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The Effects of Brazilian Second (Winter) Corn Crop on Price Seasonality, Basis Behavior and Integration to International Market

by

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THE EFFECTS OF BRAZILIAN SECOND (WINTER) CORN CROP ON PRICE SEASONALITY, BASIS BEHAVIOR AND INTEGRATION TO INTERNATIONAL MARKET

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ABSTRACT

The purpose of this study is to analyze the impact of the growth of Brazilian winter corn crop on spot price seasonality, basis patterns, and the integration to international market. A moving average method and regression analysis were used to test for seasonal variations, while econometric time-series methods tests were applied to verify the market integration. Results indicated that the expansion of the winter corn crop has changed the seasonality of prices and basis and increased the level of integration with the international market.

Keywords: corn, seasonality, basis, market integration.

INTRODUCTION

Commodity producers typically grow one crop per year. Brazil, however, has become an exception in the corn market due to its ability to harvest two crops per year. The first one ("summer crop"), planted in September-December and harvested in January-April, is concentrated in Southern and Southeastern Brazil and is generally used to meet domestic demand for feed. The second crop ("winter crop"), planted in January-March and harvested in May-August, is concentrated in the center-west and south and is primarily used to supply the international market. The winter crop was introduced in southern Brazil in the 1980's and has traditionally accounted only for a minor portion of Brazilian corn production. Only in the 2000's, when it was adopted by producers in the fast-growing Brazilian center-west, the winter crop expanded rapidly from approximately 100 million bushels in the 1990's to 2 billion bushels in 2014. As a result, total Brazilian corn production (summer and winter) increased around threefold between 1990 and 2014, reaching about 3 billion bushels in 2014 (10% of the world production).

The expansion of the winter crop in Brazil was followed by three events. First, there was a shift in the supply and demand balance throughout the year. New crop used to come to the market only in the first half of the year, but now it comes to the market all year long and specially in the second half of the year. Another effect is the increasing participation of

Brazil in the international market. During 2011-2014 annual exports exceeded 800 million bushels (close to 20% of world exports), compared to about zero in the 1990's. Consequently, a higher demand for marketing and risk management tools has been occurring in Brazilian corn market. Trading volume in the Brazilian corn futures market, for example, reached almost 1.1 million contracts in 2014, compared to an annual average of 25 thousand contracts in the early 2000's.

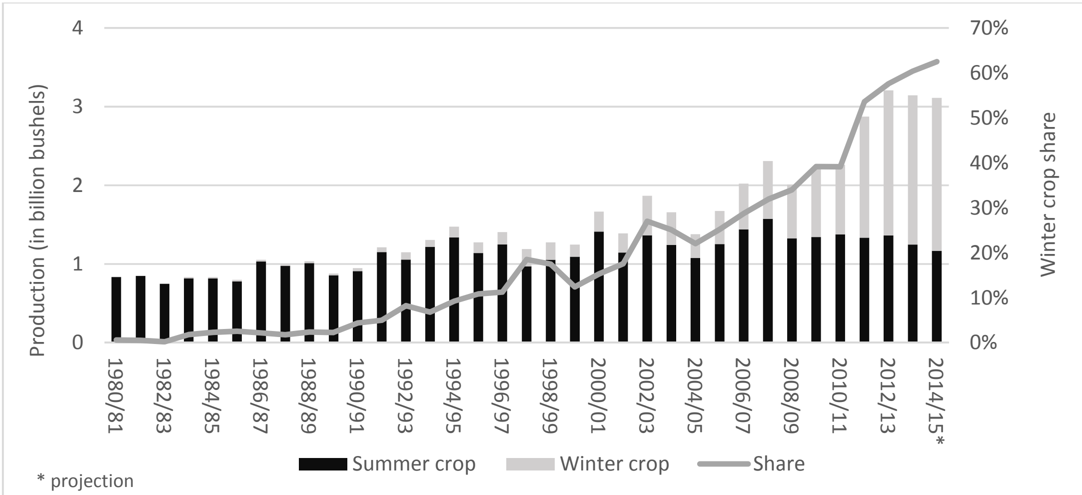
Despite these changes in the Brazilian corn market in the last 10-15 years, no study has comprehensively explored how these factors have affected corn price dynamics. The objective of this paper is to analyze the impact of Brazilian winter crop growth on spot price seasonality, basis patterns, and price transmission with the international market. We hypothesize that the expansion of the winter crop has affected spot price seasonality within the year, basis behavior, and price relationships with the international market.

This study will provide a comprehensive analysis of how the growth in Brazilian winter crop has impacted corn price dynamics. Results should offer useful insights for marketing, risk management and trading strategies adopted by producers, processors and merchandisers in Brazil. In addition, findings might also be relevant for market players in the U.S., Europe and Asia, since Brazilian corn has become increasingly present in international trade. Finally, results can provide interesting points for academic discussion regarding how changes in market structure affect price dynamics and hence marketing and risk management strategies adopted by their participants.

BRAZILIAN CORN MARKET: CHARACTERISTICS AND EVOLUTION

Figure 1 shows that the Brazilian corn production increased from 840 million bushels in 1980/81 to 3.1 billion bushels in 2014/15, registering a compound annual growth rate (CAGR) of 4% during this period. While the planted area rose from around 30 million acres to 39 million acres, productivity increased from 28 to around 82 bushels/acre. This is explained by the strong growth of the winter corn crop associated with technological advances in agriculture. The winter crop accounts for around 60% of total production and planted area in Brazil, with 22 million acres and 1.9 billion bushels, compared to about zero in the beginning of 1980's.

Figure 1: Brazilian corn production (in billion bushels) between 1980/81 and 2014/15.



Source: Conab (Brazilian Food Supply Company)[1]

The growth of Brazilian corn production has occurred especially in the center-west area (Table 1). While in 1980's this area accounted for 14% of Brazilian corn production, this share has increased to around 42% in 2010-2014. In addition, around 90% of center-west corn production comes from winter crop. The expansion of winter corn crop in the Brazilian center-west is associated with productivity growth and increase in planted area. Winter crop productivity has increased from 15 and 29 bushels/acre in 1980's and 1990's, respectively, to 80 bushels/acre between 2010/11 and 2014/15, reaching a similar level of summer crop productivity. The winter crop planted area in the center-west has reached 33% of the country's planted area, whereas in 1980's its share was close to zero (Table 2).

[1] CONAB is a public agency under the Brazilian Ministry of Agriculture. Livestock and Supply (MAPA), responsible for the execution of Brazilian agricultural policies related to price support, public storage, market supply and foreign trade. In addition, CONAB participates in the formulation of Brazilian government agricultural policy.

Table 1: Brazilian corn production (annual average) by regions between 1980's and 2010's (in million bushels).

Crop	Decade	Northern	North-eastern	Center-West	South-eastern	Southern	Total
Summer crop	1980	16.29	43.59	125.90	256.27	428.89	870.95
	1990	34.21	77.03	182.76	285.95	536.78	1.116.73
	2000	41.50	114.57	167.21	361.70	631.83	1.316.82
	2010[a]	43.59	164.16	154.67	373.26	560.98	1.296.66
Winter crop	1980	0.00	4.66	0.05	1.05	9.18	14.95
	1990	0.00	6.37	46.42	29.47	49.11	131.36
	2000	2.70	15.16	282.27	38.11	162.41	500.65
	2010[a]	22.25	80.22	1.063.65	85.05	372.09	1.623.26
Total	1980	16.29	48.25	125.95	257.33	438.07	885.90
	1990	34.21	83.39	229.17	315.42	585.90	1.248.09
	2000	44.20	129.73	449.49	399.82	794.24	1.817.47
	2010[a]	65.84	244.39	1.218.32	458.31	933.06	2.919.92

Source: Conab (Brazilian Food Supply Company)

[a] The 2010's considers the harvest seasons between 2010/11 and 2014/15.

Table 2: Brazilian corn planted area (annual average) by regions between 1980's and 2010's (in million acres).

