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Transmission of Global Commodity Prices to Domestic Producer Prices: A Comprehensive Analysis

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Abstract

Utilizing a comprehensive dataset that includes a sample of 104 countries for corn, 54 countries for soybeans, 82 countries for wheat, and 77 countries for rice and covers the period from 1991 to 2013, we estimate a globally comprehensive but heterogeneous (country-specific) transmission elasticities between international prices and domestic producer prices. We mainly utilize the traditional two-step Engel-Grange cointegration model and the recently developed nonlinear autoregressive distributed lags (NARD) model to estimate the transmission elasticities. We find mixed evidence on the existence of long-run relationship between international and domestic price. For corn 66 out of 104, for soybeans 27 out of 54, for wheat 47 out of 82, and for rice 49 out of 77 countries, we fail to have a long-run relationship. For corn and soybeans, the long-run relationship is evident in top producing countries whereas the converse is evident for wheat and rice, particularly for rice. We also find that the pass-through of international to domestic prices is asymmetric in the majority cases—these asymmetries are negative, i.e., the domestic producer prices react less fully to an increase in international prices than to a decrease and are acute in the short-run than the long-run. We also estimate the crop-specific short-run global mean transmission elasticities, which vary from 0.358 (corn) to 0.524 (soybeans).

1 Introduction

Estimation of how the supply of global agricultural commodity responds to international prices depends on the knowledge of transmission elasticities between international and domestic producer crop prices. This knowledge is particularly necessary to separate out genuine supply response from aggregate global supply response as estimated by Roberts and Schlenker (2013), Haile, Kalkuhl, and von Braun (2014), Hendricks, Janzen, and Smith (2015), and Haile, Kalkuhl, and von Braun (2015). The estimates of these authors' supply elasticity consist of two parts: the degree of transmission of international prices to domestic producer prices and the genuine supply response to expected producer prices (Haile et al. 2015). While estimating supply responses to prices, these authors assume that the transmission of international price signals to domestic markets is the same across all countries. But, the degree of transmission elasticities is supposed to differ across crops, countries, and/or regions depending on the country-specific trade policy, economic policy, market power enjoyed by agricultural products processing and marketing industries, and so on. These means the existing estimates of the global supply elasticity cannot provide a satisfactory answer about the true supply response. Thus, the research concerning the extent to which international agricultural commodity price signals is transmitted to domestic producer prices in different countries is required.

There are a number of other reasons relating to supply response enlighten us on the importance of estimating transmission elasticities between international and domestic prices. First, the issue of global land use changes caused by biofuels production and other economic shocks. In the past couple of years or so, a significant number of studies has been conducted by agricultural and environmental economists with an attempt to measure the indirect land use change caused by biofuel production in the U.S. It is argued that biofuel diverts crops from food and thereby food demand and prices rise given that the amount of supply is fixed. In response to higher prices, it is likely that farmers across the world increase their production either by increasing their crop yields on existing agricultural land or by converting land from other crops or from forest or pasture land. Given the assumption that the increase crop yield requires the invention of new seeds or technology, and which requires long-term investment, so additional production will come through the conversion of new land, which is defined as the indirect land use changes caused by biofuel production. These whole process can function well if the

changes in international prices are being transmitted to the producers prices of a country at a higher rate or perfectly.

A closely connected issue of this is the sustainable agricultural production. When the long-term transmissions of international prices to domestic markets are slow and imperfect, producers make decisions based on prices that do not represent their real social costs and benefits. As a result, there is strong empirical evidence from both developing and developed countries that any large, sustained deviation of domestic price from world prices in either direction leads to substantially suboptimal outcomes and slows the rate of economic growth (World Bank, 2012). The next important issue is the international price instability. If a fall in international prices is not fully transmitted to domestic prices, then reduction in world supply and increases in world demand that would have otherwise occurred will not take place—thereby making the price reduction more acute and prolonged—hence, on a global scale, significant local market isolation triggered by government intervention may induce augmented price fluctuations (Quiroz and Soto, 1995; Ghoshray, 2011). For example, during 2006-2010, some rice-producing countries in Asia commenced protecting policies, which lead to higher volatility of international rice price and thereby benefited them in the short-run but perhaps these policies was no good neither for the world nor for these countries, which have suppressed the price signal necessary for their own efficient supply response (World Bank, 2012).

Another motivation of this paper is to examine whether agricultural trade liberalization that started to take place from the beginning of the 1990s has any impact on the magnitude of the transmission elasticities. Price transmission from world markets to domestic markets is affected by several factors, including transport costs, countries' levels of self-sufficiency, exchange rates, and domestic shocks, but trade policy is perhaps the most fundamental determinant of the extent to which world price shocks pass through to domestic markets (FAO, 2011). In the late 1980s and early 1990s, developing countries started to liberalize their agricultural policies so that their domestic markets become more integrated into world markets (see WTO), but a globally comprehensive and country-specific differentiated empirical analysis of price transmission that covers post-reform period are not available in the existing literature. Hence, this paper will add value to the existing literature by examining the transmission of price signals from the world market to domestic producers using post-reform period data.

Last but not least, the issue of asymmetric transmission—there is a widespread belief that the pass-through of an increase in international prices is not same as that of a decrease in prices. Direct price intervention by governments may result in the domestic price being completed unrelated to the international prices or in the two prices being related in a nonlinear manner so that increases in international price are transmitted to the domestic level while decreases in international price are transmitted in relatively slowly (Ghoshray, 2011). Using large samples of diverse products (77 consumer and 165 producer goods), including agricultural products, Peltzman (2000) finds output prices tend to respond faster to input increases than to decreases in more than two of every markets examined, which in fact challenge the standard economic theory that does not explain the incidence of asymmetric price (Peltzman, 2000).

Thus, the objective this paper is to provide a worldwide but heterogeneous (country-specific) linear and asymmetric transmission elasticities between the internaltiol and domestic producer prices for four key agricultural crops namely corn, soybeans, wheat, and rice[2]. We analyze these fours crops because together these four crops make up about 75 percent of the caloric content of food production worldwide (Roberts and Schlenker, 2013) and about 51 percent of the global aggregate harvested cropland[3]. Hence, any changes in the production or land use of these four crops due to changes in international prices will have a significant impact worldwide. We use the yearly data covering the period 1991 to 2013 and consisting of both the leading and small growers of these four commodities. Along with the linear transmission, our approach accounts for nonlinear asymmetric transmission resulting from country-specific trade and economic policies, production policies, transaction costs, price support, exchange rates , and so on. In addition to traditional Engle-Granger cointegration model, we utilize the nonlinear autoregressive distributive lag (NARDL) model, recently developed by Shin et al. (2014). The NARDL model simultaneously and coherently models both the short- and long-run asymmetries and the cointegration relationship in a dynamic adjustment framework.

The rest of the paper proceeds as follows. Section 2 discusses a theoretical background on price transmission and reasons for asymmetries. Section 2 presents a review of the existing literature. Section 3 discusses the empirical model and econometric methods we utilize to

[2] International prices and world prices are used synonymously in this paper

[3] Author's calculation: 2010-2013 average and includes both temporary and permanent crops

estimate the empirical model. Section 4 provides data description. Section 5 presents the empirical findings and an interpretation of the findings. Section 6 concludes.

2 Literature Review

Most recent studies have investigated the price transmission of consumer prices rather than producer prices (e. g., Minot, 2011; Baquedano and Liefert, 2014; Kalkuhl, 2014). Studies that have focused on the transmission of producer prices are Anderson and Tyers (1992), Mundlak and Larson, (1992), Quiroz and Soto (1995), Sharma (2003), and Baquedano et al. (2011), among many others. Earlier studies such as Mundlak and Larson (1992) examine the transmission of world prices and exchange rates to producer prices for 58 countries for 1968–78 and for the countries of the European community for 1961-85. Their sample cover some 60 products and they use a simple correlation coefficient to test for the market integration. These authors find a very high transmission elasticities (median was 0.95).

Starting from 1990, agricultural applied economist rely on advanced econometric methods such as cointegration and error-correction models (ECM) to examine the international price signals domestic markets. Anderson and Tyers (1992) utilize ECM to calculate the short and long-run transmission elasticities by expressing domestic producer prices for each commodity in each country in terms of border prices. Their analysis cover 30 countries and 7 agricultural commodities for the period 1961–1983 and they find on average a transmission elasticity equal to 0.3 for most countries.

