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THE EFFECT OF BRAZILIAN CORN AND SOYBEAN CROP EXPANSION ON PRICE AND VOLATILITY TRANSMISSION

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This study aims to examine if the most recent changes in the Brazilian corn and soybean production have caused significant changes in prices and volatility transmission between Brazilian and U.S. markets. In addition to using econometric time-series methods tests to analyze price transmission among grain and oilseeds markets, we investigated the volatility spillover across U.S. and Brazil markets using causality in variance tests. Since structural break tests indicated the presence of one breakpoint, the sample was split in two periods: 1996-2006 and 2007-2014. Results suggest that the level of market integration has increased during the second period (2007-2014) with higher sensibility to price changes compared to the first period (1996-2006).

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1. Introduction

Between the 1970s and 2010s, Brazil's soybean and corn production increased nearly ten and five times, respectively (FAO, 2018). Soybean expansion happened particularly in the central-west region, as a result of biological developments and a broader use of chemical and mechanical technologies. The increase in corn production, however, was mainly related to the growth of the winter corn crop, which was stimulated by the expansion of the domestic poultry and pork industries, and the use of early-maturing soybeans, which allowed producers to plant corn directly after the soybean harvest (Mattos and Silveira, 2018).

Goldsmith (2008) summarized the reasons for the fast expansion of Brazilian grain and oilseed production. The author indicated the "availability of large tracts of arable land, soybean technology that produced yields equal to those of the United States, mechanization that allowed operational efficiency, and the lowest operating costs per hectare in the world". With the expansion of soybean production, farmers began using early-maturing soybeans, allowing for harvest during December and January. Furthermore, the possibility to cultivate the winter corn after the soybean harvest helped producers to harvest two corn crops per year (the summer and winter crop)[1].

As a result, Brazil's importance on the international grain and oilseed market has been increasing. For soybeans, the Brazilian share of global production and exports rose from 11% and 10% in the 1970s, to 28% and 37% in the 2010s, respectively, while the U.S. share of each declined from 68% and 84% to 34% and 41%, respectively, during the same period. With respect to corn, the country's export share increased from roughly zero to 17% between the 1970s and the 2010s. Conversely, U.S. corn production and exports represented 35% and 34%, respectively of the world volume in the 2010s, whereas in the 1970s the production and export share was roughly 44% and 63%, respectively (FAO, 2018). Moreover, favorable weather conditions and technology development in Brazil, as well as the severe 2012/13 drought in the United States, created new opportunities for Brazilian producers in the international corn trade.

In addition to the Brazilian market share increase, the growth of U.S. domestic corn demand for ethanol production and the Chinese demand for agricultural commodities are two other fundamental factors that have influenced agricultural commodities markets worldwide during the last decades (Park and Fortenbery, 2007; Liu and An, 2011; Li *et al.*, 2014). Moreover, other factors associated with the 2008 financial crisis – such as the U.S. dollar depreciation and the rise of oil prices – may have affected relative prices and volatilities (Irwin and Good, 2009; Headey and Fan, 2008), and consequently, affected the way agents discover prices in their domestic and international markets. According to Leuthold *et al.* (1989), the process of price discovery for many agricultural commodities occurs simultaneously in futures and spot markets, through the interaction of current supply and demand conditions.

Several other factors may have affected prices relationships and volatility levels, such as weather events, regional supply and demand conditions related to storage capacity, transportation costs, and interest rates. If the relationship among prices (and volatilities) is affected, producers may find it difficult to market their crop on the spot market in the future and to use risk management tools to reduce price variation. The use of derivatives contracts, for instance, depends on their efficiency in minimizing portfolio volatility, which also depends on assets correlations. Therefore, when volatility transmission between markets is affected, the efficiency of risk management strategies is also affected.

Corn and soybean markets are related because both commodities are produced in the same area, can be stored in the same facilities, and can be used for similar ends (e.g. livestock

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[1] While in Brazil, corn and soybeans can be planted in different periods, and therefore do not compete for the same planted area, in the U.S. producers must decide which portion of the same area will be used to plant either corn or soybeans.

feed and human consumption). Therefore, a study of how recent changes in the main producing countries affected prices and volatilities worldwide can provide important information that can be used to improve the price discovery process, support trading strategies, and make risk management more efficient. In addition, since both commodities are highly used and traded on the international market, it is also important to study how prices became related and how volatilities rippled across markets before and after the changes. According to Ceballos *et al.* (2015), understanding the sources of domestic commodity price volatility and the extent of volatility transmission between international and local markets is relevant for providing better global and regional policies to deal with high price volatility.

Therefore, our main objective is to understand if and how the most recent changes in Brazilian and U.S. soybean and corn production changed price and risk relationships between the two countries. Our goal is to investigate if the increasing Brazilian production and exports affected corn and soybean price relationships and volatility transmission in both countries. We expect to find that the markets became closely integrated after the 2000s, when the expansion of the Brazilian grain crops and exports increased significantly.