Crop	Decade	Northern	North-eastern	Center-West	South-eastern	Southern	Total
Summer crop	1980	0.77	6.68	3.42	7.27	12.23	30.37
	1990	1.37	6.41	3.05	6.09	11.31	28.23
	2000	1.15	6.15	2.00	5.06	8.71	23.20
	2010[a]	0.98	5.15	1.27	4.10	5.68	17.19
Winter crop	1980	0.00	0.60	0.00	0.04	0.35	0.99
	1990	0.00	0.58	1.40	0.93	1.62	4.53
	2000	0.06	0.84	4.82	0.81	3.00	9.53
	2010[a]	0.35	1.66	12.38	1.18	4.80	20.36
Total	1980	0.77	7.28	3.42	7.31	12.57	31.36
	1990	1.37	6.99	4.44	7.02	12.94	32.76
	2000	1.34	6.98	6.82	5.87	11.71	32.73
	2010[a]	1.33	6.80	13.65	5.28	10.48	37.55

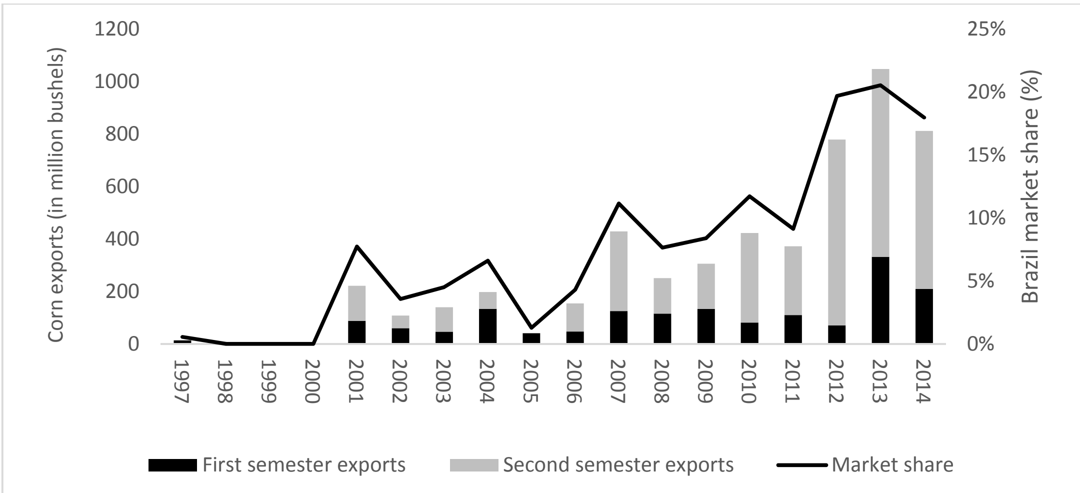
Source: Conab (Brazilian Food Supply Company)

[a] The 2010's considers the harvest seasons between 2010/11 and 2014/15.

While Brazilian summer crop comes to the market in the first half of the year and is primarily used to supply domestic meat industries, winter crop sales usually occur during the second half of the year and in general meet the international market demand. Brazilian corn exports rose from 5% of the global market share in the beginning of 2000's to almost

20% in 2014. In recent years the majority of corn shipments has occurred in the second semester since 2007 (Figure 2).

Figure 2: Brazilian corn exports (in million bushels) and world market share between 1997 and 2014.



Source: SECEX (Brazil's Foreign Trade Bureau) and USDA.

The incentive to plant the winter corn crop in Brazil is related to two main points. The first one is associated with the use of early maturing soybean (usually harvested in December-January), especially in the center-west, motivated by the possibility of applying less fungicide and insecticide (given the lower incidence of Asian soybean rust) and obtaining a price premium for exporting soybeans in the beginning of the year[2]. This has allowed for the planting of winter corn crop following the soybean harvest, which also benefited farmers due to the dilution of fixed costs and the optimization of machinery, labor and land use generated by this soybean-corn rotation.

[2] Brazilian soybean production increased sixfold during 1980-2014 (Figure 3). In recent years, Brazil has trailed the United States in soybean production and exports, reaching 30% of the world's production and 40% of world's exports.

The second factor is the strong expansion of poultry and pork industries, stimulated by domestic income growth and the insertion of Brazil in the international meat market. During 2001-2013, Brazilian producers increased corn consumption for animal feed at a CAGR of 4.7 per cent, reaching 1.8 billion bushels in 2013. In particular, corn consumption by poultry industry increased about twofold between 2001 and 2013, reaching around 1.05 billion bushels.

The changes in the Brazilian corn market in recent years are likely affecting corn price dynamics. On one hand, in the first semester, domestic supply and demand conditions tend to influence corn prices, since around 60% of Brazilian summer crop meets the demand for animal feed. On the other hand, in the second semester, with the great increase of Brazilian corn exports, the domestic price formation is likely to present different dynamics with a higher integration to international prices. In addition, the decrease of summer corn crop and the strong growth of winter crop in recent years have likely modified price seasonality.

PREVIOUS STUDIES

Previous work analyzed price and basis seasonality in commodity markets. Sorensen (2002), for example, provided a framework for estimating seasonal patterns in agricultural commodities prices, which explores time-series and cross-sectional characteristics of these series. In addition, the author estimated the seasonal patterns for soybeans, corn, and wheat in U.S. markets during 1972-1997. Crain and Lee (1996), using regression analysis, showed that the seasonal patterns in wheat price volatility changed due to the introduction of government programs in U.S. during 1950-1993. Sarfo and German (2012) examined the seasonality for cocoa markets during 1980-2009, conducting a two-state variable model. Focusing on basis variability, Jiang and Hayenga (1997) applied regression analysis to study basis behavior in U.S. grain markets during 1985 and mid-1990's. Results suggested the existence of seasonality in basis for both corn and soybean markets. Sander et al. (2003) researched basis patterns and hedging effectiveness for the Minneapolis Grain Exchange's cash-settled corn contract. They also found evidence seasonality in basis between 1997 and 2002. Seamon et al. (2001) explored basis patterns for cotton across U.S. regions. Using the nonparametric Friedman test, the authors found a significant seasonal basis pattern for regions that supplies most of their cotton to domestic textile mills, but not for exporting regions.

Additionally, several studies evaluated price transmission between the international market and regional markets in several countries. Zakari, Ying and Song (2014) found a long-run relationship between Niger grain markets and international and regional markets. Esposti and Listori (2013) investigated price transmission between Italian and international commodity markets during the price bubble period (2006-2010) and found evidence of cross-market linkages. Fossati, Lorenzo and Rodriguez (2009) conducted a cointegration analysis of commodity prices between international and regional prices in Uruguay. Rapsomanikis, Hallam and Conforti (2006) found evidence of integration with the world market for Ethiopian and Ugandan coffee, but not for Rwandan coffee and Egyptian wheat. Information transmission mechanism between different countries was also studied for corn (Booth and Ciner, 1997), wheat (Booth, Brockman, and Tse, 1998; Goychuk and Meyers, 2011), soybean and copper (Liu and An, 2011). Balcombe, Bailey and Brooks (2007) verified price transmission of wheat, maize and soya between U.S., Argentina and Brazil during the end of 1980's and beginning of 1990's, generally with causality flowing from U.S. and Argentina toward Brazil.

In the next sections, it will be discussed how the present research will explore the impact of the growth of Brazilian winter corn crop on seasonality, basis behavior, and price relationships with the international market, shedding more light on the discussion about the Brazilian corn prices dynamics.

RESEARCH METHOD

The empirical analysis of this work is conducted in two steps. The first one is based on the evaluation of the impact of Brazilian winter crop on seasonality of spot price and basis. The second step consists on the study of market integration between Brazilian and international corn markets.

Seasonality procedures

The seasonal analysis considers the classical multiplicative model, in which prices for year i (i = 1, …, n) and month j (j = 1, …, 12), P_{ij}, are modeled by the product of trend (T_t), cyclical component (C_t), seasonal term (S_t), and a random disturbance (R_t) – equation 1 (Goetz and Weber, 1986).

$$P_{ij} = P_t = T_t \times C_t \times S_t \times R_t \tag{1}$$

Where, $t = 12 \times (i - 1) + j$.