Quiroz and Soto (1995) use a dynamic ECM to estimate the transmission elasticities and find a much lower transmission for most countries, and no transmission in the long run for 30 out 78 countries using the updated data covering the period 1966 to 199. They argue that the high transmission elasticities as found by Mundlak and Larson (1992) might be due to a spurious regression problem as prices variables were non-stationary at the level form.

Using similar methods (ECM), Sharma (2003) estimates transmission elasticities for Asian cereal markets and the estimates indicate that the short-run transmission elasticities are typically in the range of 0.2 to 0.4. Baffes and Gardner (2003) examine the world price signals to domestic prices for eight countries and ten commodities and find that only 3 countries out of 8 were integrated with world markets. Based on the Autoregressive Distributed Lag (ARDL)

models, and of the corresponding Error Correction specification, Conforti (2004) examine price transmission in 16 countries, including 3 in Sub-Saharan Africa, primarily for basic food commodities. The results indicate that the African markets included in the sample are characterized by an incomplete transmission compared to Latin American and Asian markets.

Recently, Baquedano et al. (2011) investigate the level of integration of Malian and Nicaraguan agriculture into world markets, and estimate transmission elasticities between changes in the countries' border and domestic prices, for one export and one import commodity for each country, using generalized ECM. A general conclusion of their results is that Nicaraguan agriculture is more integrated into world markets than that of Mali. Relative to Nicaragua, Mali exhibits a slower convergence of producer to border price for its main export crop of cotton.

In summary, the above reviews indicate that a worldwide empirical analysis which focuses on the extent to which the world prices of key agricultural crops have been transmitted to domestic producer prices in the post-liberalization period is missing. Hence, this paper plans to fill that gap. Estimation of these is particularly important for supply analysis. The magnitude of supply responses in developing countries is shaped by transmission of world prices, not just to the retail level, but also at the farm level—if farm gate prices do not increase, there will be no supply response (FAO, 2011) and this is applicable for other countries as well.

3 Theoretical Background[4]

The law of one price (LOP), a fundamental part of the purchasing power parity (PPP) theory, is the basis of the price transmission theory. The LoP states that with complete elimination of all arbitrage and no transportation cost, the prices of traded homogenous goods would be the same in all spatially separated but competitive markets when expressed in a common currency. The Samuelsson single commodity model (1952) and the Takayama-Judge multicommodity model (1971) have similarity with the LOP, which also characterize how domestic prices are linked to commodity markets. The Takayama-Judge (1971) model, an extension of the Samuelsson single commodity model (1952), characterizes a simultaneous equilibrium in markets for several commodities, regions and time point. This model states that if the trade

[4] The discussion of this section is largely based on Liefert and Persaud (2009) and Witzke et al. (2011).

takes place between two countries, then price differences between countries cannot exceed per unit transport costs and price differences between two-time points cannot exceed per unit storage costs. The former is called arbitrage condition and the latter is called temporal arbitrage condition. The three possible regimes of the arbitrage condition $P_{cit} \leq P_{cjt} + T_{cijt}$ can be written depending on the trade balance:

(1a) $P_{cit} = P_{cjt} + T_{cijt}$; if region i import from region j with transaction cost T

(1b) $P_{cit} = P_{cjt} - T_{cijt}$; if region i export to region j with transaction cost T

(1c) $P_{cit} < P_{cjt} + T_{cijt}$; no trade will occur

where P is commodity prices with the subscripts c, i, and j refer to a crop, a home country, and a foreign country, respectively. The basic spatial arbitrage conditions stated in (1a)-1(c) are called the weak LoP. If these conditions hold with equality, then it is called strong LOP (Fackler, Goodwin, p. 978).

For price transmission to be perfect (let's denote transmission elasticity, $\beta_{cj} = \frac{\partial P_{cit}}{\partial P_{cjt}} \frac{P_{cjt}}{P_{cit}} = 1$, transaction costs need to be proportional to prices, i.e., $T_{cij} = \tau_{cij} P_{ci}$. Similarly, if a country imposes tariff on imported good, then the transmission elasticity can be perfect assuming the country levies ad valorem tariffs, where the tariff is calculated as a percentage of the world price—then any percent change in the world price may result in an identical percent change in the domestic price (assuming no domestic transport or transaction costs for the imported product).

It is barely true that the real world would satisfy every condition that is required for perfect price transmission. For example, if the tariff or transaction costs are a fixed charge per unit of good imported or exported, then the absolute changes in international prices would be fully passed on to the domestic markets , assuming that the arbitrage condition holds with equality and there are no other costs involved. Depending on the direction of trade flows, this would imply a transmission elasticity equal to greater or less than one.

Starting from the beginning of the 1990s, agricultural applied economists (e.g., Anderson, 1992; Larson, 1992; Quiroz and Soto, 1995) have begun to examine the price transmission of agricultural commodities for policy purposes and for a large set of commodities and countries,

which include both the exporting and importing countries. To include all the possible scenario (exporter or importer) that majority empirical studies cover in their analysis, we express the arbitrage conditions (1a)-1(c) using the following inequality (assuming no other trade costs other than the transaction costs)

(2) $P_{cjt} + T_{cijt} \geq P_{cit} \geq P_{cjt} - T_{cijt}$; Assuming transportation costs are symmetric, $T_{cijt} = T_{cjit}$

where $P_{cjt} + T_{cijt}$ is the domestic price for imported good and $P_{cjt} - T_{cijt}$ is the domestic price for exported good. Transportation costs (T) affects the degree of price transmission from world prices to domestic prices depending on the direction of trade. Given the fixed T, we can make the following two statements

Statement 1: As $P_{cit} > P_{cjt}$ for importing countries/commodities due to the existence of T, a given percentage change in P_{cjt} will generate a smaller percentage change in P_{cit}. As a result, the transmission elasticity between P_{cit} and P_{cjt} will be less than one, i.e.

(2.1) Transmission elasticity (importer) $\beta_{cj} = \frac{\partial P_{cit}}{\partial P_{cjt}} \frac{P_{cjt}}{P_{cit}} < 1$ as $P_{cit} > P_{cjt}$ with $T_{cijt} > 0$

Statement 2: The existence of T results $P_{cit} < P_{cjt}$ for the exporting countries/commodities. As a result, a given percentage change in P_{cjt} will generates a higher percentage change in P_{cit} and the transmission elasticity between P_{cit} and P_{cjt} will be greater than one, i.e.

(2.2) Transmission elasticity (exporter), $\beta_{ci} = \frac{\partial P_{cit}}{\partial P_{cjt}} \frac{P_{cjt}}{P_{cit}} > 1$ as $P_{cit} < P_{cjt}$ with $T_{cijt} > 0$

There are other factors that may slow down or cause international prices to be transmitted into domestic market imperfectly or asymmetrically. Such factor includes country-specific trade-related policies such as tariffs and quotas, price support, deficient market infrastructure, asymmetric information, variable transportation costs, the market power of the middlemen, and so on.

Since one of our research objectives is to estimate asymmetric transmission elasticities, we will discuss here how the above-mentioned factors can cause prices to asymmetrically transmit. Suppose, the food processors and wholesalers of countries have the market power over producers from which they purchase primary output, then for a given change in world

prices food processors and wholesalers might use their market power to reduce the degree to which they pass on the price increases that they receive to their farm suppliers. Similar to this, the market imperfection of incomplete information caused by deficient market infrastructure may result in slower pass-through of world prices to domestic prices when world prices increase. When a country's internal infrastructure is not good, then producers in isolated areas might be unaware of the world price movements. This can give wholesalers additional power over farms to control price transmission in favor of them. Figure 1 shows such kind of asymmetric transmission.

