Cereal price transmission from international to domestic markets in Africa[1]

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Abstract

This study aims to improve our understanding of the extent and speed of the transmission of international cereal prices to local markets in developing countries with a focus on African countries. We analyse a sample of cereal price transmission (PT) estimates using the FAO's GIEWS dataset and international reference prices for rice, maize and wheat. In the results, the share of cointegrated commodity markets is higher in African countries compared with the other countries in our sample (49% compared to 35%). The VECM estimates imply that on average 73% of an international price movement is transmitted to local markets and half of it within 2.2 months, more than 1 month faster than in other regions. African rice markets show the highest share of cointegrated price pairs (68%), the largest long-run PT coefficient and the fastest price reaction compared with other cereal products. In most cases domestic prices adjust to deviations from the long-run price relationship, but international prices do not. The only notable exception to this rule is rice, especially after July 2007, which suggests that the determination of international rice prices differs fundamentally from the determination of international wheat and maize prices. In a subsequent meta-regression analysis we measure how much of the variation in the samples of PT estimates can be explained by country- or product-specific factors. The choice of covariates is motivated by recent price transmission literature.

Keywords: price transmission, cointegration, developing countries, agricultural trade, maize, rice, wheat, commodity prices

JEL Classification: C32, F15, Q11, Q17, Q18

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1. Introduction

Motivated by the recent peaks in international food prices, we conducted a study to improve our understanding of the extent and speed of transmission of international cereal price changes to the domestic retail and wholesale level in developing and emerging countries (Greb et al. 2012). Other than most recent studies on world-to-domestic PT we attempted to extract general lessons about the drivers of PT by estimating PT processes with a consistent set of price data (FAO-GIEWS) for a large number of countries using a uniform methodology. Based on this report, we use this study to set the focus specifically on PT results for African countries which differ significantly from those in other regions or continents. In the sample, 35 of the 71 countries are in Africa and also roughly half of the 499 domestic price series.

The study has the following structure. In section 2, we give a brief overview of the vector error correction model that we used for estimating our sample of measures of cereal PT. In section 3, we describe how we used the GIEWS dataset and present the results of African price pairs for each cereal product and before and after a structural break in July 2007. In a subsequent meta-regression analysis we measure how much of the variation in the resulting samples of PT estimates can be attributed to factors that might be expected to influence the strength of PT (section 4). This is followed by a discussion of the results and the conclusion in section 5.

2. Method: the vector error correction model

2.1 The structure of the vector error correction model

The study of PT for homogeneous commodities in space, or for a product as it is transformed along the stages of the marketing chain (e.g. wheat – flour – bread), has attracted the interest of agricultural economists for many decades (Meyer 2004). Early empirical studies of PT were based on simple correlation and regression analyses that did not account for dynamics and lead-lag relationships in price data (for a survey, see Fackler and Goodwin, 2001). In the course of the 1980s, these methods were increasingly replaced by dynamic regression models that include lagged prices (e.g. Ravallion, 1986) and studies based on the concept of Granger causality (Gupta and Mueller, 1982). The emerging cointegration literature highlighted several pitfalls associated with the regression analysis of price data. In particular, since price data are often non-stationary, regression can lead to spurious results (Hassouneh et al, 2012). The basic insight of the cointegration approach is that to avoid the pitfall of spurious regression one must test whether non-stationary prices series (also referred to as 'integrated' price series) are not only correlated with one another but are rather 'co-integrated'. Cointegrated means that there exists a linear combination of the non-stationary series that is itself stationary, in other words that the series share a common form of non-stationarity and cannot drift apart indefinitely.

Ardeni (1989) published the first study of PT on agricultural markets based on cointegration methods. It is fair to say that with the exception of a comparatively small literature based on so-called parity bounds models (Barrett and Li, 2002) today essentially the entire empirical PT literature draws on cointegration methods and, in particular, the so-called vector error correction model (VECM). The VECM is a re-parametrization of the standard vector autoregressive (VAR) model which relates the current levels of a set of time series to lagged values of those series. A simple VECM that captures the interactions between international or world prices and domestic price takes the following form:

(1) $$\Delta p_t^d = \varphi_1 + \alpha_1 \underbrace{\left(p_{t-1}^d - \beta_1 p_{t-1}^w\right)}_{error\ correction\ term} + \delta_1 \Delta p_{t-1}^w + \rho_1 \Delta p_{t-1}^d + \varepsilon_{1t} \text{ (a)}$$

$$\Delta p_t^w = \varphi_2 + \alpha_2 \underbrace{\left(p_{t-1}^d - \beta_1 p_{t-1}^w\right)}_{error\ correction\ term} + \delta_2 \Delta p_{t-1}^w + \rho_2 \Delta p_{t-1}^d + \varepsilon_{2t} \text{ (b).}$$

where
p_t^d is the domestic price;
p_t^w is the world price; and
φ, α, β, δ, and ρ are parameters to be estimated.

In matrix notation, and allowing for more than one lag of the price difference terms, this VECM can be written compactly as:

(2) $$\begin{bmatrix}\Delta p_t^d \\ \Delta p_t^w\end{bmatrix} = \begin{bmatrix}\varphi_1 \\ \varphi_2\end{bmatrix} + \begin{bmatrix}\alpha_1 \\ \alpha_2\end{bmatrix} \begin{bmatrix}1 & \beta_1\end{bmatrix} \begin{bmatrix}p_{t-1}^d \\ p_{t-1}^w\end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix}\delta_{1i} & \rho_{1i} \\ \delta_{2i} & \rho_{2i}\end{bmatrix} \begin{bmatrix}\Delta p_{t-i}^w \\ \Delta p_{t-i}^d\end{bmatrix} + \begin{bmatrix}\varepsilon_{1t} \\ \varepsilon_{2t}\end{bmatrix}.$$

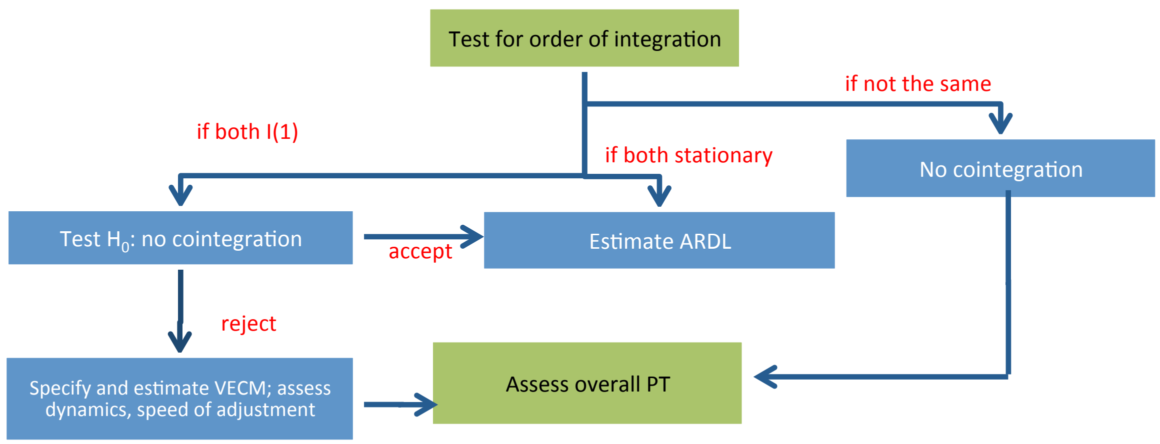
From the perspective of empirical PT analysis, the main advantage of the VECM over the VAR is that it separates the long-run equilibrium (or 'cointegrating') relationship between p^w and p^d – which is captured by the error correction term $\left(p_{t-1}^d - \beta_1 p_{t-1}^w\right)$ – from the short-run dynamics that ensure that any deviations from this long-run equilibrium are 'corrected' and thus only temporary. The key parameters in the VECM are β_1, which describes how one price reacts to changes in the other in the long run[2], and the so-called 'adjustment' parameters α_1 and α_2. If p^w and p^d are cointegrated, then α_1 and α_2 must have negative and positive signs, respectively. If this is the case, then if for example p^d becomes too large relative to p^w and the error correction term is correspondingly positive, a decrease in p^d in the first equation of the VECM, and an increase in p^w in the second equation, will drive the prices back towards their long-run equilibrium. One-to-one price transmission in the long run requires that $\beta_1 = 1$, while $0 < |\alpha_i| \leq 1$, with large (small) values of α_1 and α_2 indicating that errors are corrected rapidly (slowly).[3]

Figure 1 outlines the basic empirical strategy for estimating PT. The first step is to determine whether the individual price series p^w and p^d are both non-stationary (also referred to as 'integrated' or 'I(1)'). This is usually carried out using the ADF (Dickey and Fuller, 1979) and KPSS tests (Kwiatkowski et al., 1992). If the prices are not both I(1), they cannot be cointegrated. If they are both stationary or 'I(0)' they can be studied using Auto-Regressive Distributed Lag (ARDL) models. If the series are both I(1), the null hypothesis that they are not cointegrated can be tested using a two-step OLS procedure proposed by Engle and Granger (1987) or a maximum likelihood procedure developed by Johansen (1988). If the null of no cointegration is rejected, the VECM in equation (2) can be estimated, again using methods proposed by Engel and Granger or Johansen. Finally, the resulting estimates of β and α are interpreted.

