246	18.282***
	[0.226]	[0.000]
$H_{03}: \gamma^{+} = \gamma^{-}$	0.501	2.195
	[0.480]	[0.140]

Note: Numbers in parentheses are standard errors and those in square brackets are P-values for the asymmetry test. (***), (**), and (*) represent the 1%, 5%, and 10% significance level, respectively.

Table 9: Results of estimations of asymmetric errors correction models for the imported rice in Togo and the global markets pairings

Parameters	Cinkasse–World	Korbongou–World	Anie–World	Lome–World
		Estimated coefficients		
α	2.489	–5.698	2.264	4.296
	(2.245)	(4.098)	(3.506)	(5.386)
γ^+	–0.308***	0.011	–0.124	–0.522***
	(0.055)	(0.062)	(0.080)	(0.124)
γ^-	-0.078	–0.142	–0.122**	–0.199***
	(0.076)	(0.094)	(0.050)	(0.064)
η_1^+	–0.385***	–0.251*	–0.398***	–0.662***
	(0.098)	(0.138)	(0.113)	(0.130)
η_2^+	–0.235***	–0.344***		0.201
	(0.103)	(0.118)		(0.158)
η_3^+	–0.197**			–0.092
	(0.102)			(0.151)
η_1^-	–0.279**	–0.548***	–0.029	0.021
	(0.140)	(0.115)	(0.332)	(0.124)
η_2^-	–0.056	0.040		–0.010
	(0.143)	(0.062)		(0.125)
η_3^-	0.140			0.076
	(0.125)			(0.100)
β_1^+	0.489***	0.110	0.609***	0.034
	(0.149)	(0.234)	(0.220)	(0.426)
β_2^+	–0.362***	0.213		0.215
	(0.155)	(0.244)		(0.457)
β_3^+	0.078			–0.526
	(0.159)			(0.496)
β_1^-	0.060	–0.433	0.029	–1.590**
	(0.217)	(0.322)	(0.332)	(0.662)
β_2^-	–0.555***	–0.401		–0.414
	(0.202)	(0.322)		(0.618)
β_3^-	–0.175			–0.196
	(0.203)			(0.615)
		Diagnostic tests		
AIC	1501.357	1627.612	1727.737	1878.588
BIC	1552.085	1665.726	1753.191	1929.316
$P.Q_{LB}(4)$	0.303	0.600	0.521	0.875
$P.Q_{LB}(8)$	0.462	0.797	0.374	0.168
$P.Q_{LB}(12)$	0.101	0.927	0.630	0.144
		Hypothesis tests		
$H_{01}: \sum_{i=1} \eta_i^+ = \sum_{i=1} \eta_i^-$	6.691**	0.159	3.527*	6.433**
	[0.011]	[0.691]	[0.062]	[0.012]
$H_{02}: \sum_{i=1} \beta_i^+ = \sum_{i=1} \beta_i^-$	6.562**	5.199**	1.775	2.758*
	[0.011]	[0.024]	[0.185]	[0.099]
$H_{03}: \gamma^+ = \gamma^-$	6.444**	1.348	0.001	5.300**
	[0.012]	[0.247]	[0.982]	[0.023]

Note: Numbers in parentheses are standard errors and those in square brackets are P-values for the asymmetry tests. (***), (**), and (*) represent the 1%, 5%, and 10% significance levels, respectively.