Despite several recent studies having already analyzed price and volatility transmission among agricultural commodities, most focused on the linkages between energy and agricultural commodity prices (e.g. Trujillo-Barrera *et al.*, 2012; Gorter *et al.*, 2013; Cabrera and Schulz, 2016). However, fewer have taken a look at price and volatility transmission in grain and oilseeds markets (e.g. Ceballos *et al.*, 2015; Hernandez *et al.*, 2014). Even fewer studies have analyzed the dynamics of volatility across different countries, and the relationship between spot and futures markets (e.g. Mattos and Silveira, 2018). Therefore, this study can contribute to the current literature on the assessment of price integration and volatility transmission in Brazilian and U.S. corn and soybean spot and futures markets.

2. Previous research

Several studies have recently explored price and volatility transmission among grain markets, considering two or more different regions. Price transmission and market integration issues were analyzed by various researchers across several markets and commodities. Yang *et al.* (2003) studied wheat futures prices and volatility transmission among the main international producers (U.S., Canada, and the European Union) between 1996 and 2002. The authors used generalized forecast error variance decomposition and generalized impulse response analysis from a VECM estimation. Futures price transmission estimations showed a significant impact of U.S. market prices on the Canadian market. Meanwhile, the results from the VECM estimation showed the E.U. is self-dependent and not affected by prices of any other market. However, their findings from the volatility transmission analysis demonstrated an opposite result, where Canadian market prices affected the U.S. market and the E.U. market affected both the U.S. and Canadian markets.

Balcombe *et al.* (2007) contributed to this debate, exploring the threshold effects in price transmission among the Brazilian, Argentinean, and U.S. grains markets. The authors used a Bayesian approach to estimate Eq-TAR and Band-TAR models. Their results indicate that the existence of threshold effects on price transmission depends on each crop/market. They found that the largest effects on corn prices originate from the U.S. and Argentinean markets, rather than from Brazilian markets.

Hernandez *et al.* (2014) examined the level of interdependence and volatility transmission in global agricultural futures markets, specifically for the most traded futures contracts (i.e. soybeans, corn, wheat) on major agricultural futures exchanges in the U.S., Europe, and Asia, from 2004 to 2009. The authors estimated a MGARCH model using T-BEKK, full T-BEKK, CCC, and DCC specifications. The results suggest the existence of strong own- and cross-volatility spillovers and dependence between most exchanges, especially from Chicago to other exchanges. In addition, they found that the level of interdependence across exchanges did not increase in the later years of this period.

Beckmann and Czudaj (2014) investigated volatility spillover among corn, wheat, and cotton futures markets after the sharp rise and fall in agricultural commodities markets between 2007 and 2008. Using a GARCH-in-mean model, the results indicated that volatility spillover is observed in agricultural futures markets in the short run. Therefore, the recent increase in futures markets interdependence could be responsible for increasing agricultural price volatility. Grain price and volatility transmissions were also explored by Ceballos *et al.* (2015), focusing on the effects of international corn, wheat, rice, and sorghum prices on 41 domestic prices in Africa, Asia, and Latin America, between 2000 and 2013. They estimated a multivariate generalized auto-regressive conditional heteroskedasticity (MGARCH) model, and found—for a few cases—a lead-lag relationship from world to local prices. The authors also found many interactions across the analyzed markets in terms of volatility transmission. For example, they found that rice and wheat markets are strongly influenced by volatility in other markets, whereas they found a weaker volatility transmission to sorghum and corn markets. More recently, Ganneval (2016) examined the impact of volatility on agricultural commodity market linkages in France from 2006 to 2013. Using a threshold vector error correction model (TVECM) with two regimes, results indicate that the information in producer prices becomes more relevant for commodities without a futures market when volatility increases. In addition, Mattos and Silveira (2018) investigated the impact of the Brazilian corn production increase on price dynamics. Findings suggest that a long-run relationship between Brazilian prices and U.S. prices developed from 2002 to 2017, when Brazil's winter corn crop and exports expanded rapidly.

3. Research method

We divided our empirical analysis into three steps. First, we tested for structural breaks and stationarity in each price series. Second, we analyzed market integration between the Brazilian and U.S. markets. Third, we tested the volatility transmission between futures and spot markets. The following sections show the methods used in our analysis.

3.1. Structural break analysis and unit root tests

We assumed that there is a possible single break in our time series since we described the increase of Brazilian production and international market share as important changes that may have affected international agricultural prices and volatilities. We formally tested for structural breaks in price series using two types of tests: structural change and unit root tests.