[2] If estimation is based on prices in logarithms then β_1 can be interpreted as the long-run elasticity of price transmission.

[3] The speed of error correction captured by the magnitude of an adjustment parameter must be interpreted relative to the frequency of the data that is used to estimate it. An α of 0.4 estimated with annual data implies that 40% of any deviation from long-run equilibrium is corrected within the space of one year. An α of 0.25 estimated with monthly data is smaller in magnitude but would nevertheless lead to over 95% correction of any deviation from long-run equilibrium in the course of one year. Some authors transform α's into so-called half-lives that indicate how many units of time are required for the correction of one-half of a deviation from the long-run equilibrium. An α of 0.25 estimated with monthly data corresponds to a half-life of 2.41 months.

Figure 1: Conceptual framework for assessing price transmission



Source: Own depiction based on Rapsomanikis et al. (2003).

2.2 Limitations of the vector error correction model, and alternatives

While the VECM underlies most empirical work in PT analysis, it is restrictive is some settings. In particular, the VECM in equation (2) is linear in two senses (Hassouneh et al, 2012). First, it is linear in the sense that all of the parameters in the model are assumed to be constant over the entire sampling period. Second, it is linear in the sense that the dependent variables react linearly to changes in the independent variables. Numerous studies have shown that in many applications one or both of these types of linearity cannot be expected to hold (Hassouneh et al., 2010; Serra and Goodwin, 2003; Serra et al. 2006; von Cramon-Taubadel, 1998; von Cramon-Taubadel and Amikuzuno, 2012).

For our purposes, the first type of linearity is especially restrictive. The PT relationship that links an international price to a country's domestic market price need not be constant over time. Changes in the country's trade policy (for example an increase or reduction of import tariffs) can alter the nature of the PT relationship, as can a switch from a net export to a net import position. Furthermore, spatial equilibrium theory (Takayama and Judge, 1971) predicts that short-run price adjustments due to arbitrage will take place only if the difference between international and domestic prices exceeds a threshold that is determined by transport and transaction costs (Barrett and Li, 2002). If the difference between prices is less than this threshold, there is no incentive for traders to engage in arbitrage, and prices can move independently of one another.

In such cases PT will be characterized by different so-called 'regimes' (for example, one regime before and one regime after an import tariff change; or one regime for the net export situation, and one for the net import situation). In recent years several models of regime-dependent PT have been developed and applied in the literature. Most of these can be described as piecewise linear models in which each regime is characterized by a standard VECM as in equation (2) above, and some trigger or transition mechanism determines when the model jumps from one regime to another. This trigger can be exogenous (e.g. coinciding with the date of a policy change) or endogenous (e.g. determined by whether the distance between the international and the domestic prices exceeds a certain threshold). Hassouneh et al. (2012) review a number of the regime-dependent PT models that are common in current research, including the threshold VECM (Goodwin and Piggott, 2001), the asymmetric VECM (von Cramon-Taubadel, 1998), and the smooth transition VECM (Teräsvirta, 1994).

Estimating regime-dependent PT models is considerably more complicated than estimating a standard VECM. Some of these models require additional exogenous variables in addition to the endogenous prices, for example information on the timing of policy changes or other exogenous shocks that lead to regime changes. Others regime-dependent models such as the threshold VECM can be estimated using prices alone, but require additional information and testing to determine the appropriate number of thresholds.[4] Finally, there is no unified testing framework for comparing these regime-dependent models with one another.

Authors who are interested in analyzing PT in a specific product/country setting, or who use such a specific setting to illustrate a new regime-dependent PT model that they have developed or refined, can afford to engage in the additional data collection, specification, testing and interpretation that this entails. As outlined in section 3.2 below, however, the FAO GIEWS data provides us with domestic price series for three main cereal products (maize, rice and wheat) in 71 countries. It is beyond the scope of this study to carry out detailed regime-dependent PT analysis for each of these individual settings. Instead, we are obliged to use a comparatively simple PT model, such as the VECM, the estimation of which can be automated to permit the analysis of a large number of domestic-international price pairs. We recognize that the simple VECM specification in (2) will not be appropriate for all of the domestic-international price pairs in the GIEWS data. The additional insights that can be generated by estimating PT for a large number of price pairs and then analyzing the resulting cross-section sample of results come at the cost of a necessarily simple method of analysis that is not appropriate for each of these pairs individually.

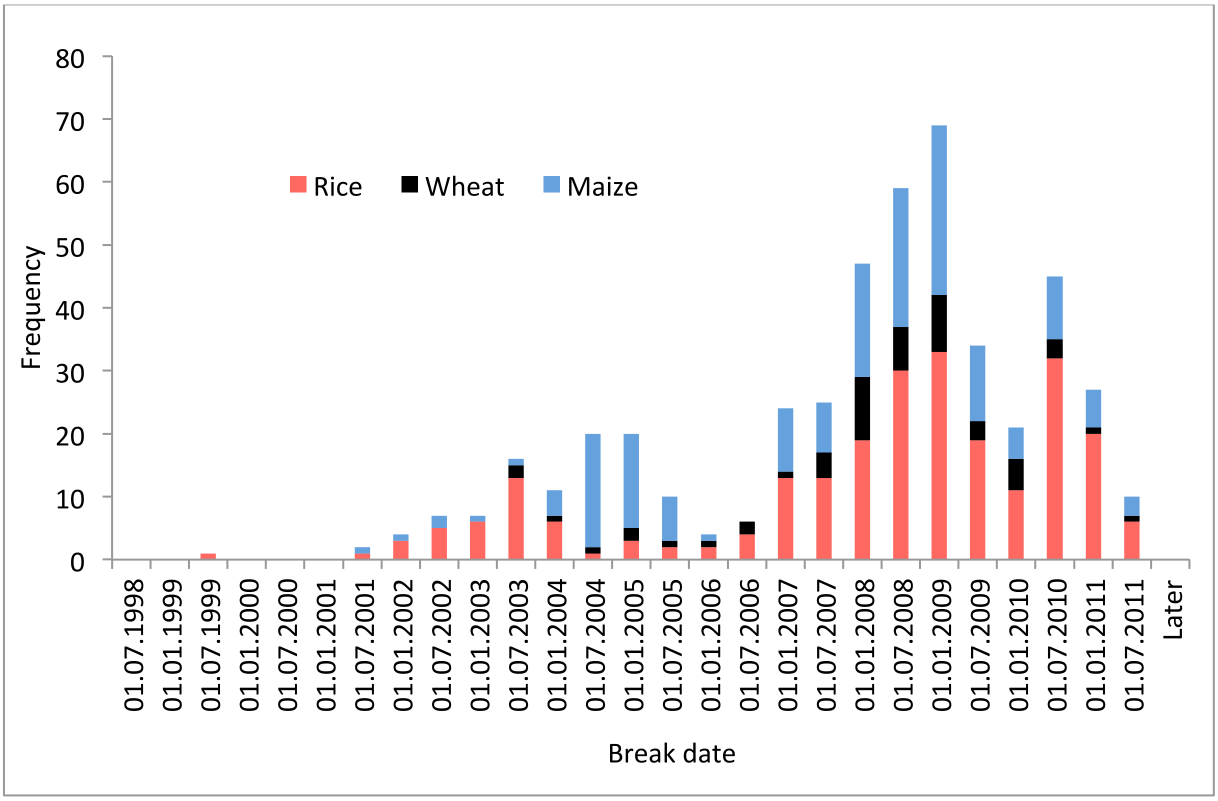
In an attempt to deal with the shortcomings of the simple VECM, we propose an alternative method of analysis. To allow for at least one possible source of non-linearity we modify the basic VECM in equation (2) to include a structural break which we postulate to have taken place in July 2007. This roughly corresponds to the beginning of the first agricultural price peak and the beginning of the recent phase of increased volatility on international commodity markets. Hence, we estimate the following model which allows the nature of price transmission between international and domestic cereal prices to change with the onset of higher and more volatile price in recent years. The resulting specification is as follows, where the superscript * distinguishes between pre-break and post-break parameters:

$$(3) \qquad \begin{bmatrix} \Delta p_t^d \\ \Delta p_t^w \end{bmatrix} = \begin{cases} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} 1 & \beta_1 \end{bmatrix} \begin{bmatrix} p_{t-1}^d \\ p_{t-1}^w \end{bmatrix} + \sum_{i=1}^k \begin{bmatrix} \delta_{1i} & \rho_{1i} \\ \delta_{2i} & \rho_{2i} \end{bmatrix} \begin{bmatrix} \Delta p_{t-i}^d \\ \Delta p_{t-i}^w \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \ t < \text{July 2007} \\ \begin{bmatrix} \alpha_1^* \\ \alpha_2^* \end{bmatrix} \begin{bmatrix} 1 & \beta_1^* \end{bmatrix} \begin{bmatrix} p_{t-1}^d \\ p_{t-1}^w \end{bmatrix} + \sum_{i=1}^k \begin{bmatrix} \delta_{1i}^* & \rho_{1i}^* \\ \delta_{2i}^* & \rho_{2i}^* \end{bmatrix} \begin{bmatrix} \Delta p_{t-i}^d \\ \Delta p_{t-i}^w \end{bmatrix} + \begin{bmatrix} \varphi_1^* \\ \varphi_2^* \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t}^* \\ \varepsilon_{2t}^* \end{bmatrix}, \ t \geq July\ 2007. \end{cases}$$

Equation (3) is thus a regime-dependent VECM that links two standard VECMs, one for the period prior to July 2007, and one for the period thereafter. To check whether July 2007 is a plausible cut-off, we applied the Gregory and Hansen (1996) test of the null of no cointegration against the alternative of cointegration with a possible regime shift to each domestic/international price pair in the GIEWS data. Figure 2 shows the distribution of the break dates selected by the Gregory and Hansen test. While there is evidence of regime shifts in some domestic/international price relationships in 2003/04 for rice and 2004/05 for maize, for all three products (rice, maize and wheat) by far the most regime shifts are indicated in 2007/08. July 2007 therefore appears to be a reasonable choice for the cut-off date in the regime-dependent VECM in equation (3).

[4] Furthermore, Greb et al. (2011) demonstrate that the maximum likelihood method used to estimate threshold VECMs in the literature to date is biased.

Table 1: The distribution of break dates chosen by the Gregory and Hansen (1996) test



Source: Own calculations with GIEWS price data.

3. Estimates of international-domestic cereals price transmission

Following the discussion of methods in the previous section, we follow a comprehensive approach to generate insights into the nature of international to domestic PT for major cereal products. Using the extensive FAO GIEWS price data set, we test whether the price series are cointegrated with a corresponding international reference price. For market pairs where this is the case we generate estimates of β and α using the VECM in equation (2) and the regime-dependent VECM in equation (3). This work is outlined in section 3.2 below. In this analysis we consider maize, rice and wheat.

This approach has its advantages and disadvantages. As discussed above, the FAO GIEWS price data includes hundreds of price series. Hence, we are obliged to automate the estimation and work with simple uniform specifications that may not be appropriate in all cases. On this count estimates in the PT literature might be more reliable. Most studies in the literature only report a few PT estimates, typically for a single product and one or relatively few counties (Table 13). As a result, the estimates in other studies can be expected to reflect detailed work by authors who have a comprehensive understanding of the markets that they study, and who have undertaken careful specification searches, for example to determine appropriate lag-lengths for the VECMs that they estimate, etc.

The FAO Global Information and Early Warning System (GIEWS) food price data set was established in 2009 as part of the FAO Initiative on Soaring Food Prices (ISFP).[5] The prices reported in GIEWS are collected from national official sources and non-official institutions. The GIEWS price series are monthly and most run through to the end of 2011; some start as early as 1995, others as late as 2008. We impose a minimum length of 10 observations for a time series to be considered in our analysis and analyze PT between domestic and the following international prices:

- wheat – US No. 2 HRW, FOB Gulf of Mexico
- rice – Thai 5%, FOB Bangkok
- yellow maize – US No. 2 yellow, FOB Gulf of Mexico
- white maize –white maize, FOB Randfontein (South Africa).

The GIEWS data includes a total of 57 domestic prices for wheat, 262 domestic prices for rice and 180 domestic prices for maize. GIEWS mainly provides results for countries in Africa, Asia/Pacific and Latin America, but only 7 for Europe and none for North America (499 in total). To estimate the VECMs in equation (2) and (3) above with the GIEWS data a decision about the number of lags (*k*) to include must be reached. As shown in Table 2, the Akaike Information Criterion (AIC – Akaike, 1974) indicates that k=1 in the great majority of cases, so for simplicity we employ one lag throughout.

Table 2: The optimal number of lags to include in VECM estimation as indicated by the AIC

Commodity	**Number of lags**											
	1		**2**		**3**		**4**		**5**		**6**	
Maize	167	92.8%	7	3.9%	3	1.7%	1	0,6%	2	1.1%	0	0%
Rice	185	70.6%	44	16.8%	13	5.0%	10	3,8%	5	1.9%	5	1.9%
Wheat	45	78.9%	9	15.8%	2	3.5%	1	1,8%	0	0%	0	0%

Source: Own calculations with GIEWS price data.

3.1 Cointegration

Tables 3 and 4 present information on the numbers and shares of international/domestic price pairs which are found to be cointegrated according to the GIEWS estimates. Overall, the sample suggests that international and domestic prices are cointegrated more often for African markets (49%) than for markets located in Asia, Pacific region, Latin America, Europe and Asia (35%). This tendency holds also the case for the estimates generated with allowing for a structual break at July 2007. Before the break 26% of all African market pairs are cointegrated and 21% of market pairs in other regions. In the period thereafter cointegration is found in 41% of African price pairs and 28% of price pairs in the rest of world.

[5] We are grateful to David Hallam for providing us with this data in electronic form.

Table 3: The prevalence of cointegration in the PT estimates

	entire period	before 7/2007	after 7/2007
Africa	121 of 248 (49%)	45 of 170 (26%)	101 of 247 (41%)
rest of the world	87 of 251 (35%)	44 of 214 (21%)	69 of 250 (28%)
Total/Σ_N	208 of 499 (42%)	89 of 384 (23%)	170 of 497 (34%)

Note: Cointegration is determined by Johansen Test with 5% significance level. Rest of the world = Asia, Pacific Region, Latin America, Europe and Oceania. For a detailed list of all countries, see Appendix, Table 15.
Source: Own calculations with GIEWS price data.

Table 4: The prevalence of cointegration by product

	Maize			**Rice**			**Wheat**		
	entire period	before 2007	after 2007	entire period	before 2007	after 2007	entire period	before 2007	after 2007
Africa	28% (30)	24% (18)	31% (33)	68% (82)	32% (25)	49% (59)	41% (9)	11% (2)	41% (9)
ROW	34% (25)	18% (12)	19% (14)	40% (57)	28% (32)	35% (49)	14% (5)	0% (0 of 32)	17% (6)

Note: Cointegration is determined by Johansen Test with 5% significance level. Number of cointegrated pairs in brackets.
Source: Own calculations with GIEWS price data.

In the results for Africa there is less frequent evidence of cointegration for maize (28%) than for rice (68%) and wheat (41%) (Table 4). The market pairs for maize in Africa display a slightly lower prevalence of cointegration than other countries (28% compared with 34%). However, in the results for rice and wheat we find a much higher share of cointegrated market pairs in Africa compared with non-African countries.

