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Price Transmission in Nigerian Food Security Crop Markets

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Abstract

This paper comprehensively examines price transmission from world, neighbour country, and internal commercial hub markets to Nigerian urban markets, as well as from urban to rural markets within the country, for seven key food security crops (maize, millet, sorghum, rice, cassava, yams and cowpeas). There are three key findings: (i) tradability matters for price transmission, but tradability varies across crops and regions. The strongest international linkages are with neighbouring countries. Rice price transmission is high across all markets, while coarse grain price correspondence is low with world prices but high with neighbour country market prices; (ii) our results imply that local conditions matter for price transmission, and are relatively more important than trade for some crops (e.g. yams, cassava) than others (e.g. imported rice, maize); (iii) larger than expected long-run price transmission parameters in world and neighbour countries for rice and coarse grains suggest that, in these select markets, there are either large transactions costs or quality premiums that vary systematically with border prices, and/or mark-ups captured by traders with market power.

Keywords: *Food prices*; *mark-ups*; *Nigeria*; *price transmission*; *tradability*.

JEL classifications: *F1, Q11, Q17.*

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1. Introduction

Research attention on the effects of world food price increases on prices in Sub-Saharan African (SSA) country markets has increased markedly since the 'food crisis' of 2007–2008. Recent food price transmission studies (e.g. Abbott and Borot de Battisti, 2011; Minot, 2011; Baltzer, 2015) expanded on earlier analyses by Baffes and Gardner (2003) and Conforti (2004), which broadly found incomplete price transmission from world to SSA country markets, but with variation across countries and crops. In light of these discoveries, Baffes *et al*. (2015) sought to discern whether regional (neighbouring country) prices or local conditions (e.g. weather) are relatively more important than world prices in local price formation.

In this study, we implement a comprehensive price transmission analysis that measures food price transmission to Nigerian markets of different 'scopes': world to commercial hubs and other urban markets, neighbour country markets to commercial hubs and other urban markets, commercial hubs to other urban markets, and urban-to-rural markets.[2] Such a comprehensive approach is unique to this study, and allows us to examine the relationships between world, regional, and internal Nigerian prices to a much greater extent than previous studies.

We focus on the markets for seven key food security crops (rice, maize, sorghum, millet, cassava, yams and cowpeas) in Nigeria. This allows for a clearer understanding of how markets for these foods are linked, which is a prerequisite for design and implementation of market interventions and food policies (Lançon *et al*., 2011). Nigeria was chosen as a case study because its large geographic size, substantial share of regional agricultural production, and large population mean that food market conditions in Nigeria are influential throughout West Africa (Elbehri *et al*., 2013). Our results indicate that price spikes spillover across neighbour country borders more so than from global markets, with significant variations in transmission across crops and across regions within Nigeria. They also imply that other factors (e.g. weather) are likely to be relatively more important than international price spikes in determining prices in all examined markets in the short run, especially in rural areas.

2. Previous Research on Food Price Transmission in Nigeria

Price transmission in Nigerian food markets has been the focus of previous studies, which inform the design of our empirical analysis. The pioneering study by Jones (1968) found price correspondence to vary between urban areas in Nigeria for a variety of foods. Nigerian grain markets, especially those in the north, have three primary flow types: (i) from rural producers to wholesale aggregators based in rural and urban markets (Hays and McCoy, 1978; Okoh and Egbon, 2005); (ii) from urban wholesalers to rural wholesalers and retailers (Okoh and Egbon, 2005); and (iii) between wholesalers in urban markets (Hays and McCoy, 1978). Local conditions (e.g. supply-use balances, transport links and weather) are likely to explain variation in price

[2]'World' or 'global' prices throughout refer to international price series from the US Gulf, and also in Thailand for rice and South Africa for maize, that are commonly used in agricultural commodity price analyses. Neighbouring country prices are in fact 'international' or border prices, but informal trade over land routes between neighbouring countries is qualitatively different from 'global' trade that arrives at ports. We will use the term 'scope' to refer to the various distinctions across Nigerian markets highlighted in this paper.

transmission between different regions of Nigeria. For example, in a recent study, markets closer to maize production regions were found to have relatively greater market integration than these production zone markets and more distant ones (Ikudayisi and Salman, 2014). Variation in price transmission across different crops has also been found within states (Momoh and Agbonlahor, 2007). In addition to spatial variation in price correspondence, market linkages have also been found to vary over time. Specifically, Delgado (1986) found relatively less trader facilitated trade between markets during harvest than in non-harvest periods.

Abbott and Borot de Battisti (2011) and Baltzer (2015) found evidence of high world price transmission to Nigerian cereals (rice, maize, millet and sorghum) markets during the period of 2005–2009 (which includes the 2007–2008 'food crisis'). We expand on their analysis through inclusion of additional market scopes and crops (cassava, yams and cowpeas), as well as using longer time series.

Price transmission between neighbouring countries and Nigerian markets has, to our knowledge, not yet been extensively studied. Terpend (2006) and Galtier (2009), however, observed substantial trade in cereals and cowpeas across West Africa,[3] which is consistent with UNComtrade data for some countries and crops in the region (mainly between Nigeria and Niger for coarse grains[4]). Krugman (1991) found that, in general, neighbour country trade is much more sizeable and regularly occurring than that between distant countries, and Baffes *et al*. (2015) found neighbour country grain price linkages to be stronger than those with global markets. These research findings and regional market observations motivate estimation of food price linkages between Nigeria and its neighbours in West Africa.

These previous studies of price transmission at different scopes (world, neighbour country, between urban areas, and between urban and rural areas) for Nigerian food markets inspired this combined comprehensive analysis of price transmission at all market scopes to allow for direct comparison. This empirical analysis is feasible because of the expansion of developing country food price databases that are now available after the 'food crisis' of 2007–2008. Sources such as the Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization of the United Nations (FAO) and the World Food Programme (WFP) provide rich price data series for Nigeria's neighbour country markets. Nigerian urban and rural prices, unavailable for post-2007–2008 'food crisis' analyses such as that by Olomola (2013) but used in the recent study by Ikudayisi and Salman (2014), became available in 2014 via release by the Nigerian National Bureau of Statistics (NBS).

3. Theoretical and Empirical Frameworks

The starting point for description of the theoretical relationship between prices in the analysed markets is the law of one price (LOP). Under the LOP, prices of a homogeneous commodity in spatially separated markets are equal due to arbitrage by traders

[3]Terpend (2006) also describes regional trade in cassava and yams as limited primarily to coastal countries and their neighbours, and in substantially smaller quantities than trade in cereals and cowpeas.

[4]No database, including UNComtrade, reports cowpea trade between Nigeria and its neighbours. Langyintuo *et al*. (2005), however, provide estimates of the quantities of cowpeas informally traded in the region using data obtained from government statistical service departments of analysed regional countries.