Zeileis *et al.* (2003) developed a simple test to identify an unknown date of break in a time series, considering a standard linear model:

$$y_i = x_i^T \beta_j + u_i \qquad (i = i_{j-1} + 1, \dots i_j \quad j = 1, \dots, m + 1) \tag{1}$$

The test consists of estimating consecutive regressions using m+1 segments of size $I_{m,n} = \{i_1, \dots, i_m\}$, starting with $i_0 = 0$ until $i_{m+1} = n$. The vector x_i is a k x 1 vector of ones, which allows to test for changes in the mean of the dependent variable, y_i. The null hypothesis to be tested is $H_0\colon \beta_i = \beta_0$ (i = 1,..., n) against the alternative that at least one coefficient varies over time. An alternative specification can also be used to test for changes in the trend when x_i contains a sequence of increasing values, such as t = 0, 1, …, T.

The residuals (u_i) are estimated via Ordinary Least Squares (OLS) and used in the traditional F statistic (Chow) test to verify the alternative hypothesis of a single change in the level of the variable y_i at an unknown time. The authors use segments (partitions) of the data sample to calculate a sequence of F statistics (one for each subsample). The null hypothesis can be rejected according to the supremum value of the test statistics.

We also conducted a unit root test developed by Zivot and Andrews (1992), which treats a possible breakpoint as endogenous - i.e., they allow a breakpoint to be estimated rather than fixed. The null hypothesis tested is that a given series $\{y_t\}_1^T$ has a unit root with a drift, and an exogenous break occurs at time $1 < T_B < T$. The alternative hypothesis is that $\{y_t\}_1^T$ is stationary about a time trend, and an exogenous change occurs in the trend at time T_B. The authors suggest three different models and, according to the specification adopted, the null hypothesis can be changed to test for a change in the intercept (Model A), in the slope of the trend function (Model B), or both (Model C). This specification follows the previous work developed by Perron (1989) who labeled models A, B, and C respectively as "crash", "changing growth", and "combo". Zivot and Andrews (1992) followed Perron's (1989) test and used a modified Augmented Dickey-Fuller (ADF) equation that includes dummy variables in the models to test for a unit root. The rule to determine the breakpoint is to find the minimum *t* statistic after estimating modified ADF regressions with different break fractions of length T_B/T.

3.2. Market integration procedures

We used the procedure described by Fossati *et al.* (2007) to test for market integration, where when two or more markets are integrated, price signals in one market should be reflected in others. The authors suggest that formal tests could be done using the widely used multivariate cointegration approach developed by Johansen (1988) to test hypotheses related to short and long-run integration. This approach is well known in the economics literature for testing the law of one price hypothesis.

To identify market integration among futures and spot markets in Brazil and in the U.S., we first tested the stationarity of the series. If all price variables have one unit root and have the same integration order, we evaluate the existence of long-run relationships among prices using the Johansen multivariate test. If we find at least one cointegration relationship, we then assume that there is some degree of integration among some or all markets. The number of relationships can be determined after estimating the vector error correction model (VECM), as follows:

$$\Delta P_t = A_0 + \Pi P_{t-1} + \sum_{i=1}^{k-1} \Pi_i \Delta P_{t-i} + \varepsilon_t \qquad (2)$$

Where A_0 is a vector containing the intercept, and ΔP_t is a $(n \times 1)$ vector of the first difference in prices. The $(n \times n)$ matrix Π, can be written as $\Pi = \alpha\beta'$ where α and β are $(n \times r)$ matrices containing the speed of adjustment parameters and the cointegrating vectors, respectively. The matrix Π_i contains all the parameters estimated to represent the impact of lagged variables in the system, and ε_t is a vector of random error terms (Lütkepohl, 2006).

When the model presented in (2) is estimated using maximum likelihood, the rank of Π is determined (Enders, 2005). Two test statistics (trace and eigenvalue) are used to test the null hypothesis of rank $\Pi = 0$. If the null cannot be rejected, then prices are not cointegrated and there is no integration among the markets. On the other hand, if the null hypothesis is rejected, a sequential test is conducted to determine the number of cointegrating relationships. Once we find the markets to be integrated, the matrix Π can be used to investigate the long-run dynamics of prices, and how they adjust to deviations towards the equilibrium.

Since some markets may not be constrained to the integration relationship(s), we can use the elements β, in the matrix Π, to test whether individual long-term parameters in the cointegration vectors i (i = 1,…, r) are statistically different from zero for each market j (j = 1,…,n). If the null hypothesis $(\beta_{ij} = 0)$ cannot be rejected, the specific market j is not integrated with the other markets.