In most cases, the share of cointegrated pairs in Africa is lower if we test for cointegration in the two regimes before and after July 2007. Many series of the earlier regime dropped out of the estimation because of the low number of observations. Furthermore, some of the shorter price series may lead to fewer positive tests of cointegration. Especially for rice price pairs (e.g. Rwanda) there is sometimes evidence for cointegration for an entire price series but not as we would logically expect also for both regimes. Deviating price movements matter more in shorter series even if they are smoothed out in the long-run and may thus distort the test. In other cases the cointegration test allowing for a regime-switch in 2007 seems more appropriate than testing for the overall period as many results for maize price pairs suggest. Taking this into account the results imply somewhat more frequent cointegration after the start of the global food price crisis on maize in Cape Verde, Chad, Ethiopia, Niger, Togo and Uganda, on rice in Guinea-Bissau and on wheat in Sudan (Table 16-18). Fewer maize markets in South Africa and Zimbabwe are cointegrated for the post-2007 period, this could indicate a certain degree of decoupling of local price levels from international prices.

3.2 Estimates of the long-run price transmission coefficient and the adjustment parameters

The results point to relatively slow PT for all cereal products and regions. Table 5 summarizes the average estimates of the long-run PT coefficient β and of the adjustment parameters α_1 and α_2 and by cereal product. On average the estimated β is 0.73 for international-domestic price pairs in African countries. This indicates that on average changes in international prices are transmitted by 73% to domestic prices. As discussed above, the adjustment parameter from the first equation in (2) above is expected to be negative. The average speed of adjustment of local prices (α_1) is -0.27. This implies that it will take roughly 2.2 months to correct one-half of any disequilibrium that emerges due to unexpected price movements on international or domestic markets. A somewhat slower response is indicated by the average across all cereals for countries in other regions (average α_1= -0.19, which corresponds to a half-life of 3.3 months). In addition, the average β is slightly smaller (0.64). In addition to the strong and above-average prevalence of cointegration with the world market price, also the largest long-run PT coefficients and the fastest price reaction was found for African rice markets. 75% of a price shock is transmitted in the long-run, with half of the adjustment of local prices taking place within 2 months. The average long-run transmission of maize prices is equivalent but with a half-life of 2.5 months. However there is evidence that for a number of rice market pairs, the world market contributes to the adjustment in prices.

Table 5: Average estimates of the long-run PT coefficient and the adjustment parameters

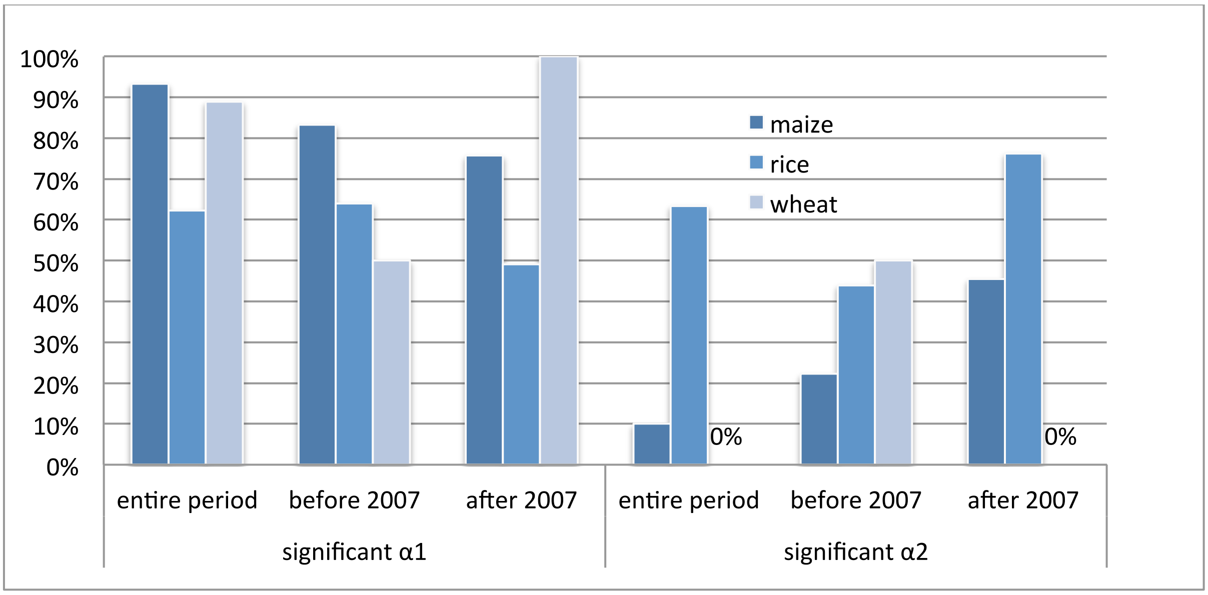
	∅ β				**∅ α_1**				**∅ α_2**		
	maize	**rice**	**wheat**	**all**	**maize**	**rice**	**wheat**	**all**	**maize**	**rice**	**all**
Africa	0.75	0.75	0.58	0.73	-0.24	-0.29	-0.21	-0.27	-0.20	0.20	0.18
ROW	0.69	0.57	1.23	0.64	-0.25	-0.17	-0.13	-0.19	0.08	0.22	0.21
Total	*0.72*	*0.67*	*0.81*	*0.69*	*-0.24*	*-0.24*	*-0.18*	*-0.24*	*-0.13*	*0.21*	*0.19*

Note: Only significant coefficients for cointegrated market pairs are considered. The expected sign of α_1 is negative. None of the wheat estimates of α^2 were significant. ROW=rest of the world
Source: Own calculations with GIEWS price data.

3.3 Price reaction on domestic level and world market side

In most cases, we focus on the adjustment parameter from the first equation in (2) above, i.e. the equation that explains changes in domestic prices, because in the majority of all cases, only this α is statistically significant. In other words, the dynamics of international/domestic cereal PT are such that domestic prices adjust to deviations from the long-run price relationship, but international prices do not. The only notable exception to this rule is rice, to which we return below.

Table 6: Share of cases in which the adjustment parameter is significant



Note: Only coefficients for cointegrated market pairs in African countries are considered. Significance level was chosen at 5%.
Source: Own calculations with GIEWS price data.

If the adjustment parameters from the second equation in (2) above are considered, we see that these are in most cases insignificant, except for rice (Table 6). Specifically, there is evidence of a statistically significant reaction by international prices to disequilibrium between domestic and international prices in 121 African market pairs (45%), of which 82 involve rice.[6] As pointed out above, the simple linear VECM is restrictive and probably not appropriate for many of the individual price pairs in the GIEWS data. Hence, a certain number of spuriously significant adjustment parameters for international prices can be expected. Nevertheless, the fact that significant adjustment parameters for international prices occur, if at all, almost exclusively for rice price pairs suggests that the determination of international rice prices differs fundamentally from the determination of international wheat and maize prices. These results confirm a very similar finding by Gilbert (2011). We can conclude that most countries are price takers on wheat and maize markets, but the evidence for rice is mixed.

3.4 Price transmission before and after July 2007

Table 7 contrasts average estimates of the coefficient of PT on cereal markets before and after the onset of the recent phase of price peaks and increased price volatility in mid-2007. If we compare the average estimates from the period prior to July 2007 with the average estimates from the period thereafter, price transmission has become stronger and faster for African-international price pairs, whereas the opposite is the case for the country group consisting of Asia, the Pacific Region, Latin America, Europe and Oceania.

On African maize and wheat markets the long-run PT coefficients (β) have increased considerably since mid-2007, from 0.08 to 0.59 and from 1.9 to 25.28, respectively.[7] On rice markets the average PT coefficient does not change after July 2007. The short-run adjustment coefficients (α_1) for maize

[6] Similar results were found for the other countries in our sample.
[7] The implausibly large average PT elasticity result is caused by an outlier for an Ethiopian wheat market with an estimated β of 166.8 after July 2007.

and wheat have increased (in absolute terms), from -0.29 to -0.37 and from -0.06 to -0.24, respectively. However, at the same time the short-run adjustment coefficients for rice (α_1) have on average fallen, from -0.59 to -0.29. This suggests that PT has become more complete and faster since mid-2007 for maize and wheat. The extent of PT for rice does not change but the price reaction becomes slower for the second period. As discussed above, after July 2007 a considerable amount of the price reaction to shocks in the rice market takes place on the world market side. The average speed of adjustment (α_2) for rice has doubled. Overall price transmission becomes faster and more complete after July 2007 for all cereal price pairs in African markets if we take the world rice market reaction into account. However, these results must be interpreted with caution. The prevalence of outliers is high in particular in the post-July 2007 VECM results, presumably due to the short length of the available time series. Furthermore, here only coefficients of cointegrated market pairs are reported, with potential biases in the results, as discussed earlier.