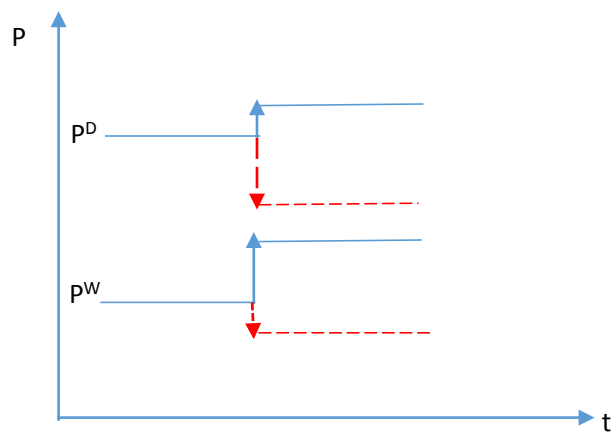

Figure 1. Asymmetric Changes in Domestic Prices (P^D) from an equivalent change in international prices (P^W) [Meyer and Taubadel, 2004]

In summary, whether transaction are fixed or proportional to prices and/or tariffs are ad valorem or fixed charge per unit of goods and/or import quotas are unchanged or not and/or every agent of the market has the access to full information is an empirical question and hard to measure as details data on these for all countries around the world are rare. An alternative approach is to ignore all these factors and to estimate the degree of transmission between domestic and world prices—then make an attempt to explain heterogeneous price transmission elasticity using some macroeconomic variables such as trade volume, inflation, real GDP, exchange rate volatility, trade share in total consumption, and so on. Our focus here is to estimate the magnitude of transmission elasticities.

3 Empirical Model and Estimation Methods

Empirical Model

Our empirical model mainly follows from the law of one price (LOP). For any particular commodity c, the spatial relationship between the domestic and world prices can be expressed as a multiplicative approximation (Richardson, 1978)[5]

(3) $P^*_{cit} = \beta_0 P^{\beta_1}_{cjt} E^{\beta_2}_{cjt} T^{\beta_3}_{cjit} R^{\beta_4}_{cjit}$

where P^*_{cit} is the domestic price of commodity c in time t, P_{cjt} is world price of commodity c in time t, E_{cijt} is the domestic exchange rate expressed in US dollar, T_{cijt} is a transaction or other trade-related costs R_{cijt} is residuals reasons for price differences between domestic and world markets and $\beta_0, \beta_1, \beta_2, \beta_3$, and β_4 are parameters. The assumption of complete commodity arbitrage along with the assumption of homogenous products across countries suggest that the strong law of one price will be satisfied if

(4) $\beta_0 = \beta_1 = \beta_2 = \beta_3 = 1$, and $\beta_4 = 0$

The converse is true if there are no commodities arbitrage and commodities are nontraded. In such situation the equation (4) becomes

(5) $\beta_1 = \beta_2 = \beta_3 = 0$

In the real world, the condition (5) will not hold if a good is traded. Similarly, the condition (4) may not hold due to the existence of transaction costs, deficient infrastructure, markets powers, and differences in product quality as we have discussed in the previous section. By admitting the limitation that we do not have worldwide data on these indicators, we rewrite the equation (3) for each country and crop as follows (lowercase letters indicating logs)

(6) $p_{cit} = \beta_{0ci} + \beta_{1ci} p_{cjt} + u_{cit}$

where $p_{cit} = P^*_{cit} / E_{cijt}$ denotes domestic prices expressed in US dollars, u_{cit} is an unobserved disturbance term which includes both omitted variable T and R. The coefficient β_1 is the elasticity of the domestic price with respect to the world price, to be called as the elasticity of transmission.

[5] Most LOP tests and/or price transmission literature utilize a model similar to this

Estimation Methods

Linear Cointegration tests

A number of time series econometric techniques such as linear cointegration, threshold cointegration, causality, ARDL models have been used by applied economists to test each of the components of price transmission. Engle and Granger (1987) or in short EG cointegration model is the most widely used one. This study uses the traditional two-stage EG model to estimate the transmission elasticities when it comes to the question of linear and symmetric transmission of international prices to domestic prices.

If we find that the two price series as shown in equation (6) are integrated of the same order, say I(*1*), that is , they contain a unit root (stochastic trend), then the regression of the domestic on international prices may produce a spurious regression. The EG model takes care of that issue and provides long run equilibrium relationships between non-stationary integrated price variables. The EG model states the two price series will be cointegrated if the linear combination of them, which takes the form $u_{cit} = p_{cit} - \beta_0 - \beta_1 p_{cjt}$, is I (0). Once we find the evidence of the existence of the long-run relationship in equation (6), we estimate the traditional linear ECM, which takes the following form

(7) $\Delta p_{cit} = \mu_{ci} + \rho_{ci} p_{cit-1} + \theta_{ci} p_{cjt-1} + \sum_{s=1}^{p-1} \phi_{cis} \Delta p_{cit-s} + \sum_{s=0}^{q-1} \pi_{cis} \Delta p_{cjt-s} + u_{cit}$

where the symbol Δ denotes a first-difference of the variables, e.g., $\Delta p_{it} = p_{it} - p_{it-1}$, p and q are the order of lags, ε_{it} is an iid process. The model in equation (7) is called symmetric ECM, which provides both the short- and long-run transmission elasticities that are linear and symmetric.

Non-Linear Cointegration test

The model in equation (7) would be miss-specified when price transmission is nonlinear and/or asymmetric. To estimate the asymmetric transmission, we employ the nonlinear autoregressive distributive lag (NARDL) model, recently developed by Shin et al. (2014). The NARDL model simultaneously and coherently models both the short- and long-run asymmetries and the cointegration relationship in a dynamic adjustment framework. One of the main advantages of using the NARDL model is it detects hidden cointegration-a concept introduced by Granger and Yoon (2002). Hidden cointegration exists if both price series are not

cointegrated in the conventional sense, but their positive and negative sums are cointegrated with each other (Granger and Yoon, 2002). With this keep in mind, we decompose international prices, p_{cjt} into its positive and negative partial sums, i.e., p_{cjt}^{+} and p_{cjt}^{-}, of increases and decreases such as

$$(8)\quad \begin{aligned} p_{cjt}^{+} &= \sum_{k=1}^{t} \Delta p_{cjk}^{+} = \sum_{k=1}^{t} \max(\Delta p_{cjk}, 0) \quad \text{and} \\ p_{cjt}^{-} &= \sum_{k=1}^{t} \Delta p_{cjk}^{-} = \sum_{k=1}^{t} \min(\Delta p_{cjk}, 0) \end{aligned}$$

After introducing the partial decomposition of equation (8) into the traditional ECM (equation 7), we get a more general ECM as follows (Shin et al., 2014)

$$(9)\quad \Delta p_{cit} = \mu_{ci} + \rho_{ci} p_{ci,t-1} + \theta_{ci}^{+'} p_{cj,t-1} + \theta_{ci}^{-'} p_{cjt-1} + \sum_{s=1}^{p-1} \phi_{cis} \Delta p_{ci,t-s} + \sum_{s=0}^{q-1} (\pi_{cis}^{+'} \Delta p_{cj,t-s}^{+} + \pi_{cis}^{-'} \Delta p_{cj,t-s}^{-}) + \varepsilon_{cit}$$

Or,

$$(10)\quad \Delta p_{cit} = \mu_{ci} + \rho_{ci} \xi_{i,t-1} + \sum_{s=1}^{p-1} \phi_{cis} \Delta p_{cit-s} + \sum_{s=0}^{q-1} (\pi_{cis}^{+'} \Delta p_{cj,t-s}^{+} + \pi_{cis}^{-'} \Delta p_{cj,t-s}^{-}) + \varepsilon_{cit}$$

where the superscripts '+' and '-' denote positive and negative partial sums defined in equation (8), p and q denote the lag order of the variables, and $\xi_{cit} = p_{cit} - \alpha_{ci} - \beta_{ci}^{+'} p_{cjt}^{+} - \beta_{ci}^{-'} p_{cjt}^{-}$ is the nonlinear error correction term where $\beta_{ci}^{+} = -\theta_{ci}^{+} / \rho_{ci}$ and $\beta_{ci}^{-} = -\theta_{ci}^{-} / \rho_{ci}$ are the associated asymmetric long-run parameters, the parameters $\pi_{cis}^{+'}$ and $\pi_{cis}^{-'}$ denote the short-run adjustments to the positive and negative shocks affecting the domestic producer prices.