Once markets are found to be integrated, we can then analyze the elements in α to verify how prices adjust from deviations to the equilibrium in the short run. If one market does not respond to deviations from the long-run relationship(s) $(\alpha_{ij} = 0)$, it is said to be weakly exogenous and can be considered as one of the markets that leads the system (Fossati *et al.*, 2007). However, if a certain market responds to deviations in the short run, the value of the estimated parameter α_{ij} can be used to calculate the number of periods (days) prices in market *i* take to adjust back to the equilibrium. The results from the VECM estimation can also be used to test for Granger causality, and to determine the impact of shocks on different prices using impulse response functions (Enders, 2015).

If we find statistical evidence of a structural break in the dataset, the sequence of tests described above needs to be implemented before and after the breakpoint. This comparison contributes to the analysis of the dynamics of market integration over time.

3.3. Volatility transmission method

To explore causal relations related to price changes between Brazilian and U.S. markets, we used a causality-in-variance test formulated by Cheung and Ng (1996). The procedure was conducted using two steps. First, we estimated a univariate GARCH (1,1) model in order to obtain a series of squared standardized residuals and calculate the cross-correlation function (CCF) of these series – equation (3).

$$r_{uv} = c_{uv}(k)(c_{uu}(0)c_{vv}(0))^{-1/2} \qquad (3)$$

Where, r_{uv} (k) is the cross-correlation in lag k; $c_{uv}(k) = T^{-1}\sum(u_t - \bar{u})(v_{t-k} - \bar{v})$; k = 0,±1, ±2, ...; $c_{uu}(0)$ and $c_{vv}(0)$ are the variances of the residuals u and v, respectively.

Second, using the CCF, we tested the null hypothesis of no causality-in-variance at a specific lag k, using the standard normal distribution (i.e., at the lag k, $\sqrt{T}\hat{r}_{uv}(k)$ was compared to a standard normal distribution).

4. Data

The dataset consists of daily futures and spot prices for corn and soybeans between November 1996 and December 2014. Futures prices represents closing quotes for corn and soybean nearby contracts from CME Group and the Brazilian Exchange (B3). The spot price analysis considered only the main producing areas in Brazil (Central West) and the U.S. (Midwest). Table I shows the descriptive statistics and correlations for spot and futures prices. Average corn prices were between \$3.00 and \$4.10 per bushel, while average soybean prices were in the range of \$7.00 to \$8.60 per bushel.

Table I. Descriptive statistics and correlations for Brazilian and U.S. spot and futures markets for corn and soybeans [(a)] (November 1996 - December 2014).

Markets	Summary statistics					Correlations			
	Mean	Med	Max	Min	SD	BRCF	BRCS	USCF	USCS
Corn markets									
Futures price (BRCF)	4.05	3.43	8.65	1.49	1.64	1.0000	0.9783	0.9016	0.8845
Spot price (BRCS)	3.05	2.60	6.60	1.25	1.25		1.0000	0.9012	0.8834
Futures price (USCF)	3.52	2.74	8.31	1.75	1.69			1.0000	0.9952
Spot price (USCS)	3.56	2.81	8.65	1.62	1.74				1.0000
Soybean markets						BRSF	BRSS	USSF	USSS
Futures price (BRSF)	8.60	7.08	20.16	3.86	3.74	1.0000	0.9874	0.9834	0.9817
Spot price (BRSS)	7.01	5.98	16.53	2.92	3.15		1.0000	0.9782	0.9764
Futures price (USSF)	8.57	7.37	17.71	4.10	3.55			1.0000	0.9974
Spot price (USSS)	8.43	7.17	17.90	3.88	3.58				1.0000

Source: Commodity Resource Bureau, B3, and Agencia Estado.

[(a)] Grain prices in U.S. and Brazil are expressed in US\$/bushel.

We observed a smaller volatility for corn and soybeans in Brazilian spot markets compared to all other markets in Brazil and the U.S. In addition, the correlations were generally high for both commodities and markets, with smaller values between Brazilian and U.S. corn prices. High correlation coefficients can be a simple (but fundamental) way to suggest integration among markets (Fossati *et al.*, 2007).

5. Results

Table II reports the results for the structural break and unit root tests. We adopted the structural break test specification, which tests the null hypothesis of no break in the level (intercept) of the price variables. The Zivot and Andrews (1992) unit root test was also applied using the level shift specification (crash model). The results pointed to the presence of one breakpoint in all variables. The null hypothesis of non-stationarity could not be rejected for any price series, indicating that all the series exhibited a unit root with a drift.