Table 7: Average price transmission parameters estimated before and after July 2007

	∅ β				**∅ α_1**				**∅ α_2**			
	maize	**rice**	**wheat**	**all**	**maize**	**rice**	**wheat**	**all**	**maize**	**rice**	**wheat**	**all**
1	0.08	0.90	1.9	0.81	-0.29	-0.59	-0.06	-0.45	-0.32	0.12	0.49	0.03
2	0.59	0.90	25.28	3.07	-0.37	-0.29	-0.24	-0.32	-0.19	0.24	-	0.13
3	0.84	0.65	-	0.69	-0.49	-0.21	-	-0.29	0.47	0.03	-	0.06
4	0.70	0.27	1.63	0.42	-0.37	-0.24	-0.26	-0.28	0.16	0.14	-	0.14

Note: Only significant coefficients for cointegrated market pairs are considered. The expected sign of α_1 is negative. 1) Africa before July 2007 2) Africa after July 2007 3) rest of the world before July 2007 4) rest of the world after July 2007
Source: Own calculations with GIEWS price data.

4. Analysis of the determinants of the strength of price transmission

4.1 Method

The averages presented above hide considerable variation in the estimates of α and β for individual country/product combinations. To explain this variation, and thus to generate insights into the factors that influence the strength of PT from international to domestic markets, we estimate meta-regressions. In each regression a set of estimated parameters (α's or β's) is regressed on a set of covariates that might be expected to influence PT. These covariates are listed and described in Table 8 and cover geographic (e.g. landlocked), infrastructural (e.g. logistics), institutional (e.g. STE) and market or commodity specific factors (e.g. net importer). We include dummy variables for cereals (omitting rice) and regions (omitting Asia/Pacific) to capture any corresponding fixed effects.

4.2 Results

We first present the results of logit regressions that predict whether pairs of international and domestic prices are cointegrated. The dependent variable equals 1 when the two prices are cointegrated, and 0 otherwise, and this variable is explained using the covariates listed in Table 8 – for example whether the country in question is landlocked, whether it has an STE for cereals, etc.

Table 8: Covariates used in the meta-analysis of the determinants of price transmission

Name	Description	Source / link	Expectation / theory
Commodity fixed effects	Wheat, maize, rice		Unobserved commodity-specific heterogeneity
Region fixed effects	Europe; East and South Africa; West and Central Africa; MENA and Asia; Oceania; Latin America	http://unstats.un.org/unsd/methods/m49/m49regin.htm	Unobserved region-specific heterogeneity
Landlocked	1 if country has no access to sea	Google maps	For landlocked countries, international trade must cross more borders
Trade openness	Total trade as a share of income, average 2006-2010 (Import + Export /GDP)	World Bank Development Indicators	Open economies are better integrated into world markets and thus PT should be stronger
STE	1 for countries that have state trading enterprises (STEs)	Literature*	STEs interfere with trade and insulate the domestic prices from international fluctuations
Ease of trade	Ease of trading across borders, between 0 (worst) to 1 (best)	World Bank, Doing Business, Ease of Trading across borders.	Transaction costs reduce PT
Logistics	Logistics performance index of quality of trade and transport-related infrastructure between 1 (worst) to 5 (best)	World Bank 2007	Better logistics mean lower costs of trade and higher PT
Net importer	Net cereal import ratio (export – import, 3 year average 2009-2011) to domestic consumption	USDA , PSD Online	If the share of staple imports in domestic consumption is high, more is undertaken to insulate domestic markets
Retail	1 if domestic price is measured at the retail rather than a more upstream level	Literature / GIEWS	The farther 'inland' a domestic price is measured, the weaker its link to international prices

*Note: * See Appendix Table 14 for a list of the countries with STEs.*

Maize and wheat are less likely to be cointegrated with the corresponding international prices than rice prices are (by roughly 30 and 20%, respectively), and domestic prices in East and South Africa, West and Central Africa and Latin America are more likely to be cointegrated with international prices (by 25, 32 and 19%, respectively). As we would expect, if an STE is responsible for trading the product in question, the probability of cointegration falls by almost 22%. If the domestic price being considered is a retail price, the probability that it is cointegrated with international prices falls by almost 13%. This result is plausible, as retail prices are further removed from international prices than wholesale or border prices. Improvements in logistics have a surprising negative impact on the probability of cointegration between domestic and international prices. Ease of trade has the expected positive impact, and being landlocked the expected negative impact on the probability of cointegration, but neither of these effects is significant. A high net import ratio may lead to more policy intervention to insulate domestic markets from international price movements, however this is not reflected in the results. Most of these results also hold if only the time period after July 2007 is considered. However, if the period prior to July 2007 is considered the logit regression is much less informative. This is probably due to the fact that many GIEWS price series are very short prior to July 2007, leaving too few observations for dependable cointegration testing. Hence, the logit regression for the pre-July 2007 period is based on fewer and less trustworthy test results.

Table 9: Logit regression of cointegration status on factors that might influence price transmission

Covariate	entire period	before July 2007	after July 2007
Maize	-0.296 ***	0.044	-0.269 ***
Wheat	-0.202 ***	-0.151	-0.130 *
East and South Africa	0.251 **	0.091	0.310 ***
West and Central Africa	0.321 ***	0.093	0.388 ***
Europe	0.189	-0.175 ***	0.163
Latin America	0.189 **	-0.041	0.286 ***
Trade openness	0.000	0.002	0.000
Net importer	0.035	0.033	0.136
STE	-0.216 ***	0.283	0.009
Retail	-0.126 **	0.064	-0.127 **
Ease of trade	0.395	0.245	0.509
Logistics	-0.527 ***	-0.152	-0.460 ***
Landlocked	-0.125	-0.074	0.119

*Note: *, ** and *** refer to significance at the 10%, 5% and 1% levels, respectively. Marginal effects rather than coefficients are reported.*

Meta-regression results for individual estimates of α and β are summarized in Tables 10, 11 and 12. Table 10 presents results for the GIEWS estimates of α and β from all domestic/international price pairs. Moreover, in Table 11 the GIEWS estimates are based only on α and β from cointegrated domestic/international price pairs. Finally, Table 12 presents estimates only for non-cointegrated domestic/international price pairs.

Table 10: Estimated coefficients for the meta-regressions (all)

Covariate	entire period		before 07/2007		after 07/2007	
	α	***β***	***α***	***β***	***α***	***β***
Intercept	-0.323***	-0.712	0.265	-2.765	-0.082	4.230
Maize	-0.067***	0.131	-0.033	-0.046	-0.137***	0.719
Wheat	0.002	0.491**	-0.025	5.088**	-0.112***	5.091***
East and South Africa	-0.013	0.148	-0.339***	2.360	0.004	3.164
West and Central Africa	-0.051*	0.148	-0.408***	2.216	-0.149***	2.648
Europe	0.038	0.644	-0.050	-0.033	0.025	3.108
Latin America	0.008	0.252	-0.356***	2.275	-0.005	3.722**
Trade openness	0.000	0.000	-0.004***	0.077**	0.000	-0.008
Net importer	0.054**	-0.227	0.014	0.102	-0.004	0.362
STE	0.031	0.390*	-0.244***	-3.216	0.019	-1.115
Retail	0.002	0.197	-0.025	-2.418	-0.020	1.095
Ease of trade	-0.035	1.303	0.197	-7.242	-0.173	9.935
Logistics	0.094***	-0.013	-0.023	0.878	0.054	-6.168***
Landlocked	0.023	0.447*	-0.076	-1.765	0.048	0.316
R^2	0.170	0.041	0.225	0.052	0.210	0.072

*Note: All meta-regressions estimated using OLS. *, ** and *** refer to significance at the 10%, 5% and 1% levels, respectively. Result based on estimates of α and β using all international/domestic price pairs.*

Table 11: Estimated coefficients for the meta-regressions (cointegrated)