The moving average method is used to calculate the seasonal index. First, we obtain a 12-month centered geometric moving average for monthly corn prices, G_t (equation 2). Next, we calculate seasonal-irregular ratios P_{ij}/G_{ij} and then compute the geometric average of these ratios for each month j across years (equation 3) to obtain 12 average seasonal indexes SI_j (one for each month). Finally, a seasonal adjusted index (SAI_j) is calculated for each month by dividing each monthly SI_j by the geometric average of all SI_j (equation 4).

$$G_t = \sqrt[12]{P_{t-6}^{0.5} \times P_{t-5} \times \ldots \times P_{t-1} \times P_t \times P_{t+1} \times P_{t+2} \times \ldots \times P_{t+5} \times P_{t+6}^{0.5}} \quad (2)$$

$$SI_j = \begin{cases} \left(\prod_{i=1}^{n-1} \frac{P_{ij}}{G_{ij}} \right)^{\frac{1}{n-1}} & if\ 7 \le j \le 12 \\ \left(\prod_{i=2}^{n} \frac{P_{ij}}{G_{ij}} \right)^{\frac{1}{n-1}} & if\ 1 \le j \le 6 \end{cases} \quad (3)$$

$$SAI_j = \frac{SI_j}{\left(\prod_{j=1}^{12} SI_j \right)^{\frac{1}{12}}} \quad (4)$$

Since the winter corn crop has increased strongly and continuously since 2005, the study considers two different periods: 1995-2004 and 2005-2014. Thus, two series of seasonal index, one for each period, are constructed and compared.

In addition, in order to test the change of monthly seasonality over time, a simple regression analysis is conducted, with SAI_j as the dependent variable and a time trend as the independent variable (equation 6).

$$SAI_{tj} = \alpha + \beta \cdot t + \varepsilon_t \quad (6)$$

where $t = 1, \ldots, 20$ represents the 20-year period (1995-2014) in the sample. This equation is estimated for each month j individually.

The same analysis is applied to the basis. However, since the moving average method to identify seasonality requires positive input values, we use the ratio between local cash price and the nearby futures price instead of the difference between the two prices.

Market integration procedures

Market integration is studied using time series approaches. First, Augmented Dickey-Fuller (ADF) and Phillips-Perron tests are performed to check the presence of unit root (non-stationarity) in the corn price series. In the presence of non-stationarity, long-run relationships between prices are tested with the cointegration methods by Engle and Granger (1987) and Johansen (1988).

If the price series are found to be cointegrated, then vector error correction models (VECM) are estimated (equation 11).

$$\Delta p_{1t} = \alpha_1 + \alpha_{1y}\hat{e}_{1t-1} + \sum_{i=1}^{k} \alpha_{11}(i)\Delta p_{1t-i} + \sum_{i=1}^{k} \alpha_{12}(i)\Delta p_{2t-i} + \varepsilon_{1t} \quad (11)$$
$$\Delta p_{2t} = \alpha_2 + \alpha_{2y}\hat{e}_{1t-1} + \sum_{i=1}^{k} \alpha_{21}(i)\Delta p_{1t-i} + \sum_{i=1}^{k} \alpha_{22}(i)\Delta p_{2t-i} + \varepsilon_{2t}$$

where p_{1t} and p_{2t} are price series and e_t is the error correction term. The coefficients α_{1y} and α_{2y} represent the speed of adjustment, i.e. how rapidly p_{1t} and p_{2t} adjust to re-establish the long-run equilibrium. Speed of adjustment parameter close to 1 (in absolute value) means the existence of fast adjustment, suggesting rapid reaction and high information flow (Schroeder, 1997).

While the long run causality between the two price series is conducted by evaluating the statistical significance of cointegrating parameters (α_{1y} and α_{2y}), the short run causality (immediate effect) is tested by analyzing the statistical significance of the lagged dynamic terms. Wald tests are used to test the joint significance of a set of coefficients associated with lags of endogenous variable. For example, the rejection of H_0: $\alpha_{12}(1) = \alpha_{12}(2) = \ldots = \alpha_{12}(k) = 0$ indicates that there is a short run causality that runs from p_{2t} to p_{1t}.

DATA

A dataset of daily corn spot and futures prices is used in this research. Spot prices refer to four important producing areas in Brazil: Cascavel-PR, Chapecó-SC, Mogiana-SP, and Rio Verde-GO. The first two areas, Cascavel and Chapecó, are located in southern Brazil, while Mogiana is in the south-east and Rio Verde is in the center-west. Futures prices refer to corn contracts traded both in the CME Group and BM&FBOVESPA (Brazilian futures exchange). All prices are quoted in Brazilian Reals (BRL) per bushel and expressed in logarithms. The sample period is from June 1995 to December 2014 (4,765 observations), except for BM&FBOVESPA prices because they started trading only in June 1997.

Descriptive statistics for corn prices and returns are reported in Table 1. Mean prices were in the 1.17-2.02 BRL/bushel range. We also can verify a slight higher volatility in the corn futures markets compared to spot markets. Corn futures returns had a daily standard deviation of 1.77% per day for Brazilian exchange and 1.90% per day for CME Group, while the standard deviation of Brazilian spot returns were in the 1.05%-1.68% range.

Table 3: Descriptive statistics of daily log prices (P_t) and percentage daily returns (R_t) (June 1995-December 2014).

	Spot markets								Futures markets			
	Cascavel		Chapecó		Rio Verde		Mogiana		BM&F[(a)]		CME	
	P_t	R_t	P_t	R_t	P_t	R_t	P_t	R_t	P_t	R_t	P_t	R_t
Observ. (n)	4,765	4,764	4,765	4,764	4,765	4,764	4,765	4,764	4,396	4,395	4,765	4,764
Mean	1.71	0.03	1.81	0.03	1.67	0.03	1.75	0.03	2.02	0.03	1.17	0.01
Median	1.80	0.000	1.92	0.00	1.76	0.00	1.82	0.00	2.12	0.00	1.07	0.00
Maximum	2.47	12.50	2.55	10.01	2.45	32.55	2.56	11.86	2.79	16.28	2.12	12.76
Minimum	0.81	-16.24	0.87	-7.93	0.63	-33.45	0.75	-13.80	0.97	-31.18	0.56	-27.62
Std. Dev.	0.42	1.05	0.44	1.13	0.47	1.68	0.44	1.65	0.43	1.77	0.42	1.90
Skewness	-0.36	-0.56	-0.40	-0.04	-0.37	-0.21	-0.28	0.10	-0.59	-1.52	0.58	-1.16
Kurtosis	1.96	23.47	1.94	10.74	1.94	67.39	1.98	12.57	2.29	46.65	2.13	22.77

(a) Corn futures prices in Brazil are available only from June 1997.

RESULTS

Seasonality analysis

Table 4 and Figure 1 (Appendix A) present seasonal indexes for spot prices in four producing areas in Brazil and for futures prices (BM&FBOVESPA and CME Group) during 1995-2004 and 2005-2014. Results for spot prices show that the range between lowest and highest prices within the year has decreased in the second period compared to the first one. In addition, there appears to be changes in the seasonal price pattern. Spot prices in the first quarter were generally above the annual average in 2005-2014, while they used to be below the annual average in 1995-2004. During 1995-2004, February and March were characterized by lower prices – the seasonal index for the four Brazilian producing areas in these two months was, on average, around 2.4% and 4.5% below the average, respectively. In 2005-2014 period, the seasonal components for February and March reached levels around 3.6% and 2.3% above the average, respectively. Further, spot prices still reach their lowest levels in July-August and then increase in September-November in both periods. However, this price increase in September-November in 2005-2014 was not as strong as it used to be in 1995-2004. The 1995-2004 period presented average seasonal index around 5.3% and 9% above the average for October and November, respectively, while during

2005-2014 these levels were 0.2% below the average in October and almost 3% above the average in November.

In futures markets, the seasonal price index for BM&FBOVESPA prices presented changes similar to what was discussed for spot prices, reflecting the impact of the winter corn crop in Brazil in the recent years. Conversely, the results for the CME seasonal price index show changes only during the second semester, when the U.S. corn harvest occurs. During 1995-2004, the seasonal index for U.S. futures prices in August-October was around 1% below the average, while during 2005-2014 it was almost 4.5% below the average. In addition, the seasonal index in December-January became higher during 2005-2014 compared to the previous period.

Estimated coefficients for the OLS regression model for the seasonal index and time trend (based on equation 5) are reported in Table 5. In general, results indicate that the trend variable was generally positive and statistically distinguishable from zero for February and March, and negative and statistically distinguishable from zero for October in Rio Verde and Cascavel. These results provide evidence that some seasonal indexes have consistently changed over the years, although this model does not identify specific periods during which changes in seasonality may have occurred.

Table 4: Seasonal corn price index during 1995-2004 and 2005-2014.