Table II. Structural break and unit root test results

Test	Zeiles *et al.* (2003)		Zivot and Andrews (1992)	
Series	Sup. F	Date of break	min (t stat)	Date of break
Corn markets				
Futures price (BRCF)	9145.7***	07-13-2007	-3.847^{NS}	07-26-2006
Spot price (BRCS)	7407.6***	10-03-2006	-3.821^{NS}	09-26-2006
Futures price (USCF)	8339.7***	11-05-2007	-3.223^{NS}	09-15-2006
Spot price (USCS)	8224.3***	11-07-2007	-3.152^{NS}	09-13-2006
Soybean markets				
Futures price (BRSF)	18866***	08-16-2007	-3.861^{NS}	05-09-2007
Spot price (BRSS)	17201***	08-27-2007	-3.936^{NS}	08-17-2007
Futures price (USSF)	14278***	08-28-2007	-3.858^{NS}	04-26-2007
Spot price (USSS)	13906***	09-26-2007	-4.025^{NS}	08-17-2007

***significant at 1%, NS = not significant

Since the estimated dates of break were different (both among series and between tests), we decided to split our analysis in two periods. The first period starts at the beginning of the sample and ends before the first break on July 26, 2006, resulting in 2,283 daily observations. The second period begins after the last break found (on November 7, 2007), and contains 1,627 daily observations. The break dates coincide with the beginning of the financial crisis, the rise of agricultural commodity prices, and the period when Brazil's summer corn crop began to decrease relative to its winter crop.

According to the unit root tests, all price series were I(1) processes. Results obtained with the Johansen cointegration tests indicated the presence of multiple cointegrating relationships in both periods. We found three statistically significant equations for the first period and five for the second, according to the maximum eigenvalue tests. Therefore, the results confirmed the existence of market integration between the two countries and among all corn and soybeans markets. Since we found multiple long run relationships, we proceeded with our market integration analysis, testing a sequence of hypotheses as suggested by Fossati *et al.* (2007). For the first period, we confirmed that all markets were integrated according to all three cointegration relationships (H_0: $\beta_{ij} = 0$ was rejected for all i and j). For the second period, however, we found that certain markets were not constrained to specific cointegration relationships and were therefore considered exogenous when determining the order of prices used to estimate the VECM. Finally, we combined our results from the weak exogeneity test with those from the Granger causality tests to determine the final order of the variables in the VECM estimation, as presented in Table III[2].

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[2] We consider a variable as endogenous when we find that it: (i) belongs to more cointegration relationships; (ii)

Table III presents the most relevant cointegrating relationships, which were normalized using the highest eigenvalue obtained from each estimation. Lags were included in the estimations to correct for residual autocorrelation problems. LM tests indicated that the null hypothesis of no autocorrelation could no longer be rejected after the introduction of the corresponding number of lags in each equation. We used the sequential modified likelihood ratio statistics to determine the appropriate number of lags in all estimations.

Once we found that markets were integrated in both periods, we used the VECM estimates to analyze how prices adjust back to equilibrium when their long-term relationship is affected. We calculated the inverse of the coefficient of adjustment $(1/\alpha_j)$ to find the number of days prices in each market take to move back to the equilibrium. As the average number of days increased from roughly 16 to 26 days, the results suggest that the degree of integration among markets decreased over time.

Table III. VECM results for the 1st and 2nd period

First period				Second period			
Variable	Long run	Adj. Coeff.	$(1/\alpha_j)$	Variable	Long run	Adj. Coeff.	$(1/\alpha_j)$
USSS	1.000^{***}	-0.153^{***}	6.531	BRCS	1.000^{***}	-0.014^{***}	73.099
USSF	-1.097^{***}	0.013^{NS}	0.000	BRSF	-0.290^{***}	-0.006^{NS}	0.000
BRSS	-0.109^{***}	0.059^{***}	17.045	USCF	1.606^{***}	0.002^{NS}	0.000
BRCS	-0.189^{***}	0.023^{***}	42.764	USCS	-1.428^{***}	0.015^{**}	65.471
USCS	-0.624^{***}	-0.028^{***}	36.140	BRCF	-0.913^{***}	0.007^{NS}	0.000
BRCF	0.190^{***}	-0.011^{NS}	0.000	BRSS	0.338^{***}	-0.044^{***}	22.779
USCF	0.947^{***}	-0.035^{***}	28.450	USSS	0.292^{NS}	-0.001^{NS}	0.000
BRSF	0.118^{***}	-0.013^{NS}	0.000	USSF	-0.307^{NS}	0.019^{***}	51.608
Intercept	-0.339	Average:	16.36 days	Intercept	0,.484	Average:	26.60 days
Lags: 23				Lags: 21			

*** significant at 1%, ** significant at 5%, * significant at 10%, NS = not significant

USCF = U.S. corn futures prices; USSF = U.S. soybean futures prices; BRCF = Brazilian corn futures prices; BRSF = Brazilian soybean futures prices; USCS = U.S. corn spot prices; USSS = U.S. soybean spot prices; BRCS = Brazilian corn spot prices; BRSS = Brazilian soybean spot prices

We also analyzed market integration using the traditional impulse and response (IR) functions. This approach determines how U.S. markets respond to shocks in Brazilian prices. Our results were significantly different between the two periods[3]. On one hand, during the first period, the results indicated a relatively low response in U.S. markets (spot and futures) from shocks in corn spot prices in Brazil. On the other hand, during the second period contemporaneous shocks in Brazilian prices caused higher and longer changes in U.S. corn and soybean markets. These results showed that the Brazilian corn and soybean spot markets became more relevant in explaining changes in the U.S. markets after 2007 (Appendix).