Covariate	entire period		before 07/2007		after 07/2007	
	α	β	α	β	α	β
Intercept	-0.262*	0.725	0.718	-0.504	0.045	-5.871
Maize	-0.069**	0.057	-0.068	0.009	-0.167***	-1.441
Wheat	0.034	0.146	-0.591	0.279	-0.170**	8.762**
East and South Africa	-0.033	-0.017	-0.778***	-0.178	-0.041	5.596
West and Central Africa	-0.031	-0.008	-0.977***	0.024	-0.184**	3.069
Europe	0.078	0.393	-	-	0.130	5.941
Latin America	-0.015	0.142	-1.043***	0.300	-0.023	4.023
Trade openness	0.000	0.001	-0.008***	0.004	0.000	0.000
Net importer	0.053	-0.160	0.278	-0.900*	-0.005	0.720
STE	-0.023	0.141	-0.826***	-0.038	0.043	-2.963
Retail	-0.020	0.004	0.008	-0.094	-0.054	1.546
Ease of trade	0.118	0.433	0.882	-0.826	0.148	3.976
Logistics	0.038	-0.282	-0.006	0.504	-0.113	-0.152
Landlocked	0.008	0.156	-0.089	0.211	0.143**	1.633
R^2	0.101	0.032	0.489	0.212	0.265	0.119

*Note: The sample before July 2007 includes too few observations for Europe to permit estimation. *, ** and *** refer to significance at the 10%, 5% and 1% levels, respectively. Results based on estimates of α and β only from cointegrated international/domestic price pairs.*

The meta-regressions in Table 10, which are based on all estimates of α and β, are generally quite similar to the corresponding meta-regressions in Table 11, which are based only on estimates of α and β from cointegrated domestic/international price pairs. For example, in both tables we see in the second column that α is roughly 7 percentage points more negative for maize prices than for rice and wheat prices, suggesting that PT on maize markets is somewhat more rapid. This supports the finding in Table 5 that α's for maize tend to be somewhat larger (in magnitude).[8] Indeed, this result is also corroborated by the results in Table 12 which are based only on non-cointegrated price pairs. Here the estimated coefficient for maize indicates that α is roughly 8 percentage points more negative for maize prices.

Similar parallels can be found across all three tables for example for the West and Central Africa fixed effect (-5.1 percentage points in Table 9, -3.1 percentage points in Table 10, and -7.7 percentage points in Table 11) and for the ratio of net imports to consumption (5.4, 5.3 and 5.8 percentage points less error correction according to the results in Tables 9, 10 and 11, respectively). Some parallel findings are counter-intuitive, however. In particular, in both Table 9 and Table 10 we see that improvements in logistics are associated with large (less negative) values of α, and therefore with slower PT.

[8] In Table 5 we consider only significant coefficients.

Table 12: Estimated coefficients for the meta-regressions (not cointegrated)

Covariate	entire period		before 07/2007		after 07/2007	
	α	β	α	β	α	β
Intercept	-0.315***	-1.893	0.285	-5.128	-0.021	6.038
Maize	-0.083***	0.200	-0.036	0.406	-0.150***	1.342
Wheat	-0.007	0.639*	0.009	7.028**	-0.115***	4.451*
East and South Africa	0.001	0.250	-0.253***	4.144	0.038	2.742
West and Central Africa	-0.077**	0.161	-0.348***	3.155	-0.105***	2.651
Europe	0.016	0.807	0.016	0.122	-0.001	3.242
Latin America	0.029	0.263	-0.211***	3.624	0.013	4.422*
Trade openness	0.001**	-0.002	-0.002***	0.093**	0.000	-0.006
Net importer	0.058*	-0.187	-0.012	0.311	-0.015	0.592
STE	0.043*	0.431	-0.130***	-5.846*	0.020	-0.318
Retail	0.007	0.362	-0.039	-3.046	-0.012	0.636
Ease of trade	-0.194	2.220	-0.149	-12.210	-0.347**	12.656
Logistics	0.120***	0.191	-0.032	2.257	0.073	-7.854***
Landlocked	0.010	0.629	-0.082	-2.150	0.008	-1.625
R^2	0.239	0.059	0.222	0.080	0.293	0.075

*Note: The sample before July 2007 includes too few observations for Europe to permit estimation. *, ** and *** refer to significance at the 10%, 5% and 1% levels, respectively. Results based on estimates of α and β only from non-cointegrated international/domestic price pairs.*

Moving to the results for the pre-July 2007 period, we again see many parallels between Tables 10, 11 and 12. In particular, all three tables display evidence of significantly more negative α's (and therefore more rapid PT) for East and South Africa and West and Central Africa, for Latin America, for more trade open countries and, surprisingly, for countries with STEs. In the post-July 2007 period, the results in all three tables point to significantly more negative α's for maize and wheat, and for West and Central Africa.

These parallels are less apparent for the meta-regressions in Tables 9, 10 and 11 that explain the variation in the β's. Overall, the meta-regressions indicate that the selected covariates are able to explain a larger proportion of the variance in the adjustment parameters (the α's) than of the variance in the long-run price transmission coefficients (the β's). The meta-regressions for the estimates of β generally produce fewer significant coefficients, and they also produce many coefficients that are implausibly large, especially in the pre- and post-July 2007 subsamples. Since β is expected to be close to 1, it is difficult for example to interpret coefficients that suggest that β increases by over 7 for price pairs involving wheat, or falls by almost 6 in the presence of an STE (see the second column of Table 11).

In summary, the meta-regressions for the α's do generate a few signals. In particular, there is strong evidence of more rapid PT for maize across all of the GIEWS results regardless of what period is considered and whether cointegrated and/or non-cointegrated results are considered. Similarly, evidence of more rapid PT in Latin America appears repeatedly in Tables 9 through 11. There is weaker evidence for a positive relationship between trade openness and the speed of PT, and a negative relationship between net import ratios and PT. Before July 2007 it appears that PT was stronger in the presence of STEs, and when estimation is carried out without allowance for a break in July 2007, it appears that better logistics are associated with slower PT. These last two results run counter to our *a priori* expectations. The meta-regressions for the β's have lower explanatory power than those for the α's, and they fail to produce many robust and plausible results.[9]

[9] We also experimented with weighted meta-regressions that account for the fact that some countries are more prevalent in the GIEWS data than others. These meta-regressions did not generate any additional insights.

5. Discussion

The results provide evidence that international cereal price changes are transmitted more frequently, stronger and faster to domestic markets in African countries compared with other countries of the sample. Roughly every second cereal price is cointegrated with the international reference price whereas this is only the case for 35% of the price pairs in Asia, Pacific region, Latin America, Europe and Oceania. Furthermore, the results point to relatively slow PT for all cereal products and regions, but with the main part of a price change being transmitted in the long run. Overall, the estimates for markets in Africa point to average long-run PT coefficients of roughly 0.73 and average adjustment parameters of roughly 0.27. This suggests that on average 73% of a change in international prices will be transmitted to domestic markets, and that it takes approximately 2.2 months for one-half of a given price shock on international cereal markets to be transmitted to domestic markets. In non-African countries, 64% of an international price change is transmitted in the long run with half of the price response within 3.3 months.

African rice markets show the highest share of cointegrated price pairs (68%), the largest long-run PT coefficient and the fastest price reaction. For wheat and maize it is mostly the domestic prices that react to disequilibrium between themselves and the corresponding world reference prices. But in the case of rice, more than 60% of all price pairs display international price reactions to disequilibrium as well. This becomes even more apparent when comparing the period before and after July 2007 where we find evidence for a shift from predominantly domestic price reactions to mainly reactions of the world market price. Hence, the determination of international prices for rice appears to differ fundamentally from that for wheat and maize. The reasons for this difference would be an interesting topic for future research. On maize markets there is evidence for a change in PT dynamics indicated by cointegration variations in combination with a stronger and faster price transmission to the domestic level after July 2007. This could be interpreted as evidence of a certain degree of decoupling of local markets from international prices in some countries, with other countries left stronger affected by international price changes. With a number of caveats we find that price transmission has become stronger for local markets in Africa after the onset of the recent phase of price peaks and increased price volatility in mid-2007. The results suggest that the opposite is the case for the country group consisting of Asia, the Pacific Region, Latin America, Europe and Oceania.

The differences between African countries and countries in other regions persist also after controlling for a number of economic, political, geographical covariates, as well as infrastructure and trade variables.[10] However, the analysis generates a number of insights into the drivers of PT from interntational to domestic cereal markets. Employing meta-regression analysis to explain variations in long-run PT coefficients (β) between domestic and international prices fails to generate compelling results. The meta-regressions for the adjustment parameters (α) do produce some more suggestive results. All other things being equal, there is some evidence of more rapid PT for maize than for wheat and rice, and more rapid PT in West and Central Africa and East and South Africa than in other regions. An increasing ratio of net imports to domestic consumption is associated with slower PT, which may be an indication of increased intervention on politically more sensitive markets. There is evidence that trade openness is positively associated with the speed of PT, but this effect is only significant in the pre-July 2007 period. In this period there is also robust evidence that the presence of an STE is associated with more rapid PT. Finally, there is some puzzling indication that improved logistics is correlated with slower PT.