Area	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Std Dev.	Ampl.
Cascavel	1995-2004	99.87	97.87	96.34	99.87	101.35	97.78	95.91	98.63	100.71	103.74	106.66	101.80	3.10	10.74
	2005-2014	101.99	104.40	101.91	99.53	99.44	99.71	97.69	96.06	98.23	97.43	101.90	102.03	2.45	8.34
Chapecó	1995-2004	100.85	95.71	95.08	97.59	99.55	96.77	95.22	98.03	102.80	105.41	108.99	105.13	4.58	13.92
	2005-2014	102.83	102.26	99.97	97.01	97.08	97.17	96.39	97.04	101.32	101.38	104.78	103.26	2.98	8.39
Rio Verde	1995-2004	102.84	98.68	95.50	98.01	98.34	95.80	93.30	95.45	100.76	106.42	110.21	106.17	5.26	16.91
	2005-2014	106.54	106.11	105.04	100.81	96.60	95.20	93.32	93.14	98.17	98.81	101.60	106.04	5.01	13.40
Mogiana	1995-2004	104.66	98.36	95.18	96.72	97.98	94.58	93.44	97.51	101.85	105.64	109.97	105.62	5.28	16.53
	2005-2014	103.83	101.76	102.12	97.76	95.86	95.99	96.46	97.66	100.58	101.42	103.13	103.97	3.11	8.10
BM&F	1995-2004	96.11	91.94	93.78	98.14	98.86	95.82	96.16	99.23	106.56	111.04	110.74	103.81	6.40	19.10
	2005-2014	101.12	99.37	98.37	96.63	98.09	97.17	96.31	98.25	102.54	101.35	105.11	106.28	3.27	9.97
CME	1995-2004	98.88	102.91	104.16	102.56	103.98	101.88	97.45	97.79	98.91	99.49	96.79	95.68	2.93	8.48
	2005-2014	102.66	102.37	104.83	102.51	103.09	102.90	98.60	94.87	95.83	95.99	97.22	99.78	3.44	9.96
Spot Average	1995-2004	102.05	97.65	95.52	98.05	99.30	96.23	94.47	97.41	101.53	105.31	108.96	104.68	4.55	14.53
	2005-2014	103.80	103.63	102.26	98.77	97.25	97.02	95.96	95.97	99.58	99.76	102.85	103.83	3.39	9.56

Table 5: Estimated regression model for corn price index considering each separated month (June 1995 – December 2014).

Area	Coeffic.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cascavel	*c*	-0.017	-0.057	-0.069	-0.008	0.030	-0.005	-0.014	0.008	0.024	0.053	0.061	0.005
	Trend	0.003	0.008 **	0.007 **	0.001	-0.003	-0.001	-0.001	-0.004	-0.003	-0.006 ***	-0.003	0.001
Chapecó	*c*	0.003	-0.063 ***	-0.066 **	-0.029	0.015	-0.012	-0.021	-0.008	0.027	0.057 ***	0.076	0.044
	Trend	0.002	0.006 ***	0.005 **	0.001	-0.003	-0.002	-0.002	-0.002	-0.000	-0.003	-0.002	-0.001
Rio Verde	*c*	0.009	-0.042	-0.084 **	-0.048	-0.014	-0.028	-0.029	-0.017	0.020	0.079 **	0.091	0.049
	Trend	0.004	0.007 ***	0.010 *	0.005	-0.001	-0.002	-0.003	-0.004	-0.002	-0.007 **	-0.005	0.000
Mogiana	*c*	0.049	-0.043	-0.097 **	-0.067	-0.018	-0.049	-0.042	-0.007	0.036	0.081 **	0.098 **	0.058
	Trend	-0.000	0.005	0.009 *	0.005	-0.001	0.000	-0.000	-0.002	-0.002	-0.006	-0.005	-0.002
BM&F	*c*	-0.054	-0.133 *	-0.108 **	-0.027	0.004	-0.013	-0.025	-0.002	0.074 ***	0.122 **	0.094	0.035
	Trend	0.004	0.009 **	0.007	0.000	-0.002	-0.002	-0.001	-0.001	-0.003	-0.008	-0.003	0.001
CME	*c*	-0.007	0.038	0.054	0.042	0.054	0.033	-0.011	-0.034	-0.032	-0.017	-0.047	-0.054
	Trend	0.002	-0.001	-0.001	-0.001	-0.002	-0.001	-0.000	-0.000	0.001	-0.001	0.002	0.003

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

The seasonal index for BM&FBOVESPA basis is reported in Table 6 and Figure 2 (Appendix A). Overall, the difference between highest and lowest indexes within the year was smaller in 2005-2014 compared to 1995-2004 in all four regions. In particular, in all regions the seasonal indexes in January-February were not as high in 2005-2014 as they used to be in 1995-2004. While January-February in 1995-2004 presented an average seasonal index for BM&FBOVESPA basis around 8% over the annual average, these values were around 3% over the annual average in 2005-2014. Further, in 1995-2004 the seasonal indexes reached their lowest points in September-October in all regions. But in 2005-2014 this behavior was observed only in Cascavel and Rio Verde. In the other two regions (Chapecó and Mogiana), the seasonal indexes reached the lowest levels in May and then remained within a narrow range until the end of the year.

Table 7 shows estimated coefficients for OLS regression model with the seasonal index and time trend. Findings are mixed across regions and months, and no clear pattern emerges from regression results. Overall, estimates were statistically distinguishable from zero for Cascavel in February (negative) and June (positive), for Chapecó in February (negative) and September-October (positive), for Rio Verde in April (positive) and November (negative), and for Mogiana in April (positive) and November-December (negative).

Table 6: Seasonal index for BM&FBOVESPA basis during 1995-2004 and 2005-2014.

Area	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Std Dev.	Ampl
Cascavel	1995-2004	106.60	110.04	104.42	101.18	101.01	100.74	98.02	97.55	92.88	92.58	96.73	99.71	5.16	17.46
	2005-2014	100.92	105.08	103.65	102.98	101.38	102.59	101.43	97.76	95.80	96.15	96.90	95.97	3.34	9.29
Chapecó	1995-2004	106.21	106.46	102.93	99.63	99.11	99.86	97.67	97.71	95.86	94.42	98.60	102.33	3.77	12.04
	2005-2014	101.71	102.91	101.66	100.35	98.96	100.00	100.13	98.74	98.82	100.06	99.66	97.13	1.56	5.78
Rio Verde	1995-2004	109.17	108.25	101.87	99.66	98.38	99.43	95.77	94.83	94.05	95.85	100.43	103.63	4.95	15.11
	2005-2014	105.41	106.79	106.88	104.27	98.47	97.95	96.89	94.75	95.73	97.54	96.65	99.76	4.47	12.13
Mogiana	1995-2004	110.07	108.16	102.15	99.01	97.93	98.43	95.85	96.70	94.91	94.94	100.25	102.91	4.94	15.16
	2005-2014	102.68	102.38	103.90	101.11	97.73	98.78	100.18	99.37	98.10	100.10	98.10	97.81	2.10	6.17
Average	1995-2004	108.01	108.23	102.84	99.87	99.11	99.61	96.83	96.70	94.42	94.45	99.00	102.14	4.70	14.94
	2005-2014	102.68	104.29	104.02	102.18	99.13	99.83	99.66	97.65	97.11	98.46	97.83	97.67	2.87	8.34

Table 7: Estimated regression model for corn BM&FBOVESPA basis index considering each separated month (June 1995 – December 2014).

Area	Coeffic.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cascavel	*c*	0.065 ***	0.110 *	0.049 **	0.005	0.003	-0.010	-0.012	-0.019	-0.075 *	-0.078 *	-0.027	-0.009
	Trend	-0.004	-0.005 ***	-0.001	0.002	0.001	0.003 ***	0.002	-0.000	0.002	0.003	-0.001	-0.002
Chapecó	*c*	0.064 ***	0.087 *	0.051 **	-0.005	-0.014	-0.017	-0.015	-0.024	-0.057 *	-0.070 *	-0.018	0.017
	Trend	-0.003	-0.005 ***	-0.003	0.000	0.000	0.001	0.001	0.001	0.003 ***	0.005 **	0.001	-0.003
Rio Verde	*c*	0.085 ***	0.085 **	0.011	-0.029	-0.035 **	-0.022	-0.019	-0.035 ***	-0.060 **	-0.037 ***	0.006	0.028
	Trend	-0.002	-0.002	0.004	0.006 **	0.002	0.001	-0.001	-0.002	0.001	0.001	-0.003 ***	-0.002
Mogiana	*c*	0.107 *	0.084 *	0.002	-0.041 **	-0.042 **	-0.039 **	-0.034	-0.030	-0.047 **	-0.037	0.017	0.035 ***
	Trend	-0.006	-0.004	0.003	0.005 **	0.002	0.002	0.002	0.001	0.001	0.002	-0.003 ***	-0.004 ***

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

Seasonal analysis for CME basis shows distinct results than for BM&FBOVESPA basis. In 2005-2014 seasonal indexes for CME basis were higher in the first quarter and lower in the last quarter compared to what they used to be in 1995-2004. For example, in 1995-2004 the average seasonal index for CME basis in March was almost 8% below the annual average, while in 2005-2014 this index was almost at the annual average. In October, the seasonal index was around 12% above the annual average during 1995-2004, but around 4% above the annual average during 2005-2014. Further, the overall behavior within the year is similar in both periods, but the seasonal curve seems to be shifted to the right during 2005-2014. Consequently, the lowest values for the seasonal index were observed around June in 2005-2014, as opposed to April in 1995-2004.