(Baffes, 1991). We begin with a base LOP price relationship for a food commodity in Nigeria that is imported from world markets in any period:

$$p = p^{w}e = p^{*}, \tag{1}$$

where p is the price in a Nigerian market in Nigerian Naira per kilogram, p^{w} is the 'world' price in foreign currency units per kilogram, and e is the exchange rate in Nigerian Naira per foreign currency unit. The convention of past price transmission studies, adjusting world prices by the exchange rate, is maintained, so a new exchange rate adjusted world price is defined as p^{*}.

We sequentially add factors that could affect the LOP relationship in equation (1) both through adjustment in the level of the domestic price and the degree to which these prices co-move. We focus on general types of factors based on whether or not they may vary systematically with the world price, and discuss which factors are relevant in the Nigerian context. We describe the factors that vary systematically with the world price in detail because in some cases large margins between world and domestic prices are observed; and, more importantly, doing so provides theoretical explanation for the possible existence of price transmission parameter estimates that are significantly greater or less than one.[5]

Some factors influence domestic market prices, but are independent of changes in the world price. Such factors could include, for example, transactions costs (e.g. shipping services) that are charged on a per ton basis (Timmer, 1974). We define these factors as the variable f, and add them to the world prices in equation (2) such that in each period:

$$p = f + p^{*}. \tag{2}$$

These transactions costs may be large and may vary over time, but unless they vary with the world price, changes in f are captured in the error term of a regression on equation (2). The commodity is importable (i.e. arbitrage is profitable) if $p \geq f + p^{*}$ (Moser *et al*., 2009). Work on 'parity bounds' emphasises that a good may sometimes be an exportable or sometimes an importable, but becomes non-tradable when transactions costs make both imports and exports too expensive (e.g. Barrett and Li, 2002). The degree to which the domestic and world price co-move adjusts if the commodity becomes non-tradable ($p^{*} - f^{*} < p < f + p^{*}$) where f are import costs and f^{*} are export costs. In such a case, prices move independently, appear 'segmented', and, are determined by prices in other markets and/or local conditions.

Another set of factors, those for which a change in the world price directly adjusts the domestic price, have a systematic relationship with the world price. Such factors could include working capital (Timmer, 1974; Dawe and Maltsoglou, 2014) or (constant) ad valorem tariffs. We account for these factors through the parameter m, and add it to equation (3) such that it reflects proportionality to the world price:

$$p = f + p^{*}(1 + m). \tag{3}$$

[5]The perfect competition assumption (and its associated characteristics of such markets) of LOP theory implies that price transmission parameter estimates equal 1 in integrated markets, but <1 in perfectly competitive but poorly-integrated markets (Minot, 2011). By implication, an estimated price transmission parameter that is >1 applies in markets for which the perfect competition assumption and its associated characteristics do not apply.

Increases (decreases) in p^* increase (decrease) p by the same proportion determined by the magnitude of m.

Most research, including ours, presumes that proportional transactions costs other than tariffs are small (Goodwin *et al*., 1990; Miljkovic, 1999; Fafchamps and Gabre-Madhin, 2001; Dawe and Maltsoglou, 2014). Factors that might make margins proportional include trade policy, market power and quality differences.

Tariffs may raise price transmission parameter estimates above one (reflected as a direct upward proportional adjustment to the domestic price in equation (3)), but endogenous policy responses (e.g. variable levies) may reduce transmission parameters all the way to zero (Abbott, 1979; Bredahl *et al*., 1979). In Nigeria, observed ad valorem tariffs are only relevant for some crops and in some years.[6] They sometimes exhibit characteristics of a poorly implemented variable levy, and are generally low in most years relative to the large margins observed for maize and rice.[7]

Perceived quality differences may account for large margins and limit the manner in which the domestic and imported good are substitutable, but the degree to which these would relate to the world price varies in different contexts. If the goods are imperfectly substitutable, there is less world to domestic price transmission (Minot, 2011). In the case of Nigeria, some quality differences have been observed, especially between imported and domestic rice (Johnson *et al*., 2013). We control for this by separately analysing imported and local rice. Moreover, we find the correlation between the domestic premium on imported rice and the world rice price varies across regions, at 83% and −1% for the Kano and Lagos commercial hubs, respectively. This implies that quality premiums adjust systematically with the world rice price to a large degree in Kano, but other factors (e.g. trade policy and/or mark-ups) are predominant in Lagos. In the case of maize, the world price is for yellow maize used as feed, while the domestic price is for white maize, a food crop that should demand a premium and is substitutable with imported maize to only a limited degree.

Mark-ups by traders of imported goods with market power are expected to increase world to domestic price transmission (Frankel *et al*., 2012). The relationship between mark-ups and world prices is, however, based on trader behaviour that may not be systematic. Mark-ups have been found to be somewhat common in US agricultural commodity markets (Applebaum, 1982; Schroeter, 1988) and in international settings (Sheldon and Sperling, 2003), and are plausibly relevant in Nigeria too.[8] We rely on

[6]United Nations Conference on Trade and Development (UNCTAD) Trade Analysis Information System (TRAINS) data on Nigerian tariffs for rice and maize for 2001–2010 are as follows. The rice tariffs were 100% in 2001, 75% in 2002, uncertain in 2002 and 2003, 50% in 2005 and 2006, uncertain for 2007 and 2008, and 5% for 2009 and 2010. For maize, the tariffs were 25% in 2001, 70% in 2002, uncertain in 2003 and 2004, 5% in 2005 and 2006, uncertain in 2007, and 5% for 2008–2010.

[7]If one assumes that the tariffs stay the same for the years for which tariff data are missing, the correlation between world maize prices and Nigerian maize tariffs is −0.51, and for rice it is −0.58. If the years for which there are missing tariff data are excluded, these correlations are −0.44 and −0.54 for maize and rice, respectively. Under a perfectly implemented variable levy system, these correlations would be −1. See Johnson and Dorosh (2015) for further description of poor implementation of rice levies in Nigeria for the recent period of 2008–2013.

[8]Informal consultations with Nigerian stakeholders and limited data obtained from industry representatives are supportive of this conjecture.

the literature of both price transmission and 'new industrial organisation' to inform our empirical framework when this may be the case.

3.1. Guidance from the price transmission and new industrial organization literature

Price transmission literature generally focuses on whether there is full (an equal change in prices) or incomplete (a less than equal change in prices) price transmission. Data examined are limited to prices at different points in space and time. In this literature, incomplete or greater than full price transmission is often attributed to unobserved factors (e.g. market imperfections, transactions costs) (Baffes and Gardner, 2003).