Equation (10) is known as NARDL model and is linear in all parameters— so a reliable estimation of equation (10) can be obtained by standard ordinary least squares (OLS). Moreover, for the NARDL model, it is not necessary that the time-series variables should be integrated of the same order. The estimation of the ECM utilizing an NARDL model is likely to improve the performance of the model in small samples, particularly in terms of the power of the power of cointegration tests and it allows modeler the flexibility of testing the absence of linear and nonlinear cointegration among the variables as well as allows ability to simultaneously estimate both short- and long-run asymmetries in a computationally simple and tractable manner (Shin et al. 2014).

Once equation (10) is estimated by standard OLS, we can then judge whether international and domestic prices share nonlinear cointegrating relationship or international price changes have both the short- and long-run symmetric or asymmetric effect(s) on domestic

producer prices. Following Shin et al. (2014), this paper uses the t-statistic called t_{BDM} to examine the existence of an asymmetric long-run relationship in equation (10)., which tests $\rho_{ci} = 0$ against $\rho_{ci} < 0$ in equation (10). If $\rho_{ci} = 0$, equation (10) reduces to the regression involving only first differences, implying that there is no long-run relationship between the levels of international and domestic prices.

Given that we obtain the asymmetric relationship (a short-run or a long-run or both) between the levels of international and domestic prices, we may observe patterns of asymmetric dynamic adjustment of the variables from initial equilibrium to a new equilibrium. The asymmetric adjustment paths of the changes of domestic prices to unexpected changes in the international prices are captured by the positive and negative dynamic multipliers associated with unit changes in p_{cjt}^{+} and p_{cjt}^{-} as follows:

(11) $$m_{cih}^{+} = \sum_{s=0}^{h} \frac{\partial p_{cit+s}}{\partial p_{cjt}^{+}} \quad and \quad m_{cih}^{-} = \sum_{s=0}^{h} \frac{\partial p_{cit+s}}{\partial p_{cjt}^{-}} \quad \text{with h=0, 1, 2…..}$$

By construction, as $h \to \infty, m_{cih}^{+} \to \beta_{ci,}^{+} \; and \; m_{cih}^{-} \to \beta_{ci,}^{-}$ where β_{ci}^{+} and β_{ci}^{-} are the asymmetric positive and negative long-run coefficients, respectively, as defined earlier. These multipliers are derived from the interaction of the impact (associated with $\pi_{cis}^{+'} \neq \pi_{cis}^{-'}$) and reaction (associated with $\beta_{ci}^{+} \neq \beta_{ci}^{-}$) asymmetries in conjunction with the error correction coefficient ρ_{ci}.

Depending on the model specification (either allowing only short-run asymmetry or long-run asymmetry or neither), the patterns of dynamic adjustment vary. When null hypothesis of long-run symmetry cannot be rejected in equation (10), we obtain the following model by imposing the long-run symmetry restrictions $\theta_{ci}^{+} = \theta_{ci}^{-} = \theta_{ci}$ in equation (10)

(12) $$\Delta p_{cit} = \mu_{ci} + \rho_{ci} p_{i,t-1} + \theta_{ci} p_{cj,t-1} + \sum_{s=1}^{p-1} \phi_{is} \Delta p_{ci,t-s} + \sum_{s=0}^{q-1} (\pi_{cis}^{+'} \Delta p_{cjct-s}^{+} + \pi_{cis}^{-'} \Delta p_{cjct-s}^{-}) + \varepsilon_{cit}$$

When null hypothesis of short-run symmetry cannot be rejected in equation (10), we obtain the following form of NARDL model by imposing the restriction $\pi_{js}^{+'} = \pi_{js}^{-'} = \pi_{js}$

(13) $$\Delta p_{cit} = \mu_{ci} + \rho_{ci} p_{ci,t-1} + \theta_{ci}^{+'} p_{ci,t-1} + \theta_{ci}^{-'} p_{cj,t-1} + \sum_{s=1}^{p-1} \phi_{cis} \Delta p_{ci,t-s} + \sum_{s=0}^{q-1} \pi_{cis} \Delta p_{cj,t-s}^{+} + \varepsilon_{cit}$$

We summarize our estimation approach as follows:

Step 1. We use the Augmented Dickey-Fuller (ADF) unit root test to examine the time-series properties of the price series.

Step 2. Following the general two-step approach of Engle and Granger (1987), we first estimate a static and long-run symmetric equation using ordinary least squares (OLS). From these estimates, we then obtain lagged residuals and use it as error correction terms in the traditional linear ECM and finally we estimate the ECM utilizing OLS.

Step 3. We adopt the linear long-run asymmetric equation and apply OLS methods to estimate the model. From the long-run model, we obtain one year lagged residuals and then introduce lagged residuals as the error correction term into traditional ARDL model and estimate the NARDL-based error correction model (ECM) proposed by Shin et al. (2014). This model provides the magnitude of both the short- and long-run asymmetric pass-through of international prices to domestic prices.

4 Data

In estimating equations (6), (7), and (10) we use a comprehensive database covering the period 1991 to 2013. We obtain annual data on international spot prices of maize, soybeans, wheat, and rice from the World Bank and domestic producer prices from the FAOSTAT database of Food and Agricultural Organization (FAO). The exchange rate that is used to convert domestic prices into U.S. dollar is obtained from the International Monetary Fund (IMF) database. The sample countries included in our analysis differ by crops. We select all countries for which prices data were available and who produce one of the fours crops. For maize, the number of sample countries is 104 and for soybeans, it is 54. The number of sample countries for wheat and rice are 82 and 77, respectively. Together these countries produce more than 96 % of the total global production of these four crops. The number of observation for each country is 23 except the countries of former Soviet Union. Prices series for these countries are available from 1994, so for them, the number of observation reduces to 20.

5 Results and Discussion

Estimates of country-specific transmission elasticities that are derived from equations (6), (7) and (10) as well as the cointegration testing results for corn, soybeans, rice, and wheat are presented in Tables 1, 2, 3, and 4, respectively. Table 5 reports the unit root test results for

international price[6]. We present the results for the countries, which together produce at least 90 % of the total global crop production. The minimum production share that we use for selecting the countries varies by crops—from 0.1 % (soybeans) to 0.5 % (corn). Country-specific production share for each crop has been calculated dividing the 1991-2013 country average production by the global crop-specific average production during the same period. We begin by testing the unit roots (non-stationary) for each country crop prices using augmented Dickey-Fuller test. Then, for each country and crop, we apply both the linear traditional and nonlinear cointegration techniques to test long-run relationship as well as to estimate the transmission elasticities. Columns (2) and (3) of the each table report the unit root and cointegrating testing results, respectively. The estimated transmission elasticities obtained using equations (6) and (8) are reported in columns (4a) and (4b). Columns (5a)-(6b) presents asymmetric transmission elasticities using equation (10). Our discussions start with the crop corn.

Corn

The unit root test results of the column (2) in Table 1 provide strong support for the hypothesis that the corn price series is nonstationary for each country with the exception of Ukraine. These findings are consistent with the existing empirical evidence that the crop prices received by producers at level forms are in general nonstationary (e. g., Rapsomanikis et al. 2006; Baquedano et al. 2011, Haile et al, 2015). This means if we regress corn producer price on the corn international price, it is likely that the regression will produce spuriously significant transmission coefficients, suggesting the existence of relationships that do not, in fact, exist (Granger and Newbold, 1974). To avoid such spurious regression results, it is common practice in the existing empirical literature to use cointegration techniques developed by econometrician (e. g., Engle and Granger, 1987; Johansen, 1988). We first use the Engle-Grange (EG) linear cointegration test and two-stage approach to avoid the spurious problem. We then use the NARDL model to investigate nonlinear cointegrating relationship.