Regression results for the OLS model with seasonal index and time trend have little to show. Only for Rio Verde there are estimates that are statistically distinguishable from zero, for March (positive) and October (negative).

Table 8: Seasonal index for CME basis during 1995-2004 and 2005-2014.

Area	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Std Dev.	Ampl.
Cascavel	1995-2004	99.05	98.77	93.08	92.83	94.64	94.89	97.46	101.80	104.67	110.16	111.19	103.56	6.24	18.36
	2005-2014	103.09	102.81	98.57	94.75	94.28	94.74	95.48	98.66	101.82	101.47	107.09	108.52	4.84	14.24
Chapecó	1995-2004	99.99	96.61	91.87	90.75	92.95	93.91	96.73	101.17	106.85	111.93	113.62	106.97	7.89	22.88
	2005-2014	103.91	100.69	96.69	92.34	92.03	92.32	94.28	99.64	105.01	105.62	110.12	109.80	6.71	18.09
Rio Verde	1995-2004	101.95	99.57	92.30	91.16	91.80	92.98	94.80	98.51	104.70	113.00	114.90	108.05	8.33	23.74
	2005-2014	107.69	104.51	101.59	95.95	91.58	90.46	91.22	95.63	101.74	102.95	106.81	112.74	7.24	22.27
Mogiana	1995-2004	103.79	99.25	92.03	89.92	91.47	91.78	94.97	100.63	105.81	112.18	114.65	107.45	8.51	24.73
	2005-2014	104.95	100.19	98.78	93.04	90.88	91.22	94.35	100.30	104.23	105.65	108.39	110.51	6.72	19.63
Average	1995-2004	101.20	98.55	92.32	91.16	92.71	93.39	95.99	100.52	105.51	111.82	113.59	106.51	7.74	22.43
	2005-2014	104.91	102.05	98.91	94.02	92.19	92.19	93.83	98.56	103.20	103.93	108.10	110.39	6.38	18.56

Table 9: Estimated regression model for corn CME basis index considering each separated month (June 1995 – December 2014).

Area	Coeffic.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cascavel	*c*	-0.029	-0.043	-0.093 ***	-0.072 ***	-0.043	-0.047	-0.005	0.047	0.072	0.114 **	0.096	0.006
	Trend	0.004	0.005	0.005	0.001	-0.002	-0.001	-0.002	-0.005	-0.004	-0.007	-0.002	0.004
Chapecó	*c*	-0.009	-0.049	-0.089 ***	-0.093 **	-0.058	-0.055	-0.013	0.030	0.075	0.119 **	0.110 ***	0.046
	Trend	0.003	0.003	0.003	0.001	-0.002	-0.002	-0.003	-0.002	-0.002	-0.004	-0.001	0.003
Rio Verde	*c*	-0.003	-0.028	-0.107 **	-0.112 **	-0.088 **	-0.070	-0.021	0.021	0.067	0.141 *	0.125 ***	0.050
	Trend	0.005	0.005	0.008 ***	0.005	0.000	-0.001	-0.005	-0.005	-0.004	-0.008 ***	-0.004	0.004
Mogiana	*c*	0.037	-0.029	-0.119 **	-0.131 *	-0.092 **	-0.092 ***	-0.033	0.031	0.083	0.143 **	0.133 **	0.060
	Trend	0.001	0.003	0.008	0.004	0.000	0.000	-0.002	-0.002	-0.003	-0.007	-0.004	0.002

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

Market integration analysis

Unit root tests suggest that all price series were non-stationary in levels and stationary in first-differences at the 1% significance level (Appendix B). Therefore, all series were integrated of order one, I(1).

Results of the Engle-Granger bivariate cointegration procedure and Johansen cointegration test generally indicate the presence of long-run relationship between Brazilian spot and CME futures prices in the recent period (2005-2014), but not during 1995-2004 (Appendix B). Similar findings were observed for Brazilian and U.S. futures prices. On the other hand, test results for Brazilian spot and futures prices showed evidence of cointegration in both periods.

Next, VEC models were estimated for both periods, 1995-2004 and 2005-2014, separately for each pair of spot and futures prices. Results for the spot-CME futures models show that speed-of-adjustment coefficients were statistically significant and negative in the ΔS_t equations for all areas in both periods, but statistically significant and positive in three ΔF_t equations only in the second period (Table 10). These findings suggest that spot prices always made the adjustment towards the long-run equilibrium, while CME futures prices only started contributing to this adjustment process in the second period. The half-life period[3] of spot price responses to a random shock during 2004-2015 was 115, 130, 81, and 83 days for Cascavel, Chapecó, Rio Verde, and Mogiana, respectively, indicating a slow adjustment process.

Table 10 also presents the results of speed-of-adjustment coefficients for spot-BM&FBOVESPA futures price pairs. Speed-of-adjustment parameters were statistically significant and negative in the ΔS_t equations and statistically significant and positive in the ΔF_t equations for both periods (except for Mogiana in the first period). Results show evidence of a faster speed of adjustment for spot prices in 2005-2014 compared to 1995-2004, with half-life decreasing around 60% from the first to the second period (from 67 days to 24 days, on average).[4]

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[3] The half-life is the expected time for a shock to decay by 50%. It is a measure of speed of adjustment and is calculated using $\ln(0.5)/\ln(1 - \alpha)$.

[4] Changes in the futures contracts, from physical delivery to cash settlement, may have also contributed to faster speed of adjustment.

Table 10: Summary of VECM estimation results.

Price Pairs	1995-2004		2005-2014	
	Speed of adjustment		Speed of adjustment	
ΔS_t equation				
Cascavel - CME	-0.0048	*	-0.0060	*
Chapecó - CME	-0.0053	*	-0.0053	*
Rio Verde - CME	-		-0.0085	*
Mogiana - CME	-		-0.0083	*
Cascavel - BM&F	-0.0104	*	-0.0263	*
Chapecó - BM&F	-0.0127	*	-0.0221	*
Rio Verde - BM&F	-0.0114	*	-0.0376	*
Mogiana - BM&F	-0.0081	*	-0.0358	*
ΔF_t equation				
CME - Cascavel	0.0022		0.0057	
CME - Chapecó	0.0025		0.0075	***
CME - Rio Verde	-		0.0084	**
CME - Mogiana	-		0.0074	**
BM&F - Cascavel	0.0188	*	0.0104	***
BM&F - Chapecó	0.0235	*	0.0199	*
BM&F - Rio Verde	0.0086	**	0.0092	***
BM&F - Mogiana	0.0064		0.0130	**
BM&F - CME	-		-0.0073	*
CME - BM&F	-		-0.0221	

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

In addition, results for short-run price dynamics suggest a faster interaction between spot and futures prices, given the optimal lag structure of the models in 1995-2004 and 2005-2014. Overall, there is not clear evidence of stronger impact of lagged futures (spot) price changes on current spot (futures) price changes. Results are mixed in terms of magnitude and statistical significance of lagged price changes in both spot and futures equations for all regions (Appendix B).

CONCLUSIONS

The purpose of this study is to analyze the impact of the growth of Brazilian winter corn crop on spot price seasonality, basis patterns, and the integration to international market.

Four distinct spot markets in Brazil are investigated, along with two futures markets (Brazil and US) to explore basis behavior.

Results from seasonality analysis for spot prices show that prices have been oscillating within a narrower range in 2005-2014 compared to 1995-2004, in addition to changes in seasonal patterns between the two periods. In the first quarter, spot prices are now generally above the annual average, while they used to be below the annual average in 1995-2004. Further, spot prices still reach their lowest levels in July-August and then increase in September-November in both periods. However, this price increase in September-November in 2005-2014 is not as strong as it used to be in 1995-2004.