The 'new industrial organisation' literature provides an alternative explanation for greater than full price transmission. Within this literature, price mark-ups above marginal cost are observed in any market that is imperfectly competitive, and they are a function of the market structure (i.e. the number and size of firms) and the market demand elasticity (Applebaum, 1982). In the presence of mark-ups, transmission from world to domestic prices is higher (Frankel *et al*., 2012), so, in such a case, it is possible that there is greater than full price transmission. This literature uses the same type of data as the price transmission literature, but attributes certain results to market power rather than unobserved costs. Transactions costs that do not systematically vary with input prices (world prices in the price transmission case) are routinely assumed to identify marginal cost.

Based on the Nigerian market context discussed above, we argue that both the price transmission and 'new industrial organisation' literature provide relevant theoretical insights to price relationships in these markets. Given the current somewhat problematic nature of measurement of these factors that influence relationships (especially for trade policy and mark-ups), we rely solely on price data. Bresnahan (1989) argued that there are commonly unmeasured aspects of price relationships, but there is still much to learn from inclusion of only observed prices in an empirical model. In place of direct control of unmeasured factors, careful interpretation of the coefficients of estimated price relationships in light of key market structure contexts allows for insights on the relevance and relative importance of unmeasured factors (Bresnahan, 1989).

3.2. Empirical framework: Cointegration

We proceed with the commonly employed price transmission cointegration framework, which is consistent with LOP theory (Ardeni, 1989). We implement a version of the two-stage cointegration method of Engle and Granger (1987). In the first stage, a linear model that includes the levels of prices in a reduced form of equation (3) is estimated:

$$p_t = \alpha + \beta p_t^* + u_t \tag{4}$$

where p_t is the Nigerian price in Nigerian Naira per kilogram in month t, p_t^* is the exchange rate adjusted world price in Nigerian Naira per kilogram in month t, α is the intercept parameter that captures transactions costs and other factors that do not vary systematically with the world price, β is the long-run world to Nigerian price transmission parameter, which also captures other factors that vary systematically with the world price, and u_t is a random error for period t. If $\hat{\beta}$ is equal to 1 then results are consistent with markets that are perfectly competitive; if $\hat{\beta}$ is <1, then results are

consistent with imperfectly integrated markets; and, if $\hat{\beta}$ is >1, then results are consistent with imperfect competition, and $\hat{\beta} - 1$ is the size of the mark-up. However, if there is imperfect competition in imperfectly integrated markets, then interpretation of the estimate of $\hat{\beta}$ is unclear.

In the second stage, an error correction mechanism (ECM) model is estimated in order to account for short-run dynamics. These time elements are important because some market arbitrage activities may occur with a lag (Ravallion, 1986). The estimated ECM model has a form similar to that outlined in Banerjee *et al*. (1986):

$$\Delta p_t = -\gamma \hat{u}_{t-1} + \delta \Delta p_t^* + \varepsilon_t, \tag{5}$$

where $\Delta p_t = p_t - p_{t\text{-}1}$, $\delta p_t^* = p_t^* - p_{t-1}^*$, $\hat{u}_{t-1}$ are the lagged residuals from the associated levels model in equation (4), δ is the short-run price transmission parameter, which measures instantaneous price transmission between markets, and, γ is the error correction parameter, which measures the average degree of adjustment toward long-run equilibrium in each month (Baffes and Gardner, 2003).

The ECM model results were used to calculate the degree of adjustment to long-run equilibrium over time. Calculations of the degree of adjustment values follow Baffes and Gardner (2003). Implementation of their method means that we define k as the equilibrium adjustment that occurs in n months, and its estimated value ($\hat{k}$) is:

$$\hat{k} = 1 - (1 - \hat{\delta})(1 - \hat{\gamma})^n, \tag{6}$$

such that $\hat{k}$ is the proportional adjustment toward long-run equilibrium that occurs in n months.

3.3. Econometric issues

Stationarity of the series was tested using the Augmented Dickey-Fuller (ADF) test of Dickey and Fuller (1979, 1981) and the Phillips–Perron (PP) test of Phillips and Perron (1988). With only a few exceptions, series were found to be non-stationary, but stationary in first differences. This implies that most series are integrated of order 1 (i.e. $I(1)$ in levels, and $I(0)$ in first differences).[9]

Cointegration was tested using both levels model residual stationarity tests (Engle and Granger, 1987), as well as tests on the statistical significance of the error correction parameter ($\hat{\gamma}$) in the ECM model (Banerjee *et al*., 1986). Levels model residuals stationarity was tested using the ADF and PP tests (Baffes and Gardner, 2003), where rejection of the null hypothesis of non-stationarity indicates cointegration.

Baffes and Gardner (2003) argued that LOP should hold over the long run. Therefore they imposed $\beta = 1$ as a constraint on the levels model, although their results rejected this constraint in many cases. This 'unitary cointegration' (which imposes $\beta = 1$) was also tested through ADF and PP tests on the stationarity of price spreads. Cointegration will be found, but unitary cointegration rejected, both when market power raises β above 1 and when imperfect price transmission lowers it below one.

[9]Out of the 183 price series included in the analysis, there were 10 series for which the null hypothesis of non-stationarity was rejected at the 5% statistical significance level by both the ADF and PP tests. Of those 10 series, 8 were in the urban-to-rural set that has the lowest number of observations (48, see the data section below). For the rural price set (and only this set), there were also 5 out of 48 series for which non-stationarity in first differences was not rejected, but in none of these five cases did this apply for both the ADF and PP tests.

Cointegration test results for those models discussed in the results section are provided in the Appendices S2 to S7, available online at the publisher's website. For all models, evidence of cointegration was found using at least two of the three cointegration tests at 5%. Unity cointegration results are also reported there, showing those cases as described above where cointegration is found, but not unitary cointegration.[10]

3.4. Expected empirical results

LOP implies perfect market integration and competition, which Goodwin and Schroeder (1991) define as the case where the prices are cointegrated and there is both full ($\beta = 1$) and instantaneous ($\delta = 1$) price transmission. The markets for which trade plausibly occurs regularly throughout a marketing year (e.g. coarse grain trade between Nigeria and its neighbours (Galtier, 2009)) are those for which full price transmission is most plausible ($\beta = 1$). The markets for which trade only occurs during a few months of a marketing year (e.g. trade between urban and rural markets (Delgado, 1986)) are expected to have incomplete price transmission ($\beta < 1$). The markets for which there are plausibly transactions costs or quality premiums that have a systematic relationship with the price, and/or mark-ups captured by traders are those for rice and coarse grains imported from global markets. In the models for these markets, there may be greater than full price transmission ($\beta > 1$). It is also conceivable that there are both imperfectly integrated and imperfectly competitive markets, but estimation expectations in such cases are indeterminate.[11]

4. Data and Summary Statistics

4.1. World prices

World Prices were obtained from The World Bank (WB), International Monetary Fund (IMF), GIEWS of the FAO,[12] FAO,[13] and the South African Futures Exchange (SAFEX).[14] For maize and rice, series included in the analysis were those for countries from which UNComtrade data show records of imports for Nigeria since 1995.