Finally, Tables IV and V present the results of Granger causality tests. The causality-in-variance results indicated that there was, in general, no causality in variance between Brazilian and U.S. corn prices during the first period (1996-2006). Conversely, according to Granger causality test results, U.S. markets caused changes in Brazilian corn prices – i.e. corn price changes in the U.S. contributed to the destabilization of Brazilian prices (Table IV). For soybean markets, the results suggest, in general, that U.S. markets contributed to the destabilization of Brazilian prices during both periods (Table V).

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cannot be considered as weakly exogenous; (iii) is Granger-caused by a large number of other variables.

[3] We used the generalized impulse response definition.

Table IV: Causality-in-variance tests for corn markets

Lag k	BR Futures-U.S. Futures 1996-2006	BR Futures-U.S. Futures 2007-2014	BR Spot-U.S. Spot 1996-2006	BR Spot-U.S. Spot 2007-2014	BR Spot-U.S. Futures 1996-2006	BR Spot-U.S. Futures 2007-2014	BR Futures-U.S. Spot 1996-2006	BR Futures-U.S. Spot 2007-2014
	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$
-5	-0.0063	0.0156	-0.0251	-0.0084	-0.0014	-0.0158	-0.0211	0.0128
-4	0.0113	-0.0044	-0.0117	0.0286	0.0000	0.0328*	0.0156	0.0039
-3	0.0077	0.0159	-0.0125	0.0210	-0.0364	0.0497**	0.0287*	0.0011
-2	0.0198	0.0055	0.0134	-0.0229	0.0052	-0.0191	0.0181	-0.0092
-1	-0.0267	0.0063	-0.0047	0.0353*	-0.0026	0.0569**	-0.0281	0.0034
0	0.0281*	0.2852***	0.0339**	0.1643***	0.0289*	0.1324***	0.0349**	0.2812***
1	-0.0297	0.0660***	0.0225	0.0495**	-0.0045	0.0727***	-0.0222	0.0577***
2	0.0531***	0.0418**	0.0115	0.0646***	0.0231	0.0402*	0.0307*	0.0400*
3	0.0082	0.0259	0.0417**	0.0421**	0.0307*	0.0430**	0.0084	0.0353*
4	0.0392**	0.0142	-0.0025	0.0705***	0.0185	0.0629***	0.0150	0.0071
5	0.0234	0.1355***	0.0011	0.0955***	-0.0067	0.1080***	0.0174	0.1095*

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table V: Causality-in-variance tests for soybean markets

Lag k	BR Futures-U.S. Futures 1996-2006	BR Futures-U.S. Futures 2007-2014	BR Spot-U.S. Spot 1996-2006	BR Spot-U.S. Spot 2007-2014	BR Spot-U.S. Futures 1996-2006	BR Spot-U.S. Futures 2007-2014	BR Futures-U.S. Spot 1996-2006	BR Futures-U.S. Spot 2007-2014
	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$	$r_{uv}(k)$
-5	-0.0355	0.0289	-0.0277	-0.0007	-0.0037	0.0274	0.0107	0.0055
-4	-0.0068	-0.0095	0.0119	0.0005	-0.0224	0.0154	-0.0168	0.0322*
-3	0.0076	0.0136	0.0069	0.0608***	-0.0019	0.0065	-0.0273	0.0206
	-0.0215	0.0032	-0.0069	-0.0055	0.0249	0.0051	-0.0090	0.0053
-1	0.0231	0.4819***	0.0571***	0.0053	-0.0247	0.3703***	0.1186***	0.0221
0	0.3257***	0.1783***	0.1498***	0.4219***	0.1457***	0.2711***	0.2603***	0.5715***
1	0.0041	-0.0318	0.0301*	0.0053	0.0176	0.0503**	0.0028	0.0149
2	0.0083	0.0202	0.0463**	0.0485**	0.0780***	0.0041	-0.0121	0.0166
3	0.0319*	-0.0074	0.1040***	0.0480**	0.0887***	0.0347*	0.0269*	0.0378*
4	0.0927***	0.0606***	0.0959***	0.0809***	0.1029***	0.0255	0.0734***	0.0608***
5	0.1129***	0.0244	0.1248***	0.2408***	0.1812***	0.0842***	0.0974***	0.1189***

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

6. Conclusions

This research explored price and volatility transmission across corn and soybean markets between 1996 and 2014 in Brazil and the U.S. Our findings show evidence of a structural break in 2007, which can be explained by certain factors, including the end of the first commodity price boom, the expansion in demand for corn-based ethanol as a fuel additive and alternate fuel in the U.S., and the significant growth of the winter corn crop in Brazil. Consequently, two separated periods were analyzed (1996-2007 and 2008-2014).