-TABLE 1 ABOUT HERE-

The first issue is whether prices are connected linearly in the long run. Column (3a) provides results for linear cointegration tests and columns (4a) and 4(b) report the transmission coefficients as estimated using the linear EG ECM. Not all country regressions are found to be

[6] All international prices contain a unit root at the level form.

cointegrated. From the Table 1, we find that 15 out of the top 22 corn producing countries have the existence of cointegrating relationship between domestic and international corn prices and therefore driven by a single common trend. Most African countries and countries in Europe are noncointegrated and are therefore domestic producer prices essentially isolated from the long-run international price changes. This implies that the extensive land use changes that have occurred in African countries in the last decade or so are either due to the changes in domestic land use policy or domestic price incentives or macroeconomic policy or higher food demand from the increasing population. A country like India, who is one of the top ten corn producing and exporting countries also fail to exhibit a long run relationship with international prices, which is an indication that corn producer in India are heavily supported by the government or corn wholesale markets are controlled by few firms. From the beginning 2000s, India has increased price support and input subsidies (see table 2.10 in OECD-FAO 2014), which may help for increasing crop production even though international price signals did not transmit properly over the last two decades. Countries that exhibit the long-run relationship with international prices are dominated by the top exporter of corn and agriculturally developed countries like the U.S., Brazil, Argentina, Indonesia, and Ukraine.

The second issue is the degree of symmetric transmission elasticities both in the short-and long-run. Of the 22 countries which exhibit a long-term relation with international prices, not all show a long-run transmission elasticity equal to one or closer to one. One would expect a long-run transmission elasticity equal to one if LOP would have held. 10 out of the 14 countries have transmission elasticities greater than 0.75. These countries are dominated by the countries in North and Latin America, Europe, and agriculturally developed countries from the Asia. Surprisingly, China, the second leading producer of the corn, has the long-term transmission elasticity equal to 0.14 only. This low value indicates that Chinese agricultural sectors are heavily distorted by government policy. The magnitude of short-run transmission elasticities varies across countries with a range of -0.002 (China) to 1.49 (U.S.). Again, high price transmission are from the same region as stated above and China has almost zero transmission elasticity in the short-run.

Failure to have a long-term relationship in a linear cointegrating framework in 7 out of the top 22 world aggregate corn producing countries give rise to our next research questions—

whether the long-run relationship is asymmetrically connected and if so, then to what degree the domestic price responds with an increase or decrease of international price. Column (3a) present the nonlinear cointegrating testing results and columns (5a)-6(b) report both the short- and long-run asymmetric transmission elasticity. Surprisingly, the number of cointegrating countries reduces. The cointegration tests are unable to reject the null hypothesis of no nonlinear cointegration in 12 out of 22 countries. Countries such as China, France, and Nigeria that were previously cointegrated in the linear case, are now non-cointegrated. Countries which did not exhibit a long run relationship in the linear cointegration test, still fail to support the evidence of a long run relationship.

The asymmetric transmission elasticities are found both in the short- and long-run. Of the 10 countries that are cointegrated, six show negative asymmetry, i.e., long-run changes in prices are upward sticky and downward flexible (Columns (5a) and (5b)). Countries in these group are U.S., Argentina, Philippines, Ukraine, Brazil, and South Africa. One explanation for this finding is that the imperfect competition in processing and exporting industries allows middlemen to abuse market power and thereby farmers receive less of the price increase than they face more drop with a decrease in international price. Industry concentration and imperfectly competitive behavior beyond the farm-gate implies that wholesalers, or middlemen with power over price, may exercise pricing strategies that result in a slow and incomplete pass-through of increases in the international price and a fast and complete transmission of decreases in the international price to prices upstream, as their margins are squeezed (Rapsomanikis et al., 2006). The asymmetries also exist in short-run and are dominated by upward stickiness (Columns (6a) and (6b)). The short-run transmission asymmetries are severe than the long run. In most countries, domestic price responds less to an increase in international price to a decrease and the absolute value of negative asymmetries are higher in short-run than the long-run.

Soybeans

As expected, the unit root test results indicate that the soybeans producer price series are nonstationary for all countries (column (2) in Table 2). The linear cointegration testing results imply that in 15 out of the 24 top soybeans producing countries have the existence of the long-run linear relationship. Surprisingly, Brazil and Argentina who together produce about 37 percent of the total global soybean production, are found to be cointegrated. The long-run

symmetric elasticities that we obtain from the model in equation 6, are very high for most of the countries and some are greater than one (Column 4a). In general, the short-run elasticities are found to be lower than the corresponding long-run one (Column 4b). This phenomenon is evident among the top soybeans producing countries, who are mainly developing countries. The nonlinear cointegration testing results indicate that 16 out of 24 countries are found to be nonlinearly cointegrated. Brazil that was previously nonintegrated in the linear case is now cointegrated. Countries that fail to have a long run relationship in the linear case, are found to be cointegrated (Column 3b). With regard to the asymmetric elasticities, we find the existence of both short- and long-run asymmetries— both short- and long-run elasticities are dominated by upward stickiness (Columns 5a-6b). In general, the short-run transmission asymmetries are more evident than the corresponding long run one.

-TABLE 2 ABOUT HERE-

Wheat and Rice

As a part of the routine check, we again conduct the unit root tests for both wheat and rice producer prices and we find all prices contain unit roots at the level form (column (2) in Tables (3) and (4)). For wheat, both the linear and nonlinear cointegration testing results indicate that almost half of the top 26 wheat producing countries does not have the existence of the long-run relationship, which are mainly developing countries. The mean value of the symmetric short-run elasticity is 0.69. Asymmetries are present both in the short-and long-term. The short-run asymmetries are more evident than the long-run with a mean value of the transmission elasticity equals 0.68 when price increases and -0.76 when price decreases (Table 3).

-TABLE 3 AND 4 ABOUT HERE-

For rice, we find that more than half of the top 21 rice producing countries are in the group of no long-run relationship— majority of them are from the top rice producing and developing countries (Table 4). The mean value of the symmetric short-run elasticity is 0.42, which is low compared to wheat. Asymmetries are present both in the short-and long-term. The mean long-run transmission elasticity equals 0.63 when price increases and -0.53 when price decreases. The converse is evident for short-run asymmetries with a mean value of the transmission elasticity equals 0.30 when price rises and -0.79 when price decreases. These results indicate

that in the short-run farmers cannot reap up the full benefits of the international price increases, perhaps middlemen of the top rice producing countries have higher market power than the farmers and/or the farmers are not fully informed about the international markets.

-TABLE 6 ABOUT HERE-

Global Mean Estimates of the Transmission Elasticities

In this subsection, we make an attempt to estimate the mean short-run transmission elasticities for each crop and for aggregate four crops by using the following equation (dynamic panel model)

(14) $$p_{cit} = \mu_c + \rho_c p_{ci,t-1} + \theta_{1c} p_{cjt} + \theta_{2c} p_{cj,t-1} + \gamma_c t + \tau_c t^* + \eta_{ci} + \varepsilon_{cit}$$

where the price variables are the same as defined before, t denotes linear time trend, t* refers to time dummy, η_{ci} is country-crop fixed effects.

We estimate the equation (14) in a panel setting, where the numbers of panel group are crop-specific total countries when we estimate mean estimates for each crop and are country-crop pairs when we estimate mean estimates for aggregate four crops. The empirical methodologies that we use are two-step system and difference generalized method of moments (GMM). Both system and difference GMM estimators take care of the so-called dynamic panel bias or Nickell (1981) bias that can arise due to the correlation between lagged dependent variable and country fixed effect. Both estimators address endogeneity issue of the variables by using its own lagged values as the instruments.

TABLE 7 AND 8 ABOUT HERE

Table 7 and 8 report short-run estimates of the crop-specific global mean transmission elasticities and global aggregate (four crops) elasticities. The results indicate that soybeans have the highest transmission elasticity (0.524) and maize has the lowest (0.358) [Table 7]. The global aggregate transmission elasticities vary from 0.322 to 0.480 depending on the number of instruments we use. One implication of these result is that the existing studies on global supply responses to prices do not reflect the true responses as all the global supply responses model assume homogenous and perfect price transmission.

We can summarize our all findings as follows. First, we find mixed evidence on the existence of long-run relationship between international and domestic prices—for corn 66 out of 104, for soybeans 27 out of 54, for wheat 47 out of 82, and for rice 49 out of 77 countries, we fail to have a long-run relationship (Table 6). For corn and soybeans, the long-run relationship is evident in top producing countries whereas the converse is present for wheat and rice, particularly for rice. This is not unexpected as the top rice producing countries fall into the category of developing countries. Second, the asymmetric pass-through is visible for all crops and countries—in most cases the asymmetry is negative, i.e., the changes in domestic prices are upward sticky but downward flexible—prices fall more than the prices rise with equivalent changes international prices. The short-run asymmetries are acute than the long-run one. Third, the crop-specific short-run global mean transmission elasticities vary from 0.358 (corn) to 0.524 (soybeans).