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[10]Unitary cointegration failure, defined as when both the ADF and PP statistics for the unitary cointegration test are not statistically significant at the 5% significance level, occurred in the following models. For each respective crop, the number of corresponding unitary cointegration failures for world (6 models), neighbour country (6 models), urban (5 models), and rural (6 models) sets are listed in parentheses: imported rice (5, 0, 0, 0), maize (3, 0, 1, 2), local rice (1, 0, 0, 2), cassava (0, 0, 0, 0), yams (n/a, 0, 0, 0), and cowpeas (n/a, 2, 0, 2). Of the three maize world market unitary cointegration failures, none were for those associated with Northern Nigerian markets.

[11]Statistical tests can indicate whether data are consistent with a particular theoretical explanation, but in this case cannot distinguish between alternative explanations.

[12]The GIEWS data for world prices are from the 'Food Price Monitoring and Analysis Tool' database, within which both 'domestic' and 'international' price series are reported. The Bangkok, Thailand cassava price is also included as a world price, but was obtained from the 'domestic' GIEWS dataset.

[13]The FAO has two primary price databases: (i) GIEWS and (ii) 'FAO Prices'. 'FAO Prices' is a more limited dataset with only globally traded food items.

[14]SAFEX white maize price data were obtained from the Johannesburg Stock Exchange.

4.2. Neighbour country prices

Prices for Benin, Togo, Ghana, Mali, Burkina Faso, Niger, Chad and Cameroon were obtained from GIEWS and the WFP Monthly Price Data Analysis Tool. These price data were available for all food security crops included in the analysis, but are relatively sparse for cassava, yams and cowpeas.

These data are often available for more than one city in our neighbour countries, so choices were made about which prices to include. In the approach taken here, two cities were chosen for each country to allow for some regional variation. Where possible, cities were chosen for each country to include an inland city, connected by roads to Nigeria, and a port city, more closely linked to markets outside West Africa. The countries and cities chosen were (moving geographically in a circle from Nigeria west to north to east to south): Cotonou and Malanville, Benin; Lomé and Korbongou, Togo; Accra and Bolgatanga, Ghana; Bamako and Mopti, Mali; Ouagadougou and Dori, Burkina Faso; Niamey and Maradi, Niger; N'Djamena and Moundou, Chad; and, Yaoundé and Garoua, Cameroon (Figure 1).

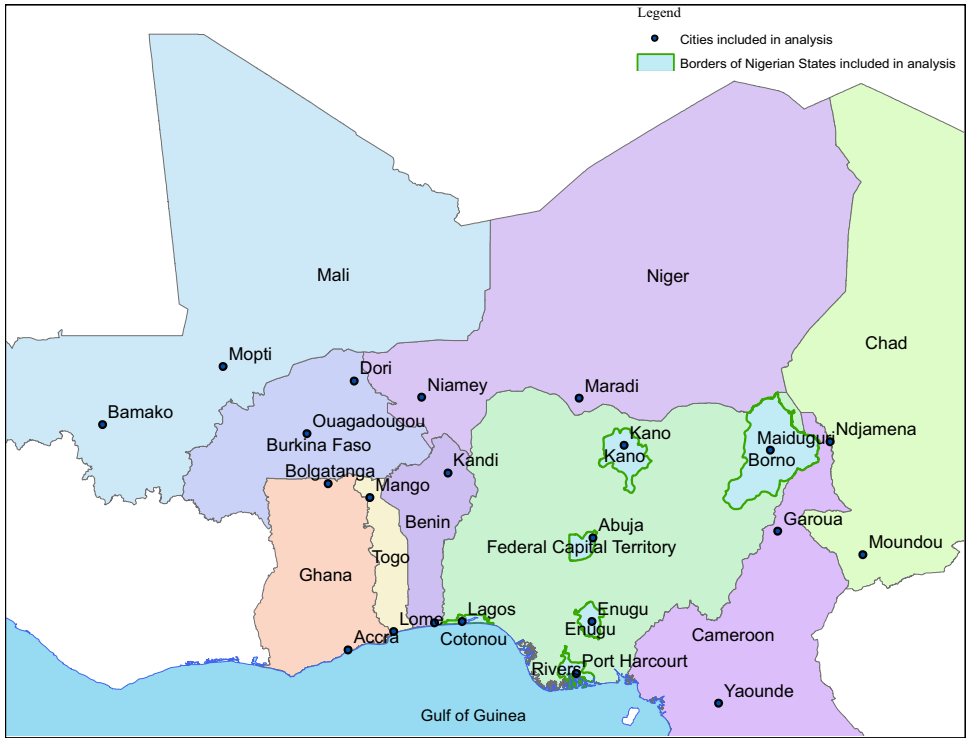

Figure 1. Map of Nigeria and neighbour countries.
***Notes*:** Malanville, Benin and Korbongou, Togo were not included in the DIVA-GIS data. The nearby cities of Kandi, Benin and Mango, Togo are included on the map to show where Malanville and Korbongou are located.
***Sources*:** DIVA-GIS and Natural Earth Data.

4.3. Nigerian state level prices

Nigerian prices are state-level retail prices, aggregated to statewide averages, obtained from the Nigerian NBS. The urban prices are monthly observations, and are, in most cases, available from January 2001 to December 2010. The rural prices are monthly also, but are only available for January 2007 to December 2010. A state with the major urban centre in each of the six major socio-economic regions, as defined in the Nigerian NBS General Household Survey-Panel 2010–2011 Basic Information Document, was included in the analysis. These states are also shown in Figure 1.

4.4. Exchange rates

World prices were adjusted to Nigerian Naira per kilogram using exchange rate data. Most of the world prices were listed in terms of in US Dollars, and for these series, the exchange rate used was the Nigerian Naira per US Dollar exchange rate from the IMF's International Financial Statistics (IFS) database. The GIEWS 'domestic' neighbouring country prices were most commonly in US Dollars or West African CFA Franc. The CFA Franc to US Dollar exchange rate was also obtained from IFS. Exceptions include the cassava prices from Thailand, prices of a few crops in Ghana, and rural maize prices in South Africa. For these prices, the Thai Baht to US Dollar and South African Rand to US Dollar exchange rates were obtained from the Federal Reserve Economic Database of the St. Louis Federal Reserve, and the Ghanaian Cedi to US Dollar exchange rate was obtained from the Bank of Ghana. After these were converted to US Dollars, they were converted to Nigerian Naira per kilogram using the IMF IFS exchange rate series.