The main results suggested that the price relationships between Brazilian and U.S. markets changed. Corn and soybean futures and spot markets became more integrated after 2007. Furthermore, in the later years of our analysis U.S. price responses to variations in Brazilian spot markets intensified significantly. In addition, the analysis of volatility spillovers showed that U.S. markets have contributed to the destabilization of Brazilian prices in both periods.

Overall, findings provide useful insights for producers, investors, and policy makers who use futures prices as risk management tools and arbitrage strategies in both futures and spot markets, for example, are more affected by changes in Brazilian prices than they were before 2007. In addition, understanding the prices relationships between markets provides better basis to evaluate and design policies related to agricultural markets. Further, price dynamics analysis help to evaluate the potential impact of the grain prices fluctuations on economic activity, especially for countries that depend on the revenues from grain exports. This topic can be further investigated with the use of high frequency data and the insertion of oil and ethanol prices series. Finally, the analysis of volatility transmission across markets can be also improved, using multivariate GARCH models.

References

Balcombe, K., A. Bailey and J. Brooks (2007) “Threshold effects in price transmission: the case of Brazilian wheat, maize, and soya prices” *American Journal of Agricultural Economics* **89**, 308-323.

Beckman, J. and R. Czudaj (2014) “Volatility transmission in agricultural futures markets” *Economic Modelling* **36**, 541-546.

Cabrera, B.L. and F. Schulz (2016) "Volatility linkages between energy and agricultural commodity prices" *Energy Economics* **54**, 190-203",

Ceballos, F., M.A. Hernandez, N. Minot and M. Robles (2015) “Grain price and volatility transmission from international to domestic markets in developing countries” Proceedings of the AAEA & WAEA Annual Meeting, San Francisco, CA.

Cheung, Y.W. and L.K. Ng (1996) “A causality-in-variance test and its application to financial market prices” *Journal of Econometrics* **72**, 33-48.

Enders, W. (2015) *Applied Econometric Time Series*, Wiley: New York.

FAO - Food and Agriculture Organization of the United Nations (2018) Statistics Division. Available at: www.fao.org/faostat

Fossati, S., F. Lorenzo, and C.M. Rodriguez (2007) “Regional and international market integration of a small open economy” *Journal of Applied Economics* **10**, 77-98.

Ganneval, S. (2016) “Spatial price transmission on agricultural commodity markets under different volatility regimes” *Economic Modelling* **52**, 173-185.

Goldsmith, P. (2008) “Soybean production and processing in Brazil” in *Soybeans: chemistry, production, processing and utilization* by L.A. Johnson, P.J. White and R. Galloway, Eds., AOCS Press: Urbana, 773-798.

Gorter, H., D. Drabik, D.R. Just and E.M. Kliauga (2013) "The impact of OECD biofuels policies on developing countries" *Agricultural Economics* **44**, 477-486.

Headey, D. and S. Fan (2008) ‘‘Anatomy of a crisis: the causes and consequences of surging food prices’’ *Agricultural Economics* **39**, 375-91.

Hernandez, M. A., R. Ibarra and D.R. Trupkin (2014) “How far do shocks move across borders? Examining volatility transmission in major agricultural futures markets” *European Review of Agricultural Economics* **41**, 301-325.

Irwin, S.H. and D.L. Good (2009) “Market instability in a new era of corn, soybean, and wheat prices” *Choices* **24**, 6-11.

Johansen, S. (1988) "Statistical analysis of cointegration vectors" *Journal of Economic Dynamics and Control* **12**, 231-254.

Leuthold, R.M., J.C. Junkus and J.E. Cordier (1989) *The theory and practice of futures markets*, Lexington Books: Lexington.

Li, Y., W. Zhang, L. Ma, L. Wu, J. Shen, W.J. Davies, O. Oenema, F. Zhang and Z. Dou (2014) “An analysis of China’s grain production: looking back and looking forward” *Food and Energy Security* **39**, 19-32.

Liu, Q. and Y. An (2011) “Information transmission in informationally linked markets: Evidence from US and Chinese commodity futures markets” *Journal of International Money and Finance* **30**, 778-795

Lütkepohl, H. (2006) *New introduction to multiple time series analysis*, Springer: Berlin.

Mattos, F.L. and R.L.F. Silveira (2018) “The expansion of the Brazilian winter corn crop and its impact on price transmission” *International Journal of Financial Studies* **6**, 1-17.