Conclusion

By investigating the degree of price transmission from international prices of key four agricultural commodities to domestic producer prices, this paper makes two major contributions to the existing literature. First, it provides a globally comprehensive but heterogeneous (country-specific) transmission elasticities between international prices and domestic producer prices. Second, using both the traditional linear cointegration and recently developed nonlinear cointegration methods, it provides the magnitude of both symmetric and asymmetric short- and long-run pass-through of international prices to domestic prices, which can be defined as transmission elasticity as well.

Utilizing a comprehensive dataset that includes a sample of 104 countries for corn, 54 countries for soybeans, 82 countries for wheat, and 77 countries for rice and covers the period from 1991 to 2013, we find mixed evidence on the existence of long-run relationship between international and domestic price. For corn 66 out of 104, for soybeans 27 out of 54, for wheat 47 out of 82, and for rice 49 out of 77 countries, we fail to have a long-run relationship. For corn and soybeans, the long-run relationship is evident in top producing countries whereas the converse is present for wheat and rice, particularly for rice. This is not unexpected as the top rice producing countries fall into the category of developing countries. We also find that the

pass-through of international to domestic prices is asymmetric for all crops and countries. In most cases the asymmetries are negative, i.e., the domestic prices react less fully to an increase in international prices than to a decrease. The short-run asymmetries are acute than the long-run one. This is bad for the farmers as they gain less with an increase in international prices than they lose with a decrease. Last but not least, our results also indicate that the crop-specific short-run global mean transmission elasticities vary from 0.358 (corn) to 0.524 (soybeans).

We expect our empirical estimates of transmission elasticity will be valuable inputs for measuring the actual global agricultural supply response caused by recent higher world commodity prices. We also hope our analysis and findings will complement and provide further insights on the discussion of "the degree of pass-through of international prices to domestic producer prices" in the agricultural commodity prices transmission literature.

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Appendix

Table 1. Cointegration Testing Results and Estimated Transmission Elasticities of Corn for Countries who produce at least 0.5 % of the total global corn production

country	Production Share	Unit Root Test	Cointegration Tests		Symmetric Elasticities from EG model		Asymmetric Elasticities from NARDL model			
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6a)	(6b)
		t-ADF Stat.*	Traditional: t-EG value*	Asymmetric: t-BDM value*	Long -run	Short -run	Long -run (+)	Long -run (-)	Short -run (+)	Short -run (-)
USA	0.389	-1.66	-4.82	-5.14	0.99	1.49	1.03	-1.07	1.62	-1.63
China	0.200	-2.05	-3.61	-3.10	0.14	0.00	0.43	0.18	0.34	0.25
Brazil	0.062	-1.14	-4.43	-3.86	0.84	0.85	0.78	-0.84	0.99	-0.57
Mexico	0.029	-1.38	-2.22	-0.13	0.72	0.60	-4.35	8.67	0.81	0.03
Argentina	0.024	-1.15	-3.97	-3.23	0.87	0.78	0.87	-1.05	0.69	-0.93
France	0.023	-1.27	-4.20	-2.52	0.90	0.86	0.80	-0.96	0.57	-1.17
India	0.021	-1.55	-2.91	-1.45	0.36	0.21	0.00	0.56	0.34	0.20
Indonesia	0.017	-1.52	-5.06	-4.01	0.87	0.82	0.92	-0.86	0.95	-0.70
SA	0.014	-1.75	-4.67	-4.12	0.71	0.80	0.68	-0.78	0.77	-0.84
Italy	0.014	-0.66	-3.19	-2.48	0.96	0.88	0.78	-1.02	0.66	-1.03
Romania	0.014	-2.22	-4.35	-3.57	0.60	0.92	0.55	-0.04	1.09	-0.54
Canada	0.013	-1.49	-4.16	-3.89	0.78	0.71	0.80	-0.73	0.87	-0.50
Ukraine	0.011	-4.93	-7.01	-6.82	0.99	1.33	0.82	-0.86	1.06	-1.38
Hungary	0.010	-1.54	-3.78	-3.29	0.79	1.10	0.80	-0.60	0.92	-1.28
Nigeria	0.009	-2.88	-3.43	-2.99	0.53	0.68	0.32	-0.98	1.40	0.54
Egypt	0.009	-1.87	-3.04	-2.50	0.42	0.33	0.43	-0.05	0.55	-0.01
Philip.	0.008	-1.23	-5.84	-4.97	0.84	0.70	0.85	-1.14	0.76	-0.75
Thailand	0.006	-1.17	-5.95	-4.26	0.81	0.86	0.87	-0.86	0.98	-0.91
Spain	0.006	-1.41	-2.58	-1.43	0.81	0.69	0.42	-0.28	0.50	-0.74
Germany	0.005	-1.00	-3.04	-2.69	0.96	1.06	0.79	-1.00	0.79	-1.32
Ethiopia	0.005	-2.27	-2.91	-2.20	0.70	0.24	1.01	-1.03	-0.06	-0.70
Tanzania	0.005	-1.39	-5.41	-5.20	0.65	0.28	0.92	-1.29	0.31	-0.66

Notes: * Critical values for t-ADF, t-EG, t-BDM are 3.24, 3.24, and 3.21, respectively at the 10 % level of significance ; White (no shaded) indicates countries that are cointegrated in both linear and nonlinear tests , dark white (shaded) indicates countries that are noncointegrated in both linear and nonlinear tests, and blue (shaded) denotes countries who are cointegrated in either tests.

Table 2. Cointegration Testing Results and Estimated Transmission Elasticities of Soybeans for Countries who produce at least 0.1 % of the total global soybeans production

country	Production Share	Unit Root Test (Producer Prices)	Cointegration Tests		Symmetric Elasticities from EG model		Asymmetric Elasticities from NARDL model			
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6a)	(6b)
		t-ADF Stat.*	Traditional: t-EG value*	Asymmetric: t-BDM value*	Long-run	Short-run	Long-run (+)	Long-run (-)	Short-run (+)	Short-run (-)
USA	0.420	-1.54	-4.87	-4.53	0.97	1.33	0.97	-0.96	1.14	-1.82
Brazil	0.225	-1.08	-3.08	-3.30	1.05	0.90	1.16	-1.17	0.84	-1.11
Argentina	0.144	-0.75	-2.43	-2.28	0.85	0.76	1.11	-1.68	0.57	-1.35
China	0.083	-1.96	-3.55	-2.88	0.72	0.73	0.92	-0.67	0.95	-0.53
India	0.040	-1.18	-5.84	-4.52	0.77	0.60	0.69	-1.00	0.14	-1.34
Paraguay	0.020	-1.09	-6.39	-5.51	1.27	1.12	1.26	-1.34	0.97	-1.40
Canada	0.016	-1.39	-4.82	-4.33	0.86	0.75	0.93	-0.85	0.59	-1.06
Indonesia	0.007	-1.45	-4.37	-3.99	1.21	1.09	1.12	-1.45	0.25	-3.22
Bolivia	0.007	-1.73	-3.07	-3.20	0.92	0.54	1.09	-0.88	0.62	-0.41
Italy	0.005	-1.93	-7.25	-8.01	1.01	1.05	0.84	-0.97	1.12	-0.60
Russia	0.003	-2.59	-4.32	-3.96	0.61	0.60	1.01	-0.42	0.78	-0.68
Ukraine	0.003	-2.32	-5.25	-4.03	0.57	0.69	0.77	-0.18	1.14	0.07
Uruguay	0.002	-1.31	-2.87	-3.14	1.55	1.24	1.63	-1.95	1.07	-1.66
Nigeria	0.002	-2.72	-2.64	-2.55	0.64	0.70	1.06	-2.76	1.14	-0.54
Thailand	0.002	-0.86	-5.17	-3.36	0.88	1.13	0.81	-1.01	0.92	-1.46
Mexico	0.002	-1.78	-3.67	-2.84	1.06	0.80	0.90	-0.92	0.89	-0.36
South Africa	0.001	-1.27	-4.11	-3.63	1.15	1.37	0.99	-1.25	1.32	-1.34
Japan	0.001	-2.05	-2.47	-2.04	-0.29	-0.09	-0.37	-0.06	0.04	0.16
France	0.001	-1.98	-8.17	-9.97	1.08	1.28	0.92	-0.56	1.29	-0.79
Vietnam	0.001	-0.92	-1.85	-2.13	0.69	0.34	1.16	-1.12	0.40	-0.45
S. Korea	0.001	-2.97	-4.58	-3.71	-0.16	-0.16	0.05	0.68	-0.90	-1.02
Iran	0.001	-1.99	-3.07	-2.83	0.56	-0.45	0.69	-0.73	-0.32	1.14
Romania	0.001	-1.58	-3.73	-3.29	1.10	0.95	0.98	-0.90	0.45	-1.54
Ecuador	0.001	-1.77	-2.92	-3.53	-1.23	-0.33	-0.54	4.40	0.78	2.45