Seasonal analysis for BM&FBOVESPA basis also indicates a narrower range within the year for 2005-2014 compared to the previous period. In all regions, the seasonal indexes in January-February are not as high in 2005-2014 as they used to be in 1995-2004. In addition, seasonal indexes reached their lowest points in September-October in all regions in 1995-2004. However, in 2005-2014 this behavior was observed only in Cascavel and Rio Verde. In the other two regions (Chapecó and Mogiana), the seasonal indexes reached the lowest levels in May and then remained within a tight range until the end of the year. With respect to the CME basis, results are distinct from findings for BM&FBOVESPA basis. The overall behavior of the CME basis within the year is mostly similar in both periods, with two distinctions. Seasonal indexes in the first and last quarter are respectively higher and lower in 2005-2014 compared to 1995-2004. Further, seasonal curves seem to be shifted to the right during 2005-2014, i.e. the lowest values for the seasonal indexes are now observed around June, as opposed to April in 1995-2004.

The findings described above appear to be stronger in southern and south-eastern Brazil. In the center-west area (Rio Verde), there is a relatively smaller change in basis range within the year. This suggests greater unpredictability for Rio Verde-BM&FBOVESPA basis (i.e. higher basis risk) compared to other areas, which may impact hedging effectiveness in BM&FBOVESPA futures market.

With respect to market integration, overall results suggest that Brazilian corn prices are experiencing higher integration to international prices in the more recent period. In general, cointegration tests indicate that Brazilian corn prices and CME futures prices have shared common long-run information since mid-2000's, which coincides with a large increase of Brazilian production and exports stimulated by the expansion of winter corn crop. Thus, both spot and CME futures prices now adjust to reestablish their long-run equilibrium relationship, whereas only spot prices used to make the adjustment in 1995-2004. Regarding spot and BM&FBOVESPA futures prices, both prices participate in the adjustment to their long-run equilibrium in both periods. Finally, comparison of speed-of-adjustment coefficients for spot-CME futures and spot-BM&FBOVESPA futures prices pair reveals faster adjustment in the relationship spot-BM&FBOVESPA futures price. The half-life period of shocks associated to spot-BM&FBOVESPA futures prices (24 days, on average) was lower than the result obtained in the spot-CME futures prices pair (102 days, on average).

These changes in seasonal patterns and spot-futures prices relationships have implications to marketing and risk management strategies. In principle, stronger relationship between spot and futures markets suggest more effective opportunities for futures hedging. The next steps of this research are to explore current effectiveness of marketing strategies used in the past compared to what it used to be in 1995-2004, and to investigate new strategies taking into account new price and basis patterns.

REFERENCES

Baffes, J. and B. Gardner (2003). The transmission of world commodity prices to domestic markets under policy reforms in developing countries. The Journal of Policy Reform, 6, 159-180.

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.

Bekkerman, A. and D. Pelletier (2009). Basis volatilities in corn and soybeans in spatially separated markets: the effect of ethanol demand. Proceedings of the AAEA & ACCI Annual Meeting, Milwaukee, WI.

Booth, G. G. and C. Ciner (1997). International transmission on information in corn futures markets. Journal of Multinational Financial Management, 7, 175-187.

Booth, G. G., P. Brockman, and Y. Tse (1998). The relationship between US and Canadian wheat futures. Applied Financial Economics, 8, 73-80.

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.

Crain, S. J. and J. H. Lee (1996). Volatility in wheat spot and futures markets, 1950–1993: government farm programs, seasonality, and causality. The Journal of Finance, 51, 325-343.

Esposti, R. and Listorti, G. (2013). Agricultural price transmission across space and commodities during price bubbles. Agricultural Economics, 44, 125-139.

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.

Goetz, S. and M. Weber (1986). Fundamentals of price analysis in developing countries. Food systems: A training manual to accompany the microcomputer software program MSTAT. MSU International Development Papers. Working Paper 29, Department of Agricultural Economics, Michigan State University.

Goychuk, K. and W. H. Meyers (2011). Black sea wheat market integration with the international wheat markets: some evidence from co-integration analysis. Proceedings of Agricultural and Applied Economics Association Annual Meeting, July 24-26, 2011, Pittsburgh, Pennsylvania.

Jiang, B., and M. Hayenga (1997). Corn and soybean basis behavior and forecasting: fundamental and alternative approaches. Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Chicago, IL.

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

Mundlak, Y. and D. F. Larson (1992). On the transmission of world agricultural prices. World Bank Economic Review, 6, 399-422.

Nazlioglu. S., C. Erdem, and U. Soytas (2013). Volatility spillover between oil and agricultural commodity markets. Energy Economics, 36, 658-665.

Rapsomanikis, G., D. Hallam, and P. Conforti (2006). Market integration transmission in selected food and cash crop markets of developing countries: review and applications. In: Sarris, A. and Hallam, D. Agricultural Commodity Markets and Trade: New Approaches to Analyzing Market Structure and Instability.

Sanders, D. R., and T. D. Greer (2003). Hedging spot corn: an examination of the Minneapolis grain exchange's cash settled corn contract. Journal of Agribusiness, 21, 65-81.

Sarfo, S. and H. Geman (2012). Seasonality in cocoa spot and forward markets: empirical evidence. Journal of Agricultural Extension and Rural Development, 4, 164-180.

Schroeder, T.C. (1997). Fed cattle spatial transactions price relationships. Journal of Agricultural and Applied Economics, 29, 347–62.

Seamon, V. F., K. H. Kahl, and C. E. Curtis Jr (2001). Regional and seasonal differences in the cotton basis. Journal of Agribusiness, 19, 147-161.

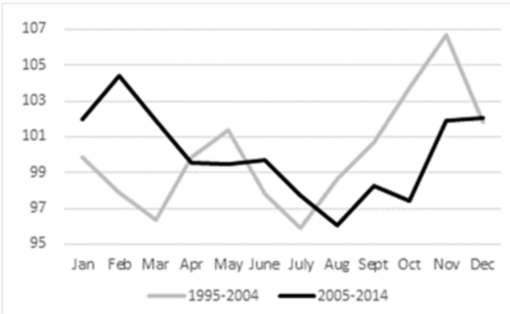
Sorensen, C. (2002). Modelling seasonality in agricultural commodity futures. Journal of Futures Markets, 22, 393-426.

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.

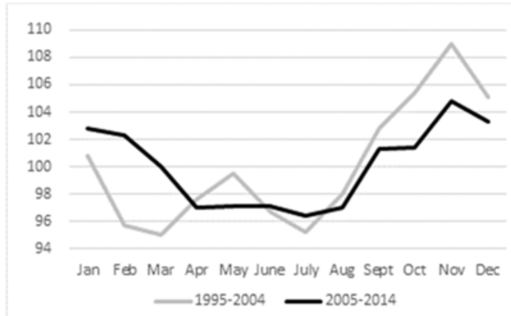
Zakari, S., L. Ying, and B. Song. (2014). Market integration and spatial price transmission in Niger grain markets. African Development Review, 26, 264-273.

Appendix A. Figures

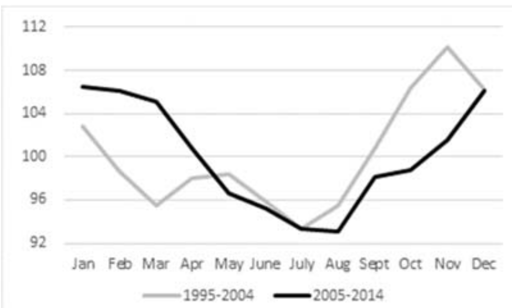
Figure A1: Seasonal price index during 1995-2004 and 2005-2014.