Park, H. and T.R. Fortenbery (2007) “The effect of ethanol production on the U.S. national corn prices” Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Chicago, IL.

Perron, P. (1989) “The great crash, the oil price shock and the unit root hypothesis” *Econometrica* **57**, 1361-1401.

Trujillo-Barrera, A., M. Mallory and P. Garcia (2012) "Volatility Spillovers in U.S. Crude Oil, Ethanol, and Corn Futures Markets" *Journal of Agricultural and Resource Economics* **37**, 247-62.

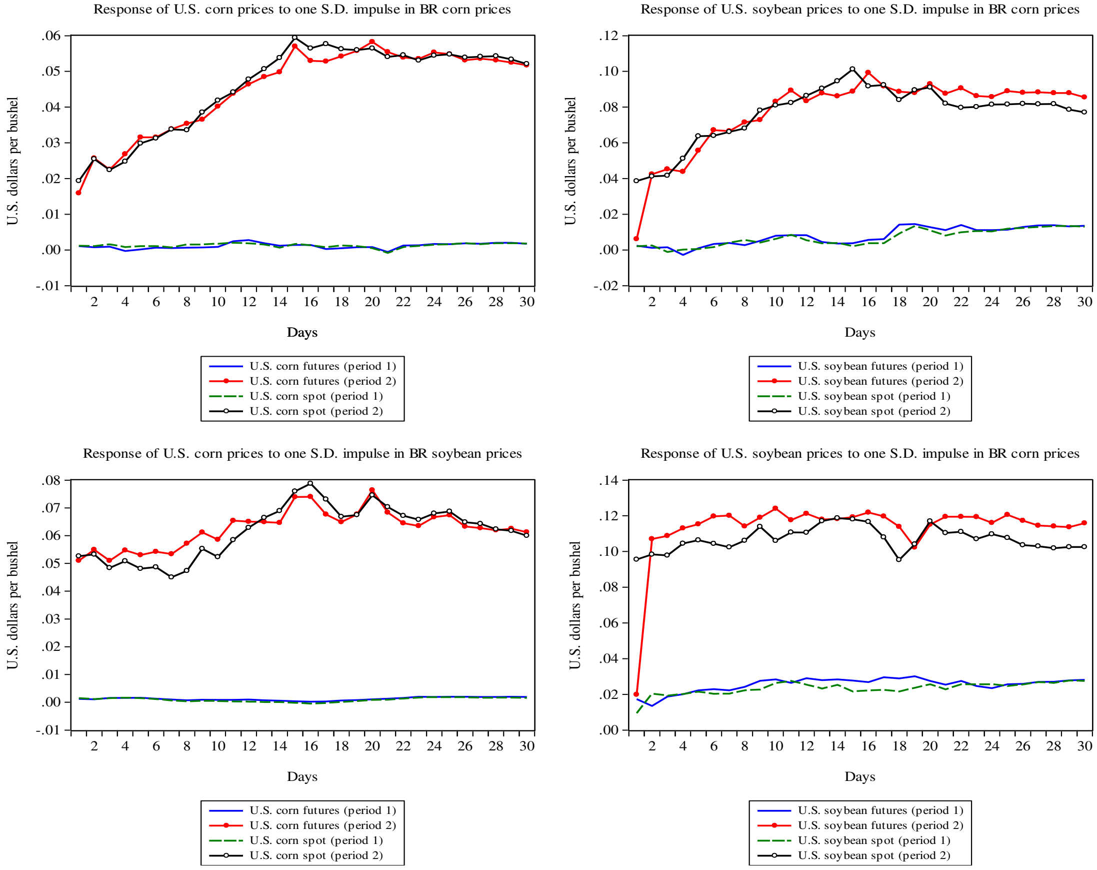
Yang, J., J. Zhang and D.J. Leatham (2003) “Price and volatility transmission in international wheat futures markets” *Annals of Economics and Finance* **4**, 37-50.

Zeileis A., C. Kleiber, W. Krämer and K. Hornik (2003) “Testing and dating of structural changes in practice” *Computational Statistics and Data Analysis* **44**, 109-123.

Zivot. E. and D.W.K. Andrews (1992) “Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis” *Journal of Business & Economic Statistics* **10**, 251-270.

Appendix

Figure 1: Change in different variables to one standard-deviation impulse in Brazilian prices



Response of U.S. corn prices to one S.D. impulse in BR corn prices

Response of U.S. soybean prices to one S.D. impulse in BR corn prices

Response of U.S. corn prices to one S.D. impulse in BR soybean prices

Response of U.S. soybean prices to one S.D. impulse in BR corn prices

Notes: Standard deviation values, in dollars per bushel: BRCS (period 1) = 0.4074; BRCS = 1.0609; BRSS (period 1) = 0.9727; BRSS (period 2) = 2.4198.