The results presented here must be interpreted with caution. First, a lack of cointegration between two prices does not necessarily mean that there is no PT between (McNew and Fackler, 1997). The underlying PT relationship may be characterized by regime-dependence, for example as a result of policy intervention or shifts between net import and net export positions. Hence, failure to find

[10] Regressions on an income variable did not produce any significant results.

evidence of cointegration might be due to a failure to test for the right type of cointegration. The strength of the GIEWS price data is that it provides broad and consistent coverage of a large number of country/product combinations. However, the sheer number of price series available in GIEWS means it is not possible to implement a detailed modeling strategy for each individual series. Instead, we must resort to a uniform modeling strategy that can be automated. We have estimated one slightly more flexible VECM that allows for a regime shift in July 2007, but this is no substitute for careful, case-by-case specification and estimation of an appropriate model for each individual price pair. Second, the GIEWS price series are quite short. Few series have more than 150 monthly observations, and many have considerably less. It is reasonable to expect that the nature of cereal price transmission from international to domestic markets has changed in recent years at prices have increased and become more volatile, and some of the results that we produce with the GIEWS data appear to confirm this expectation. There are, however, only roughly 55 monthly observations available for the period since 2007.

Additional work might lead to additional or more robust insights into PT. First, the simple VECM employed to estimate the GIEWS price data might be made somewhat more flexible. It could be modified to allow for asymmetric price transmission, i.e. to test whether increases in international prices are transmitted to domestic prices in the same manner as decreases (von Cramon-Taubadel, 1998). The results of the simple non-parametric analysis of agreement in the direction of international and domestic price changes suggests that increasing international prices are being transmitted more often to domestic prices than decreasing international prices. Alternatively, it might be possible to estimate threshold VECMs (TVECMs) with the GIEWS data (Goodwin and Piggott, 2001; Greb et al., 2011). The TVECM can account for phases with and without trade and trade reversals and by distinguishing between these phases or regimes provide better estimates of PT parameters.

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7. Appendix

Table 13: List of studies analysing world to domestic price transmission for African countries

Authors, Year Published	Title	Institution / Publication	Type of publication	Number of market pairs	Country
Baquedano, Liefert, & Shapouri, 2011	World market integration for export and food crops in developing countries: a case study for Mali and Nicaragua	Agricultural Economics	Journal	4	Mali
Gilbert, 2011	Grains Price Pass-Through, 2005-09	FAO	Report	10	Benin, Kenya, Malawi
Minot, 2011	Transmission of World Food Price Changes to Markets in Sub-Saharan Africa	IFPRI	Report	58	Ethiopia, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda, Zambia, Ghana,
Myers & Jayne, 2011	Multiple-regime spatial price transmission with an application to maize markets in southern Africa	American Journal of Agricultural Economics	Journal	3	Zambia
Bamuturaki, 2009	World market integration and price transmission in selected markets in Tanzania	U of Hohenheim	Thesis	2	Tanzania
Rapsomanikis et al., 2009	The 2007-2008 Food Price Swing: Impact and policies in Eastern and Southern Africa	FAO	Report	42	Kenya, Malawi, South Africa, Uganda, Zambia
World Bank, 2009	Eastern Africa: A study of the regional maize market and marketing costs	U of Göttingen, World Bank	Report	12	Kenya, Tanzania, Uganda
Cudjoe, Breisinger, & Diao, 2008	Local impacts of a global crisis: food price transmission and poverty impacts in Ghana	IFPRI	Report	2	Ghana
Thomas & Morrison, 2006	Trade reforms and food security: Country Case Studies and Synthesis	FAO	Report	18	Tanzania
Conforti, 2004	Price transmission in selected agricultural markets	FAO	Report	134	Egypt, Ethiopia, Ghana, Senegal, Uganda
Baffes & Gardner, 2003	The transmission of world commodity prices to domestic markets under policy reforms in developing countries	Journal of Policy Reform	Journal	44	Egypt, Ghana, Madagascar
Rapsomanikis et al., 2003	Market integration and price transmission in selected food and cash crop markets of developing countries: review and applications	FAO	Report	3	Ethiopia, Rwanda, Uganda (coffee), Egypt (wheat)

Table 14: Countries with state trading enterprises (STEs) for maize, rice or wheat

Product	Countries with STEs
Maize	China, Kenya, Malawi, Zambia, Zimbabwe
Rice	Australia, China, Dominican Republic, India, Iraq, Japan, Kenya, Korea, Malaysia, Pakistan, Philippines, Thailand, Vietnam
Wheat	Australia, Canada, China, Cyprus, Egypt, Arab Rep., India, Iran, Japan, Korea, Pakistan, Sri Lanka, Sudan, Syria, Tajikistan, Tunisia

Source: Compiled using Ackerman (1997; 1998), Ackerman and Dixit (1999), Chang and de Gorter (2004), OECD (2007), Young (1999) and Young and Abbott (1998).

Table 15: Cointegration between international and domestic prices by product and country

Country	Maize						Rice						Wheat					
	entire period		pre- break		post- break		entire period		pre- break		post- break		entire period		pre- break		post- break	
	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs
Afghanistan													3	4	0	4	2	4
Argentina	1	1	0	1	1	1							0	3	0	3	0	3
Bangladesh													0	4	0	3	0	4
Benin	7	7	5	7	2	7	4	4	3	4	1	4						
Bhutan							1	2			1	2	0	1			0	1
Bolivia	1	3	1	3	1	3	4	6	0	6	4	6	0	3	0	3	0	3
Brazil	1	2	0	2	0	2	3	5	0	5	0	5	1	2	0	2	0	2
Burkina Faso							8	9	0	3	8	9						
Burundi	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Cambodia							0	4	0	3	1	4						
Cameroon	0	5	0	5	0	5	5	5	2	5	4	5						
Cape Verde	1	9	0	3	2	9	2	6	2	6	0	6						
Chad	1	3	0	3	3	3	3	3	2	3	2	3						
China							0	2	1	2	0	2						
Colombia	3	3	0	3	1	3	4	5	0	5	5	5						
Costa Rica	0	2	0	1	0	2	0	2	0	2	0	2						
D.R. Congo	0	3			0	3	2	4			2	4						
Djibouti							2	2	1	2	1	2						
Dominican Republic	0	2	0	2	1	2	3	4	2	4	4	4						
Ecuador	2	8	2	8	0	8	4	9	0	9	3	9						
Egypt	0	4			0	4	2	4			2	4	0	2			0	2
El Salvador	0	2	1	2	0	2	2	2	0	2	2	2						

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 15: Cointegration between international and domestic prices by product and country (continued)

Country	Maize						Rice						Wheat					
	entire period		pre- break		post- break		entire period		pre- break		post- break		entire period		pre- break		post- break	
	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs
Eritrea													1	1			0	1
Ethiopia	1	8	0	4	4	8							7	11	2	11	7	11
Gabon							0	1			0	1						
Ghana	0	3	0	3	0	3	0	2	0	2	0	2						
Guatemala	3	3	1	3	3	3	2	3	0	2	1	3						
Guinea							0	2			1	2						
Haiti	1	14	2	14	1	14	3	14	2	13	1	14						
Honduras	3	3	0	1	1	3	2	2			2	2						
India							2	8	2	8	2	8	0	8	0	8	0	8
Indonesia							1	1			1	1						
Israel	0	1	0	1	0	1							0	1	0	1	0	1
Kenya	0	6	1	5	1	6												
Lao People's Dem. Rep.							1	3	1	3	0	3						
Lesotho							0	1			0	1						
Madagascar							0	2	0	2	0	2						
Malawi	0	6			2	6	0	2			0	2						
Mali							11	14	0	4	11	14						
Mauritania							0	1	0	1	0	1	0	1			0	1
Mexico	4	5	2	5	2	5	1	4	0	4	3	4						
Mongolia							0	1			0	1						

Mozambique	11	14	9	14	5	13	8	10	2	10	4	10						

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 15: Cointegration between international and domestic prices by product and country (continued)