4.5. Data issues

There were some data issues with the Nigerian NBS price data. First, there are no data for any of the crops included in the analysis for Borno State for 2001, so these series all begin in January 2002. Data are also missing for Kano State for all crops except cassava and cowpeas for 2008. The millet data for 2008 were clearly subject to transcription error, and so were excluded. Nevertheless, millet results were broadly similar to the results for the other coarse grains so our discussion of patterns applicable to coarse grains remains relevant for millet.

4.6. Price series summary statistics

The summary statistics for the prices in our models are included in Appendix S1, available online at the publisher's website. For the period of analysis, world prices for maize, rice and cassava were substantially lower than those in the Nigerian commercial hubs for these crops (Kano and Lagos, respectively). Standard deviations (SD) for the world prices are all substantially lower than those in Nigeria, especially for imported rice. Mean prices in neighbour country markets were lower than Nigerian commercial hub means for imported rice, cassava, yams and cowpeas, but higher for local rice and maize. These disparities in means and SDs are generally much smaller than those between world and Nigerian commercial hubs.

5. Empirical Results

Each of the world set models (equations (4) and (5)) included price series corresponding to the previously described world price databases, which vary somewhat across sources. For maize, there are 7 models including price series from the US, Argentina and South Africa; for rice (both imported and local), there are 13 models with price series from Thailand, Vietnam, the US, Uruguay, and India; for sorghum, there are 3 models with prices from the US Gulf; for cassava there is 1 model with prices from Bangkok, Thailand.

The neighbour country market set of models is comprised of those for which data were available from the 16 cities described above. In this set, there are: 14 maize models; 14 rice models for each type (imported and local); 13 sorghum models; 6 cassava models; 4 cowpeas models; and 2 yams models. The commercial hub-to-urban and urban-to-rural sets of models are comprised of models associated with each of the six states for each crop.

In order to choose which results to report,[15] goodness-of-fit statistics from the estimated levels models were compared across models from each set (except for the urban-to-rural set for which results for all models in the set are reported) and for each crop. For the world and neighbour country market model sets, the model with the highest adjusted R^2 was chosen for each crop. In the commercial hub-to-urban set, for each crop with multiple potential hubs, the primary commercial hub was identified as that among of the contenders that was associated with the highest adjusted R^2 value.[16] Since results for maize, sorghum and millet are broadly quite similar, only maize results are reported here.

For simplification of results reporting and presentation, figures display the key parameter estimation results from both the levels and ECM models and to allow the reader to visualise the observed regional variation in results. The contents of each figure (2–7) are described beneath Figure 2.

5.1. Maize

Summarised empirical results for maize are shown in Figure 2. Estimated price transmission (EPT) parameters for all models were statistically significantly >0, which suggests that maize prices in the analysed markets co-move to at least some degree. The EPT parameters were statistically significantly >1 in models for the Southern and Central Nigerian states of Lagos, Rivers, Enugu and FCT (Abuja). The highest degree of 3-month adjustment value for the world set is only 59%, which suggests that Nigerian

[15]Comprehensive results are available from the authors upon request.

[16]To do this, a few potential contending hubs were chosen based on the presence of a known commercial hub market, proximity to major producing areas using state-level production data, and secondary sources such as those that describe substantial imports through country ports located in Southern Nigeria (Johnson *et al*., 2013). Kano was identified to be the likely commercial hub for maize, sorghum, millet and cowpeas, because Kano is home to Dawanau Market, the hub market for food crop trade across West Africa (Terpend, 2006). Coarse grains and cowpeas are also grown in Kano's Northwest region, or in the other nearby regions (Northeast or North-Central). The potential hubs for imported and local rice, due to proximity to ports and/or substantial nearby production, were: Lagos, Rivers, Enugu and Kano; for cassava they were: Lagos and Kano; and, for yams they were: FCT (Abuja) and Kano.

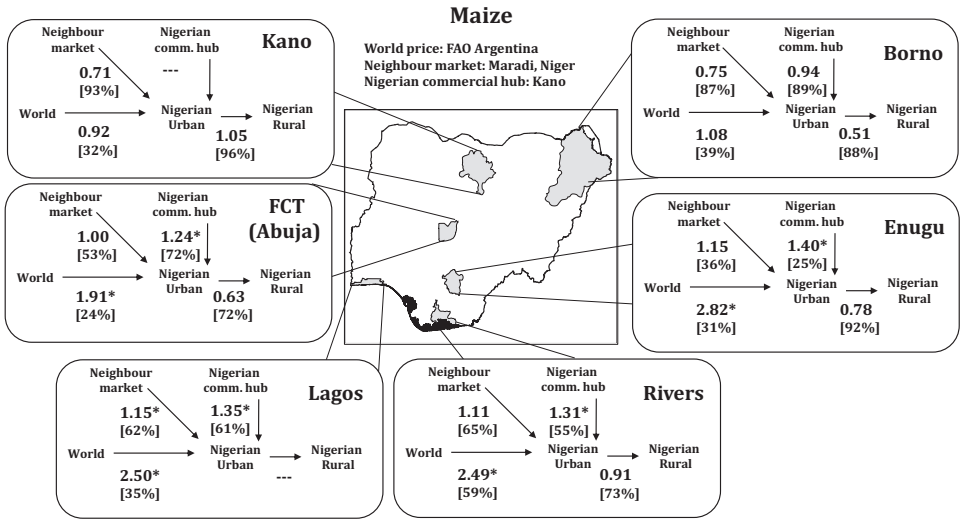

Figure 2. Summarised empirical results for levels and ECM models for maize.
***Notes*:** Estimated Price Transmission (EPT) parameters ($\hat{\beta}$) are statistically different than 0 for all models. The EPT parameters have a star (*) next to them if they are statistically significantly >1 at the 5% significance level. The 3-month degree of adjustment value is presented in brackets [. . .] below the EPT parameters as a percentage. If the estimated error correction parameter ($\hat{\gamma}$) was not statistically significant at the 5% significance level, then the results were excluded because there is insufficient information for accurate calculation of the 3-month equilibrium adjustment value.[17]

maize prices adjust to world prices with a long lag. The 3-month degree of adjustment values are higher for the neighbour market models than world models for all states, and approach 100% for the Kano and Borno State models. Commercial hub-to-urban EPT parameters were statistically significantly >1 in some cases, and broadly had low 3-month degree of adjustment values (an exception was Borno State). EPT parameters for the urban to rural set are broadly lower than for all other sets (Kano State was an exception). These results suggest rural maize prices do not co-move with those in urban areas to a high degree. The patterns of estimates for maize were broadly similar for sorghum and millet.

[17]That the error correction parameter is not statistically significantly different from zero at the 5% significance level does not imply that these series are not cointegrated. In Appendices S2-S7 (available online at the publisher's website) which has cointegration results for the reported models, it is shown that the models for which the error correction parameter is not statistically significantly different from zero at the 5% level have residuals that are stationary at the 5% significance level (at least) based on the ADF and PP statistics. Given that all models show evidence of cointegration based on at least two of the three cointegration tests undertaken at this chosen significance level, we consider all reported series as cointegrated. Therefore, we focus on hypothesis testing of the parameters in the reported results.