Note: * Critical values for t-ADF, t-EG, t-BDM are 3.24, 3.24, and 3.21, respectively at the 10 % level of significance ; White (no shaded) indicates countries that are cointegrated in both linear and nonlinear tests , dark white (shaded) indicates countries that are noncointegrated in both linear and nonlinear tests, and blue (shaded) denotes countries who are cointegrated in either tests.

Table 3. Cointegration Testing Results and Estimated Transmission Elasticities of Wheat for Countries who produce at least 0.5 % of the total global wheat production

Country	Production Share	Unit Root Test (Producer Prices)	Cointegration Tests		Symmetric Elasticities from EG model		Asymmetric Elasticities from NARDL model			
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6a)	(6b)
		t-ADF Stat.*	Traditional: t-EG value*	Asymmetric: t-BDM value*	Long-run	Short -run	Long -run (+)	Long -run (-)	Short -run (+)	Short -run (-)
China	0.175	-1.50	-2.56	-3.16	0.67	0.28	1.06	-0.91	0.37	-0.33
India	0.117	-1.67	-3.90	-2.87	0.41	0.23	0.52	-0.22	0.37	-0.10
USA	0.099	-1.33	-5.41	-6.30	1.04	1.24	1.07	-1.09	1.05	-1.58
Russia	0.071	-2.96	-5.33	-4.45	0.71	0.76	1.22	-1.12	0.87	-1.23
France	0.058	-1.23	-4.16	-2.85	1.12	0.97	0.98	-1.11	0.61	-1.18
Canada	0.042	-1.91	-3.34	-2.70	0.63	0.66	0.86	-0.33	1.02	-0.26
Germany	0.034	-0.75	-3.18	-2.62	1.15	1.09	1.00	-1.19	0.84	-1.26
Turkey	0.032	-2.09	-3.14	-2.55	0.60	0.40	0.88	-0.70	0.50	-0.48
Australia	0.032	-1.64	-4.62	-3.54	0.82	0.68	0.88	-0.87	0.73	-0.75
Pakistan	0.032	-1.72	-2.91	-2.35	0.32	-0.21	0.70	-0.35	0.09	0.47
Ukraine	0.027	-2.16	-6.42	-5.17	0.64	0.65	0.85	-0.54	0.44	-1.08
UK	0.024	-0.68	-3.41	-2.76	1.08	0.93	1.00	-1.13	0.78	-1.00
Argentina	0.021	-1.31	-2.56	-2.12	0.78	0.76	0.97	-1.24	0.61	-1.04
Kazakhstan	0.019	-2.21	-3.90	-3.17	0.92	0.59	1.17	-1.03	0.85	-0.68
Iran	0.018	-1.62	-3.03	-2.70	0.37	0.42	0.23	0.48	0.63	0.21
Poland	0.014	-1.18	-4.37	-3.52	0.94	0.98	0.95	-1.02	0.99	-1.03
Italy	0.013	-1.40	-3.67	-3.13	1.12	1.03	0.99	-1.18	1.08	-0.85
Egypt	0.011	-1.21	-2.90	-2.63	0.61	0.41	0.90	-0.66	0.47	-0.45
Romania	0.009	-1.83	-5.01	-4.67	0.60	0.76	0.64	-0.38	0.47	-0.98
Spain	0.009	-1.20	-3.75	-2.75	1.09	0.89	0.91	-1.07	0.82	-0.83
Denmark	0.008	-0.78	-3.07	-2.52	1.15	1.07	1.02	-1.20	0.90	-1.16
Hungary	0.007	-1.28	-5.93	-5.23	0.92	0.97	1.03	-0.83	0.87	-1.18
Czech	0.007	-1.51	-4.42	-3.15	0.82	0.90	0.92	-0.65	1.02	-0.85
Morocco	0.006	-1.65	-4.78	-4.17	0.43	0.39	0.40	-0.54	0.30	-0.48
Brazil	0.006	-1.80	-5.58	-5.53	0.81	0.63	0.90	-0.83	0.60	-0.78
Mexico	0.006	-1.11	-3.61	-3.12	0.89	0.71	0.94	-1.14	0.49	-1.01

Note: * Critical values for t-ADF, t-EG, t-BDM are 3.24, 3.24, and 3.21, respectively at the 10 % level of significance ; White (no shaded) indicates countries that are cointegrated in both linear and nonlinear tests , dark white (shaded) indicates countries that are noncointegrated in both linear and nonlinear tests, and blue (shaded) denotes countries who are cointegrated in either tests.

Table 4. Cointegration Testing Results and Estimated Transmission Elasticities of Rice for Countries who produce at least 0.4 % of the total global rice production

country	Production Share	Unit Root Test (Producer Prices)	Cointegration Tests		Symmetric Elasticities from EG model		Asymmetric Elasticities from NARDL model			
	(1)	(2)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)	(6a)	(6b)
		t-ADF Stat.*	Traditional: t-EG value*	Asymmetric: t-BDM value*	Long-run	Short-run	Long-run (+)	Long-run (-)	Short-run (+)	Short-run (-)
China	0.308	-2.97	-2.59	-2.41	0.33	0.37	0.77	-0.54	0.04	-1.55
India	0.215	-1.72	-2.85	-0.89	0.67	0.40	0.44	0.56	0.27	-0.34
Indonesia	0.089	-0.29	-2.34	-2.09	0.87	0.45	1.07	-0.33	0.12	-1.32
Bangladesh	0.060	-1.55	-3.02	-2.55	0.31	0.29	0.26	-0.09	0.14	-0.54
Viet Nam	0.053	-1.54	-3.44	-2.91	0.54	0.50	0.74	-0.19	0.67	-0.23
Thailand	0.045	-1.60	-4.67	-3.10	0.74	0.92	0.82	-0.71	0.63	-1.83
Philippines	0.021	-1.46	-2.70	-2.51	0.68	0.42	0.86	-0.96	0.43	-0.57
Japan	0.019	-1.66	-2.56	-1.84	0.28	0.10	0.28	-0.62	0.05	-0.20
Brazil	0.018	-1.73	-4.43	-3.52	0.70	0.72	0.75	-0.62	0.52	-1.25
USA	0.015	-1.91	-4.75	-3.53	0.88	0.92	0.95	-0.89	0.68	-1.67
Pakistan	0.011	-1.60	-3.89	-4.41	0.41	0.07	0.59	-0.23	-0.11	-0.80
S. Korea	0.011	-2.33	-3.02	-2.49	-0.10	-0.05	0.01	0.21	-0.08	-0.18
Egypt	0.009	-1.99	-3.32	-2.96	0.46	0.19	0.74	-0.61	0.07	-0.70
Cambodia	0.008	-1.64	-3.95	-3.62	0.78	0.82	0.80	-0.73	0.59	-1.61
Nepal	0.006	-1.88	-3.50	-3.87	0.45	0.07	0.62	-0.20	0.07	-0.14
Nigeria	0.006	-2.62	-3.93	-4.66	0.68	1.18	0.37	-1.49	0.16	-3.82
Madagascar	0.005	-2.96	-4.26	-2.68	0.39	0.12	0.53	-0.42	0.18	-0.27
Sri Lanka	0.005	-1.51	-3.00	-4.32	0.60	0.45	0.62	-0.63	0.84	0.54
Iran	0.004	-2.00	-3.47	-3.22	0.83	0.30	0.74	-1.08	0.56	1.16
Malaysia	0.004	-2.44	-3.07	-2.73	0.24	0.20	0.29	-0.12	0.17	-0.36
Laos	0.004	-1.11	-4.18	-3.46	1.03	0.48	1.09	-1.36	0.35	-0.98

Note: * Critical values for t-ADF, t-EG, t-BDM are 3.24, 3.24, and 3.21, respectively at the 10 % level of significance; White (no shaded) indicates countries that are cointegrated in both linear and nonlinear tests , dark white (shaded) indicates countries that are noncointegrated in both linear and nonlinear tests, and blue (shaded) denotes countries who are cointegrated in either tests.