Country	Maize						Rice						Wheat					
	entire period		pre- break		post- break		entire period		pre- break		post- break		entire period		pre- break		post- break	
	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs
Myanmar							1	1			1	1						
Namibia	0	1			0	1												
Nicaragua	3	6	3	5	2	6	10	10	1	8	10	10						
Niger	0	6	0	6	2	6	9	12	5	12	6	12						
Nigeria	0	1	0	1	0	1												
Pakistan							0	5	2	5	1	5	0	4	0	4	4	4
Panama	0	2	0	2	0	2	1	2	1	2	2	2						
Peru	0	2	0	2	0	2	0	1	0	1	0	1	1	2	0	2	0	2
Philippines	2	8	0	8	0	8	6	28	19	28	2	28						
Republic of Moldova	0	2			0	2												
Russian Federation	0	1	0	1	0	1	1	1	0	1	0	1	0	1			0	1
Rwanda	1	1	0	1	1	1	1	1	0	1	1	1						
Samoa									0	1								
Senegal							9	11			8	11						
Somalia	6	11	0	10	5	11	9	12	6	11	3	12						
South Africa	0	1	1	2	0	2							0	1	0	1	0	1
Sri Lanka							1	1	0	1	1	1						
Sudan													1	5	0	5	2	5
Thailand	0	1	0	1	0	1	1	1	1	1	0	1						

Timor-Leste	0	1			0	1	1	1			1	1						
Togo	0	6	0	6	2	6	4	6	1	6	2	6						
Tunisia							1	1	1	1	1	1						

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 15: Cointegration between international and domestic prices by product and country (continued)

Country	Maize						Rice						Wheat					
	entire period		pre- break		post- break		entire period		pre- break		post- break		entire period		pre- break		post- break	
	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs	# of cointegrated pairs	# of pairs
Uganda	0	3	0	1	1	2	2	3	0	3	2	3						
Ukraine	1	1	0	1	1	1							0	1	0	1	0	1
United Rep. of Tanzania	2	5	1	1	3	5												
Uruguay							0	1			0	1	0	1	0	1	0	1
Vietnam							1	1			0	1						
Zambia	0	1	0	1	0	1	0	1			0	1						
Zimbabwe	0	1	1	1	0	1												
Sum	55	179	30	141	47	178	139	251	57	193	108	251	14	57	2	50	15	57
Share of cointegrated pairs	30.7%		21.3%		26.4%		55.4%		29.5%		43.0%		24.6%		4.0%		26.3%	

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 16: Cointegration between international and domestic prices in African countries (maize)

	Maize								
	Entire period			Before 2007			After 2007		
	coint	obs	% coint.	coint	obs	% coint.	coint	obs	% coint.
Benin	7	7	100%	*5*	*7*	*71%*	*2*	*7*	*29%*
Burkina Faso									
Burundi	0	1	0%	0	1	0%	0	1	0%
Cameroon	0	5	0%	0	5	0%	0	5	0%
Cape Verde	1	9	11%	0	3	0%	2	9	22%
Chad	1	3	33%	0	3	0%	3	3	100%
Congo, D.R.	0	3	0%				0	3	0%
Djibouti									
Egypt	0	4	0%				0	4	0%
Eritrea									
Ethiopia	1	8	13%	0	4	0%	4	8	50%
Gabon									
Ghana	0	3	0%	0	3	0%	0	3	0%
Guinea-Bissau									
Kenya	0	6	0%	1	5	20%	1	6	17%
Lesotho									
Madagascar									
Malawi	0	6	0%				2	6	33%
Mali									
Mauritania									
Mozambique	11	14	79%	*9*	*14*	*64%*	*5*	*13*	*38%*
Namibia	0	1	0%				0	1	0%
Niger	0	6	0%	0	6	0%	2	6	33%
Nigeria	0	1	0%	0	1	0%	0	1	0%
Rwanda	1	1	100%	*0*	*1*	*0%*	1	1	100%
Senegal									
Somalia	6	11	55%	*0*	*10*	*0%*	*5*	*11*	*45%*
South Africa	0	1	0%	1	2	50%	0	2	0%
Sudan									
Tanzania	2	5	40%	1	1	100%	3	5	60%
Togo	0	6	0%	0	6	0%	2	6	33%
Tunisia									
Uganda	0	3	0%	0	1	0%	1	2	50%
Zambia	0	1	0%	0	1	0%	0	1	0%
Zimbabwe	0	1	0%	1	1	100%	0	1	0%
Africa	30	106	28%	18	75	24%	33	105	31%
ROW	25	73	34%	*12*	*66*	*18%*	*14*	*73*	*19%*
World Total	55	179	31%	*30*	*141*	*21%*	*47*	*178*	*26%*

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 17: Cointegration between international and domestic prices in African countries (maize)

	Rice								
	Entire period			Before 2007			After 2007		
	coint	obs	% coint.	coint	obs	% coint.	coint	obs	% coint.
Benin	4	4	100%	*3*	*4*	*75%*	*1*	*4*	*25%*
Burkina Faso	8	9	89%	*0*	*3*	*0%*	8	9	89%
Burundi	0	1	0%	0	1	0%	0	1	0%
Cameroon	5	5	100%	*2*	*5*	*40%*	*4*	*5*	*80%*
Cape Verde	2	6	33%	2	6	33%	*0*	*6*	*0%*
Chad	3	3	100%	*2*	*3*	*67%*	*2*	*3*	*67%*
Congo, D.R.	2	4	50%				2	4	50%
Djibouti	2	2	100%	*1*	*2*	*50%*	*1*	*2*	*50%*
Egypt	2	4	50%				2	4	50%
Eritrea									
Ethiopia									
Gabon	0	1	0%				0	1	0%
Ghana	0	2	0%	0	2	0%	0	2	0%
Guinea-Bissau	0	2	0%				1	2	50%
Kenya									
Lesotho	0	1	0%				0	1	0%
Madagascar	0	2	0%	0	2	0%	0	2	0%
Malawi	0	2	0%				0	2	0%
Mali	11	14	79%	*0*	*4*	*0%*	11	14	79%
Mauritania	0	1	0%	0	1	0%	0	1	0%
Mozambique	8	10	80%	*2*	*10*	*20%*	*4*	*10*	*40%*
Namibia									
Niger	9	12	75%	*5*	*12*	*42%*	*6*	*12*	*50%*
Nigeria									
Rwanda	1	1	100%	*0*	*1*	*0%*	1	1	100%
Senegal	9	11	82%				*8*	*11*	*73%*
Somalia	9	12	75%	*6*	*11*	*55%*	*3*	*12*	*25%*
South Africa									
Sudan									
Tanzania									
Togo	4	6	67%	*1*	*6*	*17%*	*2*	*6*	*33%*
Tunisia	1	1	100%	1	1	100%	1	1	100%
Uganda	2	3	67%	*0*	*3*	*0%*	2	3	67%
Zambia	0	1	0%				0	1	0%
Zimbabwe									
Africa	82	120	68%	*25*	*77*	*32%*	*59*	*120*	*49%*
ROW	57	142	40%	*32*	*116*	*28%*	*49*	*142*	*35%*
World Total	139	262	53%	*57*	*193*	*30%*	*108*	*262*	*41%*

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.

Table 18: Cointegration between international and domestic prices in African countries (wheat)

	Wheat								
	Entire period			Before 2007			After 2007		
	coint	obs	% coint.	coint	obs	% coint.	coint	obs	% coint.
Benin									
Burkina Faso									
Burundi	0	1	0%	0	1	0%	0	1	0%
Cameroon									
Cape Verde									
Chad									
Congo, D.R.									
Djibouti									
Egypt	0	2	0%				0	2	0%
Eritrea	1	1	100%				*0*	*1*	*0%*
Ethiopia	7	11	64%	*2*	*11*	*18%*	7	11	64%
Gabon									
Ghana									
Guinea-Bissau									
Kenya									
Lesotho									
Madagascar									
Malawi									
Mali									
Mauritania	0	1	0%				0	1	0%
Mozambique									
Namibia									
Niger									
Nigeria									
Rwanda									
Senegal									
Somalia									
South Africa	0	1	0%	0	1	0%	0	1	0%
Sudan	1	5	20%	0	5	0%	2	5	40%
Tanzania									
Togo									
Tunisia									
Uganda									
Zambia									
Zimbabwe									
Africa	9	22	41%	*2*	*18*	*11%*	9	22	41%
ROW	5	35	14%	0	32	0%	6	35	17%
World Total	14	57	25%	2	50	4%	15	57	26%

Note: Empty cells indicate that there were no or insufficient (<10) observations for the country/product/period combination in question. Cointegration tested by Johansen at 5%.