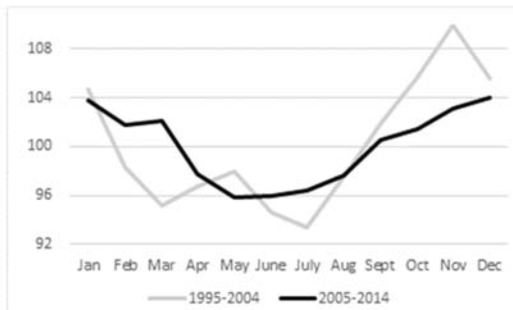
(a) Cascavel



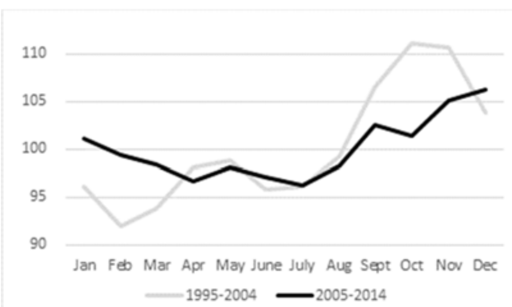
(b) Chapecó



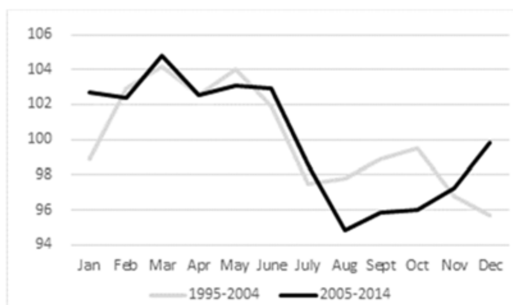
(a) Rio Verde



(b) Mogiana

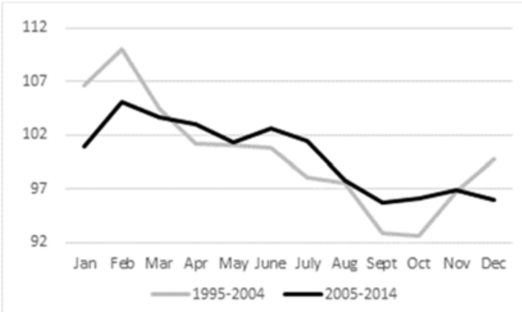


(a) BM&FBOVESPA

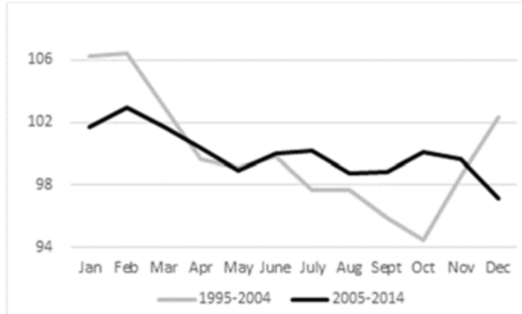


(b) CME

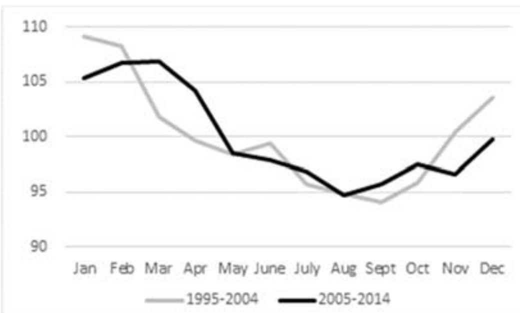
Figure A2: Seasonal BM&FBOVESPA basis index during 1995-2004 and 2005-2014.



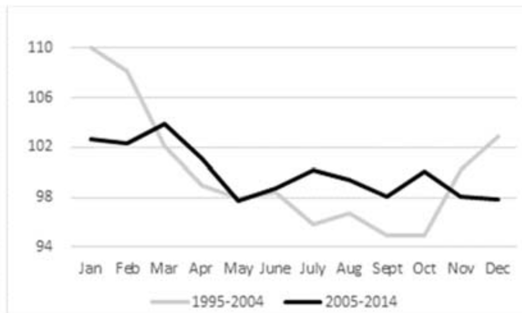
(a) Cascavel



(b) Chapecó

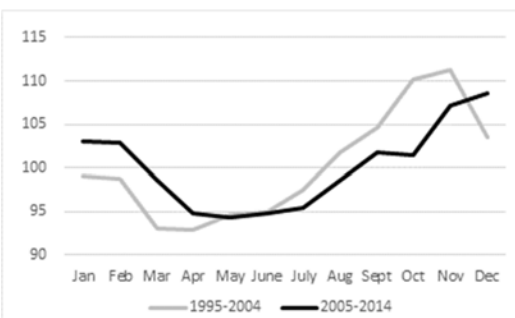


(c) Rio Verde

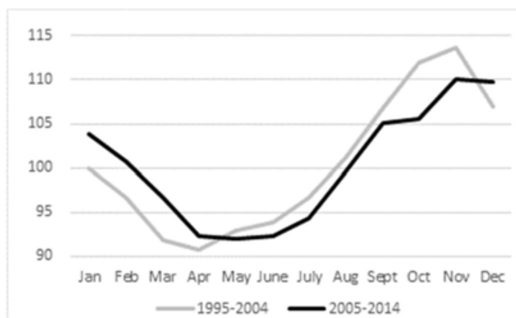


(d) Mogiana

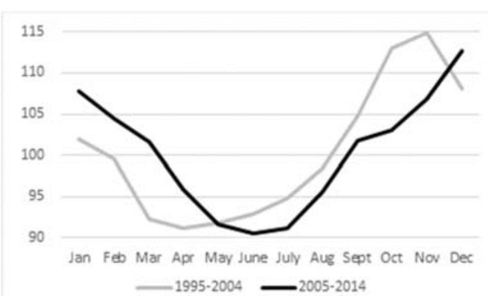
Figure A3: Seasonal CME basis index during 1995-2004 and 2005-2014.



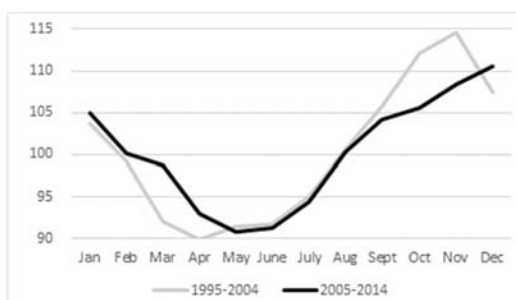
(a) Cascavel



(b) Chapecó



(c) Rio Verde



(d) Mogiana

Appendix B. Tables

Table B1: Unit root tests for daily corn log-prices during 1995-2004 and 2005-2014.

	Level Prices				1st Difference of Prices			
	With Trend		Without Trend		With Trend		Without Trend	
	ADF[(a)]	PP[(b)]	ADF[(a)]	PP[(b)]	ADF[(a)]	PP[(b)]	ADF[(a)]	PP[(b)]
1995-2004 period								
Cascavel	-2.09	-2.20	-2.09	-1.66	-13.39 *	-61.35 *	-13.38 *	-61.39 *
Chapecó	-2.29	-2.20	-2.29	-1.51	-12.49 *	-62.31 *	-12.49 *	-62.44 *
R.Verde	-2.36	-2.06	-2.36	-1.71	-10.69 *	-61.11 *	-10.66 *	-61.14 *
Mogiana	-2.46	-2.15	-2.46	-1.81	-13.09 *	-62.18 *	-13.07 *	-62.22 *
BM&F	-2.18	-2.45	-2.18	-1.50	-44.32 *	-44.47 *	-44.33 *	-44.48 *
CME	-2.02	-2.08	-2.02	-1.67	-44.00 *	-44.06 *	-44.00 *	-44.07 *
2005-2014 period								
Cascavel	-2.84	-2.82	-2.84	-2.37	-19.82 *	-41.53 *	-19.82 *	-41.53 *
Chapecó	-2.92	-2.57	-2.92	-2.04	-14.37 *	-51.32 *	-14.37 *	-51.34 *
R. Verde	-2.36	-2.81	-2.36	-2.44	-21.99 *	-52.41 *	-21.99 *	-52.41 *
Mogiana	-2.00	-2.55	-2.00	-2.22	-54.33 *	-54.60 *	-54.33 *	-54.61 *
BM&F	-2.90	-3.26	-2.90	-2.47	-44.35 *	-45.02 *	-44.36 *	-45.03 *
CME	-2.38	-2.38	-2.38	-1.76	-48.70 *	-48.71 *	-48.71 *	-48.72 *

[a] Unit root test developed by Dickey and Fuller (1981). The optimal lags selected in the test were based on the Schwartz criterion.
[b] Unit root test developed by Phillips and Perron (1988).
Note: *, ** and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table B2: Engle-Granger tests for cointegration between corn price pairs.