Table 5. Unit Root Test (ADF) Results: International Prices

	H0: No Unit Root	
Variables/Series	Level-p value	Difference-p value
Corn	0.715	0.002
Soybeans	0.615	0.000
Wheat	0.452	0.005
Rice	0.756	0.100

Note: ADF test includes one year lag and a linear time trend

Table 6. Classification of Countries Based on the Existence of Nonlinear Cointegration Relationship

Crop	Categories	Countries
Corn (104)	No Long Run (66)	China, Mexico, France, India, Italy, Nigeria, Egypt, Spain, Germany, Ethiopia, Russia, Turkey, Kenya, VietNam, Pakistan, Greece, Austria, Venezuela, Nepal, Colombia, Iran, Chile, Cameroon, Slovakia, Portugal, Ecuador, Bolivia, Burkina Faso, CÃ´te d'Ivoire, Mali, Honduras, Czech Republic Guinea Australia Kazakhstan Bangladesh Cambodia Madagascar Albania Uruguay Switzerland New Zealand Morocco Netherlands Senegal Azerbaijan Panama Tajikistan Republic of Korea Bhutan Sri Lanka Yemen Malaysia Namibia Belize Gambia Costa Rica Jordan Eritrea Botswana Cabo Verde Congo Lebanon Jamaica Mauritius Puerto Rico
	Long Run (38)	USA Brazil Argentina Indonesia South Africa Romania Canada Ukraine Hungary Philippines Thailand Tanzania Croatia Paraguay Poland Ghana R. Moldova Peru Mozambique El Salvador Togo Nicaragua Georgia Laos Slovenia Belarus Rwanda Burundi F.Y. Macedonia Israel Sudan (former) Dominica Republic Niger Trinidad and Tobago Qatar Fiji Algeria Suriname
Soybeans (54)	No Long Run (27)	Moldova Albania Argentina Austria Bhutan Bolivia Burkina Faso China Ethiopia Georgia Iran Japan Laos Mexico Morocco Nepal Nicaragua Nigeria Pakistan Peru Philippines Rwanda Slovenia Sri Lanka Uruguay Venezuela Viet Nam
	Long Run (27)	Australia Belize Brazil Cambodia Canada Colombia Croatia Ecuador Egypt France Hungary India Indonesia Italy Kazakhstan Paraguay R. Korea Romania Russia Slovakia South Africa Spain Suriname Thailand Turkey Ukraine USA
Wheat (82)	No Long Run (47)	Albania Algeria Argentina Austria Bangladesh Bolivia Burundi Canada Chile China Czech Denmark Egypt Eritrea Ethiopia Finland France Georgia Germany India Iran Italy Japan Kazakhstan Kenya Lebanon Lithuania Madagascar Mexico Mongolia Namibia Nepal Netherlands Niger Nigeria Pakistan Rwanda Saudi Arabia Slovenia South Africa Spain Switzerland Tajikistan Tunisia Turkey UK Yemen
	Long Run (35)	Australia Azerbaijan Belarus Bhutan Brazil Colombia Croatia Cyprus Ecuador Estonia Greece Hungary Ireland Israel Jordan Latvia Macedonia Malta Moldova Morocco New Zealand Norway Paraguay Peru Poland Portugal Qatar Romania Russia Slovakia Sudan (former) Sweden Ukraine Uruguay USA
Rice (77)	No Long Run (49)	Burundi Argentina Thailand Portugal Mali Rwanda Egypt Bhutan Viet Nam Suriname Venezuela Niger Malaysia Colombia Madagascar Cameroon Trinidad and Tobago Bangladesh Hungary Philippines R. Korea Spain Chile China Australia Brunei Darussalam Guinea Greece Tajikistan Indonesia Ghana Senegal Turkey Bolivia Togo Japan Kenya Burkina Faso Ecuador Ethiopia France Gambia Dominican Republic Panama Morocco Congo India Mozambique Jamaica
	Long Run (28)	Sudan (former) Algeria Costa Rica Honduras Macedonia Romania El Salvador Peru Nigeria Russia Pakistan Sri Lanka Belize Nepal Azerbaijan Nicaragua Mexico Cambodia Paraguay Kazakhstan CÃ´te d'Ivoire USA Brazil Laos Uruguay Italy Iran Ukraine

Table 7. Crop-Specific Global Mean Estimates of the Transmission Elasticities using Two-step System GMM

Explanatory Variables	(1) Domestic Corn price	(2) Domestic Soybeans price	(3) Domestic Wheat price	(4) Domestic Rice price
Lag Domestic price	0.512**	0.544**	0.633**	0.644**
	(0.086)	(0.108)	(0.069)	(0.052)
International Price	**0.358****	**0.524****	**0.450****	**0.410****
	(0.063)	(0.094)	(0.073)	(0.087)
Lag International Price	-0.044	-0.115	-0.145	-0.225**
	(0.070)	(0.111)	(0.092)	(0.067)
Constant	1.049*	0.327	0.363	0.914+
	(0.435)	(0.439)	(0.350)	(0.484)
N	2226	1159	1748	1670
Instrument count	53	33	33	33
Panel group	103	54	82	77
Chi2 (p)	0.000	0.000	0.000	0.000
Sargan test (p-value)	0.010	0.000	0.000	0.078
Hansen test (p-value)	0.003	0.655	0.001	0.006
Group min obs.	19	15	9	18
Group max obs.	22	22	22	22
Time dummy	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. Coefficients of all Columns (1) - (4) are estimated utilizing two-step system-GMM estimator, where both lagged domestic prices and international prices area treated as endogenous. Standard error is corrected using Windmeijer (2005) finite sample correction. All the instrument matrices are "collapsed". The Sargan and Hansen test report the p-values for the goodness of the instrument set. Prices are in log values.

Table 8. Global Mean (all four crops) Estimates of the Transmission Elasticities using GMM Estimators

Explanatory Variables	(1) Domestic Price	(2) Domestic Price	(3) Domestic Price	(4) Domestic Price	(5) Domestic Price	(6) Domestic Price
Lag Domestic Price	0.605**	0.603**	0.854**	0.345**	0.601**	0.621**
	(0.049)	(0.050)	(0.046)	(0.069)	(0.045)	(0.050)
International Price	**0.458****	**0.460****	**0.434****	**0.480****	**0.336****	**0.322****
	(0.042)	(0.042)	(0.034)	(0.037)	(0.050)	(0.051)
Lag International Price	-0.155**	-0.157**	-0.323**	-0.022	-0.128*	-0.131*
	(0.048)	(0.048)	(0.039)	(0.055)	(0.054)	(0.056)
Constant	0.544*	0.557*	0.181	1.142**	1.094**	
	(0.259)	(0.266)	(0.167)	(0.267)	(0.307)	
N	6801	6801	6801	6801	6801	6484
Instrument count	53	57	97	52	62	59
Panel group	315	315	315	315	315	315
Chi2 (p)	0.000	0.000	0.000	0.000	0.000	0.000
Sargan test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
Hansen test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
Group min obs.	18	18	18	504	18	16
Group max obs.	22	22	22	504	22	21
Time dummy	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. Coefficients of all Columns (1) - (5) are estimated utilizing two-step system-GMM estimator. Column (6) is estimated utilizing two-step diff-GMM estimator. In both cases, the lagged domestic prices and international price area treated as endogenous. Standard error is corrected using Windmeijer (2005) finite sample correction. All the instrument matrices are "collapsed". The Sargan and Hansen test report the p-values for the goodness of the instrument set. Prices are in log values.