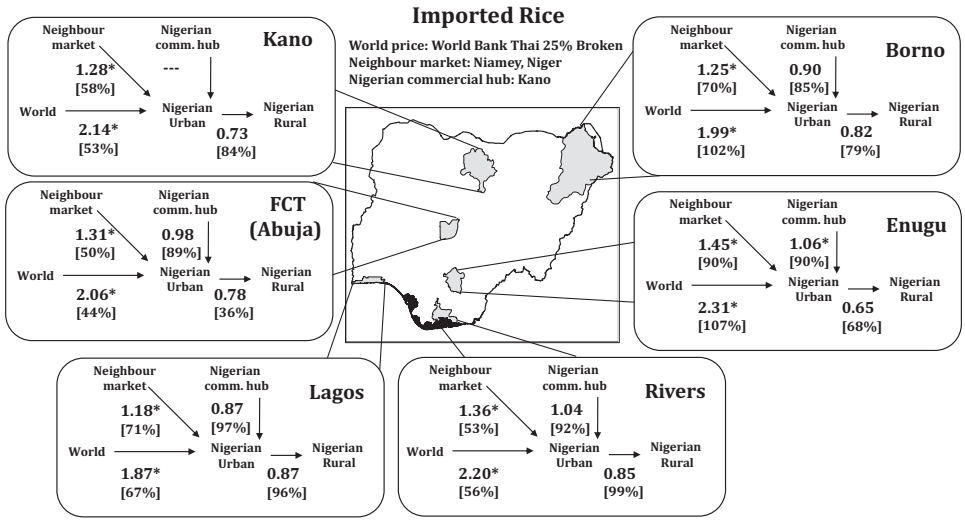

Figure 3. Summarised empirical results for levels and ECM models for imported rice.
***Note*:** See Figure 2 for the description of information for reported parameter estimates and associated statistics.

5.2. Imported rice

Figure 3 includes summarised results for imported rice. All EPT parameters were statistically significantly >0. A notable result is that the EPT parameters were statistically significantly >1 for all models in the world set, and often had magnitudes near 2. The degree of 3-month adjustment to the world price exceeded 100% for the Enugu and Borno State models, and ranged from 44% to 67% in the other states. These results suggest that equilibrium adjustment to world prices is considerably faster for rice than coarse grains, especially in some regions. EPT parameters for all neighbour country models were also statistically significantly >1. EPT parameters for the commercial hub-to-urban set are all near 1 and all corresponding 3-month adjustment values were above 80%, which implies that imported rice prices in urban areas in Nigeria equilibrate quicker than those of coarse grains. There was wide variation in degree of adjustment values for the urban-to-rural set (36% to 99%). This result implies that urban areas have stronger linkages with each other than with rural areas.

5.3. Local rice

Summarised empirical results for local rice are provided in Figure 4. All EPT parameters are statistically significantly >0. The magnitudes for the world set are all statistically significantly >1, but smaller in magnitude than those of imported rice. Neighbour country model EPT parameters were also lower in magnitude than those for imported rice. Only the Lagos neighbour country model had an EPT parameter significantly >1. EPT parameter magnitudes for the commercial hub-to-urban set, however, were more commonly >1 for the local rice models than imported rice models. Similar to imported rice, 3-month adjustment speeds varied across regions, but

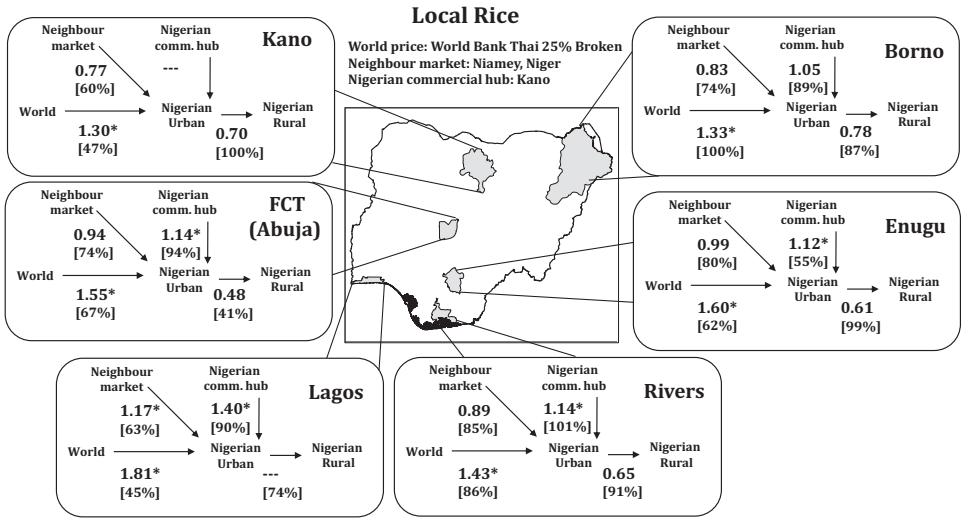

Figure 4. Summarised empirical results for levels and ECM models for local rice.
***Note*:** See Figure 2 for the description of information for reported parameter estimates and associated statistics.

were relatively high for all commercial hub-to-urban models (except for Enugu). The urban-to-rural 3-month adjustment values were broadly higher for local rice than imported rice for all states except Lagos and Rivers states in Southern Nigeria (where the major ports are located).

5.4. Cassava

Figure 5 includes summarised empirical results for cassava. All EPT parameters are statistically >0. Three-month adjustment values to world prices varied greatly across regions. Those for Enugu and Lagos in Southern Nigeria exceeded 100%, implying rapid equilibrium adjustment, while those for Kano and FCT (Abuja) were only near 30%. For the Kano State case, higher 3-month adjustment to the neighbour market prices than world prices was found, but the opposite applied for Lagos. The 3-month adjustment values for the commercial hub-to-urban and urban-to-rural models had distinct regional variation. In Southern Nigeria, cassava price adjustment between urban areas and between urban and rural areas is rapid, but in Northern Nigeria it is slow.

5.5. Yams

Summarised empirical results for yams are included in Figure 6. All EPT parameters are statistically significantly >0. Relatively low neighbour market set EPT parameters were found for yams as compared to other crops. This suggests that Nigerian yam prices are more independent from changes in international yam prices than is the case for other crops. For the commercial hub-to-urban and urban-to-rural sets, estimated 3-month adjustment values were all above 50%, suggesting that there is somewhat rapid adjustment (especially relative to coarse grains) of yams prices throughout Nigeria.

