A THRESHOLD COINTEGRATION ANALYSIS OF ASYMMETRIC ADJUSTMENTS IN THE GHANAIAN MAIZE MARKETS

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ABSTRACT
This paper analyzes the long-run equilibrium relationship between retail and wholesale Ghanaian maize prices with cointegration test assuming asymmetric adjustment. Using the Enders-Siklos asymmetric cointegration tests, it is found that the retail and wholesale prices are cointegrated with threshold adjustment. Furthermore, the adjustment process is asymmetric when the retail and wholesale prices adjust to achieve the long-term equilibrium. Finally, there is faster convergence for negative deviations from long-term equilibrium than for positive deviations. These results imply that price increases tend to persist whereas decreases tend to revert quickly towards equilibrium.

KEY WORDS
Threshold cointegration; Asymmetric adjustment; Price transmission; Maize; Equilibrium relationship; Negative deviations.

Cointegration technique has been extensively employed to investigate relationship among price variables. The two widely used cointegration methods are Johansen and Engle-Granger two-step approaches. However these methods assume symmetric relationship between variables. These methods do not test for the possibility that the long run relationship may be asymmetric in nature. The technique of Enders and Siklos (2001) is well suited to the task of uncovering long-run relationships between time series when deviations from the long-run are asymmetric in nature. The technique generalizes the standard Dickey–Fuller test by allowing for the possibility of asymmetric movements in time-series data. This makes it possible to test for cointegration without maintaining the hypothesis of asymmetric adjustment to a long-term equilibrium. This study is aimed at empirically testing Enders and Siklos’s hypothesis of asymmetric adjustment to a long-run equilibrium between the Ghanaian retail and wholesale maize prices. First, this study test for the order of integration of the price series. Second the study analyzes asymmetric adjustment using threshold cointegration methodology.

Asymmetric price transmission. Empirical studies analyzing whether prices rise faster than they fall, have categorised the price dynamics into symmetric and asymmetric processes. Meyer and von Cramon-Taubadel (2004) notes that those processes for which the transmission differs according to whether the prices are increasing or decreasing (i.e. asymmetric price transmission) are of keen interest. By definition, asymmetry is an unreciprocal relationship between rises and falls in prices.

Price transmission has extensively been studied in agricultural commodity markets. However, a major limitation of some earlier studies (Mohanty, Peterson and Kruse, 1995; Boyd and Brorsen, 1998) is that they fail to take into account the possibility of the presence of an equilibrium relationship between any price series being examined (von CramonTaubadel, 1998). The first attempt to draw on cointegration technique in testing for asymmetry in vertical price transmission is von Cramon-Taubadel and Fahlbusch (1994) and later elaborated by von Cramon-Taubadel (1998). Numerous price transmission studies (Capps and Sherwell, 2007) implements von Cramon-Taubadel and Loy testing procedure for asymmetric price transmission or some variants of their proposed Error Correction Modeling (ECM) approach.

Following the introduction of the threshold technique, it is possible to consider an intuitively appealing type of ECM in which deviation from
the long-run equilibrium between two prices will lead to a price response if they exceed a specific threshold level. Balke and Fombe (1997) point out that the presence of fixed costs of adjustment may prevent economic agents from adjusting continuously. Only when deviation from equilibrium exceeds a critical threshold do the benefits of adjustment exceed the costs and cause economic agents to act to move the system back towards the equilibrium. Due to the above reasons, the threshold models of dynamic economic equilibrium have gained increased attraction in the analysis of price transmission asymmetries. Subsequently, several studies (Esso, 2010; Awokuse et al, 2009; Meyer, 2004; Cook, 2003; Cook, 2003; Cook et al, 2002; Hansen, 2002; Cook, 2000; and Balke and Fomby, 1997) measuring asymmetric price transmission have used the threshold modeling approach.

**METHODOLOGY**

**Stationarity test.** Kwiatkowski et al. (1992) proposed a LM-test for testing trend and/or level stationarity (henceforth: KPSS-test). They consider the following model:

\[
\begin{align*}
\Delta x_t &= \xi_t + \epsilon_t &\text{eq. (1)} \\
\epsilon_t &= \epsilon_{t-1} + \eta_t &\text{eq. (2)}
\end{align*}
\]

where \(\Delta x_t\) is a random walk and the error process is assumed to be i.i.d \((0, \sigma^2_\epsilon)\). The initial value \(r_0\) is fixed and corresponds to the level. If \(\xi=0\), then this model is in terms of a constant only as deterministic regressors. Under the null hypothesis, \(\epsilon_t\) is stationary and therefore \(y_t\) is either trend stationary or in the case of \(\xi=0\), level stationary.