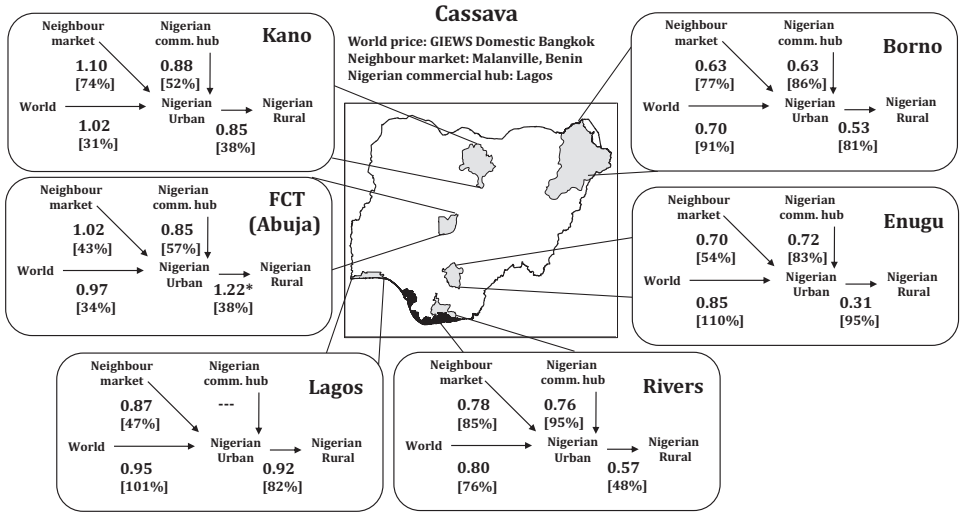

Figure 5. Summarised empirical results for levels and ECM models for cassava.
***Note*:** See Figure 2 for the description of information for reported parameter estimates and associated statistics.

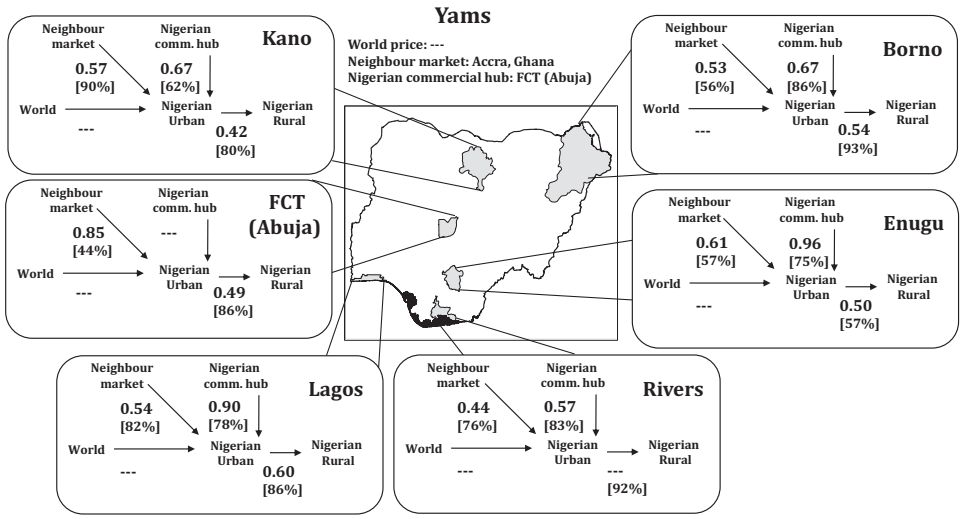

Figure 6. Summarised empirical results for levels and ECM models for yams.
***Note*:** See Figure 2 for the description of information for reported parameter estimates and associated statistics.

5.6. Cowpeas

Figure 7 displays summarised empirical results for cowpeas. For the neighbour market set, all EPT parameters were statistically significantly >0. The 3-month adjustment

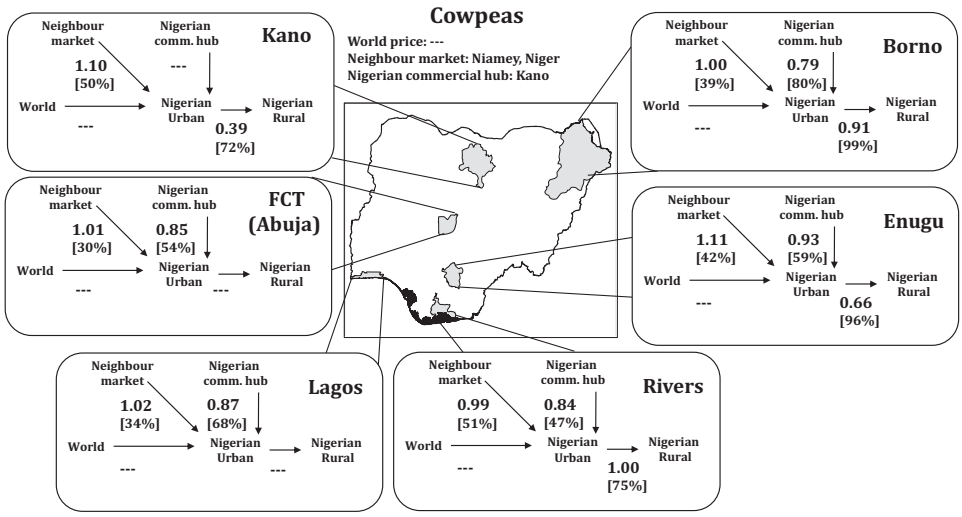

Figure 7. Summarised empirical results for levels and ECM models for cowpeas.
***Note*:** See Figure 2 for the description of information for reported parameter estimates and associated statistics.

values for this set, however, ranged from 30% to 51%, which suggest long lags in adjustment. There are higher 3-month adjustment values for the commercial hub-to-urban and urban-to-rural sets than for the neighbour country set. These results suggest that cowpea prices within Nigeria are more highly linked than Nigerian and neighbour country prices. The 3-month adjustment values were higher for the urban-to-rural set than the commercial hub-to-urban set.

5.7. Comparison across models and sets

Table 1 includes the average adjusted R^2 values for the reported levels models, average estimated EPT parameters from those levels models, average adjusted R^2 values from corresponding ECM models, and average 3-month adjustment values from the ECM models for results in Figures 2–7, in order to facilitate comparison between models and across crops.