First, regress \(y_t\) on a constant or on a constant and a trend depending on whether one wants to test level or trend stationary; second, calculate the partial sums of the residuals \(\tilde{\epsilon}_t\) from this regression as:

\[
S_t = \sum_{i=1}^{t} \tilde{\epsilon}_i, \ t = 1, 2, ..., T. \text{ eq. (3)}
\]

The test statistic is then defined as:

\[
LM = \frac{\sum_{t=1}^{T} \tilde{\epsilon}^2_s}{\bar{\sigma}^2_\epsilon} \text{ eq. (4)},
\]

with \(\bar{\sigma}^2_\epsilon\) being an estimate of the error variance from step one. The authors suggest the utilization of a Bartlett window \(w(s, \tilde{\epsilon}_1) = 1-s/ (1+s)\) as an optimal weighing function to estimate the long run variance \(\bar{\sigma}^2_\epsilon\); that is:

\[
\bar{\sigma}^2_\epsilon = s^2(T) = T^{-1} \sum_{t=1}^{T} \tilde{\epsilon}^2_t + 2T - 1 \sum_{s=1}^{1} \sum_{t=s}^{T} \tilde{\epsilon}_t \tilde{\epsilon}_{t-s} \text{ eq. (5)}
\]

The upper tail critical values of the level and trend stationary version are given in Kwiatkowski et al. (1992).

**Econometric Model.** The Engle-Granger two-stage approach focuses on the time series property of the residuals from the long run equilibrium relationship (Engle and Granger, 1987).

Consider \(y_t\) the retail prices and \(x_t\) the wholesale prices both of which are integrated of the order one.

Let the co integration relationship be:

\[
y_t = \beta_0 + x_t + u_t \text{ eq. (6)},
\]

where \(u_t\) measures the deviation from the equilibrium relationship between \(x_t\) and \(y_t\). Consistent estimates of the equilibrium error \(u_t\) can be obtained using ordinary least squares method. For the two variables to be cointegrated, \(u_t\) should be stationary.

In order words, rejecting the null hypothesis of no co integration, that is \(\rho=0\) against accepting the alternative hypothesis of cointegration, that is \(-2<\rho<0\), implies that the residuals in equation 1 is stationary.

\[
\Delta u_t = \rho u_{t-1} + \sum_{i=0}^{P} \phi_i \Delta u_{t-i} + \epsilon_t \text{ eq. (7)},
\]

where \(\epsilon_t\) is white-noise disturbance.

This framework can be employed to analyse symmetric price transmission. The above co integration tests assume symmetric price transmission. This implicit assumption of symmetric price adjustment is problematic if adjustments are asymmetric. Enders and Siklos (2011) argue that the test for co integration is misspecified and proposes a two-regime threshold co integration approach to entail asymmetric adjustment in the co integration analysis. The alternative model modifies equation 2 such that:

\[
\Delta u_t = \rho_1 l_t u_{t-1} + \rho_2 (1 - l_t) u_{t-1} + \sum_{i=1}^{P} \phi_i \Delta u_{t-i} + \epsilon_t \text{ eq. (8)}
\]

\[
l_t = 1 \text{ if } u_{t-1} \geq \tau, \ 0 \text{ otherwise}
\]

\[
\sum_{i=1}^{P} \phi_i = 0
\]

\[
\rho_1 + \rho_2 = 1
\]

\[
\phi_i = 0 \text{ for all } i > P
\]

The upper and lower tail critical values are given in Kwiatkowski et al. (1992).
Threshold cointegration analysis. The nonlinear cointegration analysis is conducted using the Threshold Autoregression models. The TAR and Consistent TAR models are estimated and the results are reported in Table 2. In selecting an appropriate lag to address possible serial correlation in the residual series, a maximum lag of 12 is specified and tried at the beginning. Diagnostic analyses on the residuals through AIC and BIC all reveal that a lag of 2 is sufficient. In estimating the threshold values for consistent TAR, the method by Chan (1993) is followed. The lowest sum of squared errors for the consistent TAR model is 1191.69 at the threshold value of -2.554. Alternatively, the threshold value for