The world models for coarse grains and cassava have lower levels model adjusted R^2 values than those for imported and local rice, but the opposite was found for the neighbour market set. These results imply that Nigerian coarse grains and cassava have relatively higher price correspondence with neighbour countries than with those in world markets. Hence, trade for coarse grains is mostly with neighbours, whereas substantial rice trade is with global sources. Yams models in the neighbour country set have the lowest levels model average adjusted R^2 values of all neighbour country models. These results suggest that other (local) factors are relatively more important than trade in explaining yam price variation. The highest levels model average adjusted R^2 values of all models in Table 1 are those for the commercial hub-to-urban set for imported rice, which was 0.90, and those for local rice and cowpeas were above 0.80. Average levels adjusted R^2 values (and EPT parameters) were higher for the

Table 1

Average adjusted R^2 and EPT parameter values for levels models, and average adjusted R^2 and degree of adjustment in 3 months for ECM models for results in Figures 2–7

	World	Neighbour country	Commercial hub-to-urban	Urban-to-rural
Levels adj. R^2				
Maize	0.47	0.68	0.57	0.61
Imported rice	0.86	0.87	0.90	0.70
Local rice	0.79	0.80	0.84	0.46
Cassava	0.54	0.58	0.64	0.53
Yams	...	0.21	0.50	0.20
Cowpeas	...	0.61	0.81	0.69
Levels EPT values				
Maize	1.95	0.98	1.25	0.78
Imported rice	2.10	1.31	0.97	0.78
Local rice	1.50	0.93	1.17	0.64
Cassava	0.88	0.85	0.77	0.73
Yams	...	0.59	0.75	0.51
Cowpeas	...	1.04	0.86	0.76
ECM adj. R^2				
Maize	0.09	0.23	0.18	0.27
Imported rice	0.20	0.19	0.35	0.30
Local rice	0.21	0.22	0.30	0.32
Cassava	0.18	0.18	0.24	0.23
Yams	...	0.23	0.23	0.25
Cowpeas	...	0.14	0.18	0.23
Degree of adjustment in 3 months				
Maize	37%	66%	60%	70%
Imported rice	72%	65%	91%	77%
Local rice	68%	73%	86%	82%
Cassava	74%	63%	75%	64%
Yams	...	68%	77%	82%
Cowpeas	...	41%	62%	57%

Note: ECM, error correction mechanism; EPT, estimated price transmission.

commercial hub-to-urban set than the urban-to-rural set. This implies that urban market prices are linked to one another to a greater degree than are urban and rural prices.

Levels model EPT parameters are higher than 1 for maize, imported rice and local rice in the world set, and for the neighbour country set for imported rice. These large EPT parameter magnitudes imply that these markets either have high transactions costs or quality differences between imported and local versions of these goods *that vary systematically with the border prices* for these foods, or there are mark-ups by importing firms (or all of these). In these cases, cointegration is not rejected, but unitary cointegration is.

Average adjusted R^2 values for the ECM models are mostly substantially lower than those of the associated levels models (the exception is for yams in the neighbour country and urban-to-rural sets). These values, however, are higher in most cases for the sets within Nigeria than those with international markets. Coarse grains are exceptional in that there are higher adjusted R^2 values for the ECM models for the

neighbour country set than commercial-hub-to-urban set. Again, this is consistent with the strong linkages between Nigerian coarse grain markets (especially in the north) and those in neighbour countries. These same patterns broadly apply for the average 3-month degree of adjustment values. It is notable that none of the sets had an average adjustment close to full adjustment after 3-months, which suggests broadly long lags in price adjustment in all examined markets.

6. Concluding Remarks

This paper has three main findings, and the comprehensive study design added instructive nuances for each finding. First, crop tradability is found to be a key determinant of price transmission, consistent with the findings of Abbott and Borot de Battisti (2011), but also that tradability varies across crops and scopes of markets. Price correspondence between world rice prices and Nigerian urban rice (both imported and local) prices is strong for all regions. World coarse grain prices (maize and sorghum) do not correspond well with those in Nigeria. However, this does not mean that coarse grains are non-traded. Our results show strong price correspondence between Nigerian coarse grain prices and those of its neighbour countries in West Africa, even those for which there is currently sparse UNComtrade data. Indeed, in some cases, linkages between neighbours and Nigerian markets were closer than those within Nigeria. The implications are that there is regular movement of coarse grains across borders throughout West Africa, and to a higher degree than they are imported by sea through Southern Nigerian ports. Cowpea results, and to a lesser extent those of yams and cassava, are also consistent with greater regional than global trade. These findings are consistent with cowpea trade estimates of Langyintuo *et al.* (2005) and observations of Terpend (2006) and Galtier (2009) of substantial trade in cereals and cowpeas (and cassava and yams in relatively smaller quantities) throughout West Africa. They also support the empirical results of Baffes *et al.* (2015) who found relatively greater coarse grain price correspondence among East African Countries than between those countries and global markets. Trade in rice occurs by road between Nigeria and its inland neighbour countries, but contrary to coarse grains, also to a similarly substantial degree through the ports in the south.

Our second key result is that local market conditions (e.g. supply-use balances, extreme weather anomalies) appear to matter for price transmission, especially in the short run. Our results imply that local (or other) conditions matter for all examined crops, but most prominently for coarse grains and cowpea markets, reflected in both the substantial lags in adjustment across all markets and the low adjusted R^2 of the ECM models. The implication is that price formation in local markets takes place primarily in local markets, even for crops that are widely traded between urban areas.

Our third key finding is that there are larger estimated price transmission parameters than would be expected under perfectly competitive and well-integrated markets, even with the presence of factors expected to reduce price transmission. These apply especially for rice and coarse grains in models for international markets. For coarse grains, this result is only relevant for Southern Nigeria, but is applicable in all regions for rice. In these cases, cointegration was found, but unitary cointegration, which imposes theoretical constraints from the LOP, was rejected. The implications of these estimates is that there are either substantial transactions costs or quality differences that result in premiums for imported food *that vary systematically with the border price*, and/or mark-ups by traders that import coarse grains and rice on world

markets. Evidence from Nigerian markets suggests that quality differentials exist, and may be systematically related to world prices in some markets (e.g. Kano) but not others (e.g. Lagos). Also, ad valorem tariffs are unlikely to explain the large observed price margins and have not varied with world prices in a way that should give rise to large price transmission parameters (rather, the opposite). This finding motivates further investigation into the structure (e.g. number of traders) of these markets, to ascertain the extent to which interpretation of market power as a key factor in rice and some maize markets is supported by that evidence. Informal consultations with Nigerian stakeholders, supported by limited data obtained from rice industry representatives, suggest that concentration ratios of marketing agents are high for rice importers from global markets, but lower for trade between commercial hubs and with neighbouring countries.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Summary statistics for price series included in the models for which results are in figures 2-7 for the period January 2001 to December 2010.

Appendix S2. Cointegration and unitary cointegration results associated with the maize models in figure 2.

Appendix S3. Cointegration and unitary cointegration results associated with the imported rice models in figure 3.

Appendix S4. Cointegration and unitary cointegration results associated with the local rice models in figure 4.

Appendix S5. Cointegration and unitary cointegration results associated with the cassava models in figure 5.

Appendix S6. Cointegration and unitary cointegration results associated with the yams models in figure 6.

Appendix S7. Cointegration and unitary cointegration results associated with the cowpeas models in figure 7.

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