<table>
<thead>
<tr>
<th>n/n</th>
<th>Test statistics</th>
<th>Critical values 10% 5% 2.5% 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale (Levels)</td>
<td>0.2755</td>
<td>0.119 0.146 0.176 0.216</td>
</tr>
<tr>
<td>Wholesale (First Difference)</td>
<td>0.017</td>
<td>0.119 0.146 0.176 0.216</td>
</tr>
<tr>
<td>Retail (levels)</td>
<td>0.3839</td>
<td>0.119 0.146 0.176 0.216</td>
</tr>
<tr>
<td>Retail (First Difference)</td>
<td>0.0151</td>
<td>0.119 0.146 0.176 0.216</td>
</tr>
</tbody>
</table>

Source: Author’s calculation
TAR is set at 0. While the competing threshold cointegration models have similar results (table 2), the consistent TAR model has the lowest AIC statistic of 1908 and BIC statistic of 1930, and therefore, is deemed to be the best. Focusing on the results from the consistent TAR model, this study finds that the F-test for the null hypothesis of no cointegration has a statistic of 18.371 and it is highly significant at the 1% level. Thus, the retail and wholesale prices of maize in Ghana are cointegrated with threshold adjustment.

### Table 2 – Estimates of the speed of adjustments parameters of the Threshold Model

<table>
<thead>
<tr>
<th>n/n</th>
<th>Threshold Autoregressive Model (TAR)</th>
<th>Consistent Threshold Autoregressive Model (CTAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_1$</td>
<td>-0.12057(-4.517)*</td>
<td>-0.11202(-4.5671)*</td>
</tr>
<tr>
<td>$\rho_2$</td>
<td>-0.14732(-3.948)*</td>
<td>-0.19787(-4.327)*</td>
</tr>
<tr>
<td>$\rho_1\rho_2$</td>
<td>17.081(0.000)**</td>
<td>18.371(0.000)**</td>
</tr>
<tr>
<td>$\rho_1\rho_2 = 0$</td>
<td>0.354(0.550)**</td>
<td>2.779(0.096)**</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0</td>
<td>2.554</td>
</tr>
<tr>
<td>SSE</td>
<td>1197.313</td>
<td>1191.693</td>
</tr>
<tr>
<td>AIC</td>
<td>1911</td>
<td>1908</td>
</tr>
<tr>
<td>BIC</td>
<td>1932</td>
<td>1930</td>
</tr>
</tbody>
</table>

Notes: * Values in the parentheses are t values. ** Values in the parentheses are estimated probability values; outside parentheses are the F statistic values. Source: Author’s calculation.

Furthermore, the F statistic for the null hypothesis of symmetric price transmission has a value of 2.779 and it is also significant at the 10% level. Therefore, the adjustment process is asymmetric when the retail and wholesale prices of Ghanaian maize adjust to achieve the long-term equilibrium.

The point estimate for the price adjustment is -0.11202 for positive shocks and -0.19787 for negative shocks. The point estimate of $\rho_1$ (-0.11202) for the retail and wholesale prices indicates that approximately 11.2% of a positive deviation from the long-run equilibrium relation is eliminated within a week. Alternatively, the point estimate of $\rho_2$ (-0.19787) indicates that 19.8% of a negative deviation from the long-run equilibrium relation is eliminated within a week. In effect, the adjustment is almost 1.7 times faster for negative deviations from equilibrium than for positive deviations. Therefore, there is substantially faster convergence for negative (below threshold) deviations from long-term equilibrium than positive (above threshold) deviations.

Model estimation results suggest that the Consistent TAR model detects asymmetry whilst TAR model fails to support this evidence. These results imply that differences in inferences are possible depending on weather the threshold parameter is estimated from the data or imposed by the researcher.

### CONCLUSION

This study estimated the price transmission in the Ghanaian maize market using retail and wholesale prices. Specifically, the study tested for the order of integration of the price series and analyzed asymmetric adjustment using threshold cointegration methodology. The threshold cointegration technique makes it possible to test for cointegration without maintaining the hypothesis of a symmetric adjustment to a long-term equilibrium. The results of the KPSS test show that the retail and wholesale prices are non stationary and integrated of the order one. The retail and wholesale prices of maize in Ghana are cointegrated with threshold adjustment. The Enders and Silkos (2001) procedure provides support for the alternative hypothesis of asymmetric adjustment. The findings of this study indicate that there is a faster convergence for negative deviations from long-term equilibrium than positive deviations. These results suggest that price increases tend to persist whereas decreases tend to revert quickly towards equilibrium.

Furthermore, alternative threshold modeling approaches leads to differences in conclusion. It is recommended that CTAR be used together with the TAR and the cause of the positive asymmetry identified be investigated.
REFERENCES