Price Pair	1995-2004	2005-2014
	CRADF	CRADF
Cascavel – CME	-2.76	-3.49 **
Chapecó – CME	-2.57	-3.49 **
R.Verde – CME	-2.51	-4.16 *
Mogiana – CME	-2.50	-3.72 **
BM&F – CME	-2.80	-3.79 **
Cascavel – BM&F	-5.03 *	-6.86 *
Chapecó – BM&F	-5.61 *	-6.61 *
R.Verde – BM&F	-4.37 *	-7.22 *
Mogiana – BM&F	-4.15 *	-7.59 *
CME – BM&F	-2.75	-3.67 **

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

Table B3: Johansen tests for cointegration between corn price pairs.

Price Pairs	**Null Hypothesis**	**1995-2004**				**2005-2014**			
		Max-Eigen Stat.		**Trace Stat.**		**Max-Eigen Stat.**		**Trace Stat.**	
Cascavel - CME	$r = 1$	15.32	**	18.11	**	16.65	**	19.56	**
	$r \leq 1$	2.79	***	2.79	***	2.90	***	2.90	***
Chapecó - CME	$r = 1$	13.02	***	15.39	***	14.33	**	17.52	**
	$r \leq 1$	2.38		2.38		3.18	***	3.18	***
R.Verde - CME	$r = 1$	12.16		14.73	***	15.48	**	19.20	**
	$r \leq 1$	2.57		2.57		3.72	***	3.72	***
Mogiana - CME	$r = 1$	10.19		13.00		16.10	**	19.82	*
	$r \leq 1$	2.81		2.81		3.71	***	3.71	**
BM&F - CME	$r = 1$	10.91		12.80		16.81	**	19.70	**
	$r \leq 1$	1.89		1.89		2.89	***	2.89	***
Cascavel - BM&F	$r = 1$	27.21	*	30.04	*	79.17	*	15.49	*
	$r \leq 1$	2.83	***	2.83	***	6.19	**	6.19	**
Chapecó - BM&F	$r = 1$	33.22	*	35.53	*	85.46	*	91.03	*
	$r \leq 1$	2.32		2.32		5.57	**	5.57	**
R.Verde - BM&F	$r = 1$	17.89	**	21.55	*	66.82	*	73.17	*
	$r \leq 1$	3.66	***	3.66	***	6.35	**	6.35	**
Mogiana - BM&F	$r = 1$	21.59	*	24.31	*	52.78	*	58.61	*
	$r \leq 1$	2.81	***	2.81	***	5.88	**	5.88	**
CME - BM&F	$r = 1$	10.91		12.81		16.81	**	19.70	**
	$r \leq 1$	1.89		1.89		2.89	***	2.89	***

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

Table B4: Error-correction model parameter estimates for Cascavel.

	Cascavel-CME		CME-Cascavel		Cascavel-BM&F		BM&F-Cascavel	
	ΔS_t 1995-2004	**ΔS_t 2005-2014**	**ΔF_t 1995-2004**	**ΔF_t 2005-2014**	**ΔS_t 1995-2004**	**ΔS_t 2005-2014**	**ΔF_t 1995-2004**	**ΔF_t 2005-2014**
C	0.0002	0,0001	0.0002	0.0003	0.0001	0.0001	0.0003	0.0001
Coint. Eq.	-0.0048 *	-0.0060 *	0.0022	0.0057	-0.0104 *	-0.0262 *	0.0188 *	0.0104 ***
ΔS_{t-1}	-0.1593 *	0.2045 *	0.0416	-0.0179 ***	-0.1286 *	0.1829 *	0.1094 **	0.0736 **
ΔS_{t-2}	0.1124 *	0.1390 *	-0.0083	-0.0770 **	0.1166 *	0.1159 *	0.0494	0.0389
ΔS_{t-3}	0.1797 *	0.0937 *	0.0362	0.1135	0.1312 *	0.0671 *	0.0333	0.0679 ***
ΔS_{t-4}	0.0913 *	0.0561 *	-0.0967 **	-0.0076	0.0613 *	0.0365 **	0.0976 **	
ΔS_{t-5}	0.0748 *		0.0067		0.0629 *		0.0996 **	
ΔS_{t-6}	0.0574 *		-0.0302		0.0794 *		0.0461	
ΔS_{t-7}	0.0607 *		0.0396		0.0502 **		0.0328	
ΔS_{t-8}	0.0428 **		0.0328		0.0254		0.0155	
ΔS_{t-9}	0.0214		0.1017 **					
ΔS_{t-10}	0.0106		0.0148					
ΔF_{t-1}	0.0171	0.0545 *	0.0998 *	0.0140	0.0194 ***	0.0676 *	-0.0005	0.0326
ΔF_{t-2}	0.0130	0.0437 *	-0.0184	-0.0170	0.0143	0.0326 *	0.0469 **	0.0984 *
ΔF_{t-3}	0.0344 *	0.0150	0.0076	0.0068	0.0198 ***	0.0188	0.0060	0.0124
ΔF_{t-4}	0.0087	0.0061	0.0121	0.0107	0.0344 *	0.0148	-0.0255	0.0248
ΔF_{t-5}	0.0083		0.0132		0.0101		0.0333	0.0063
ΔF_{t-6}	0.0016		0.0014		0.0117		0.0482 **	
ΔF_{t-7}	0.0061		-0.0116		0.0091		-0.0334	
ΔF_{t-8}	-0.0019		0.0394 ***		0.0111		0.0007	
ΔF_{t-9}	-0.0067		0.0421 **					
ΔF_{t-10}	-0.0041		-0.0448 **					
Wald F stat.	1.2967	6.3253 *	1.7263 ***	2.5856 ***	0.5504	4.1355 *	0.5674	0.2989

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

Table B5: Error-correction model parameter estimates for Chapecó.

	Chapecó-CME		CME-Chapecó		Chapecó-BM&F		BM&F-Chapecó	
	ΔS_t 1995-2004	ΔS_t 2005-2014	ΔF_t 1995-2004	ΔF_t 2005-2014	ΔS_t 1995-2004	ΔS_t 2005-2014	ΔF_t 1995-2004	ΔF_t 2005-2014
C	0.0002	0.0001	0.0002	0.0003	0.0001	0.0001	0.0003	0.0001
Coint. Eq.	-0.0052 *	-0.0053 *	0.0024	0.0075 ***	-0.0126 *	-0.0221 *	0.0235 *	0.0199 *
ΔS_{t-1}	-0.3137 *	0.0274	0.0501	0.0677	-0.1895 *	0.0107	0.1235 *	0.0932 **
ΔS_{t-2}	-0.0804 *	0.1429 *	0.0194	0.0814	-0.0413 ***	0.1316 *	0.0730 ***	0.1629 *
ΔS_{t-3}	0.1083 *	0.1204 *	-0.0355	0.1313 **	0.1370 *	0.1153 *	0.0355	0.1095 *
ΔS_{t-4}	0.1217 *	0.0856 *	-0.0320	0.0475	0.1005 *	0.0810 *	0.0361	0.0420
ΔS_{t-5}	0.0993 *	0.0703 *	-0.0798 *	-0.0789	0.0982 *		0.0793 **	
ΔS_{t-6}	0.1121 *	0.0627 *	0.0273	-0.0560	0.0680 *		0.0576	
ΔS_{t-7}	0.1580 *	-0.0151	0.0313	0.0344	0.0647 *		0.1261 *	
ΔS_{t-8}	0.0118		0.0457		0.0613 *		-0.0427	
ΔS_{t-9}	0.0572 *		-0.0214					
ΔS_{t-10}	0.0326		0.0039					
ΔF_{t-1}	0.0255 ***	0.0358 *	0.0983 *	0.0089	0.0272 **	0.0542 *	0.0024	0.0968 *
ΔF_{t-2}	0.0119	0.0287 *	-0.0148	-0.0229	0.0248 ***	0.0237 **	0.0476 **	0.0092
ΔF_{t-3}	0.0158	0.0191 **	0.0071	-0.0028	0.0186	0.0141	0.0078	0.0199
ΔF_{t-4}	0.0045	0.0132 ***	0.0190	0.0028	0.0373 *	0.0047	-0.0237	0.0052
ΔF_{t-5}	0.0176	0.0139 ***	0.0098	-0.0245	0.0280 **		0.0322	
ΔF_{t-6}	-0.0010	0.0147 ***	0.0058	-0.0354 ***	0.0192		0.0440 ***	
ΔF_{t-7}	0.0067	0.0164 **	-0.0163	0.0105	-0.0200		-0.0331	
ΔF_{t-8}	-0.0026		0.0432 **		0.0178		0.0062	
ΔF_{t-9}	0.0069		0.0390 ***					
ΔF_{t-10}	0.0088		-0.0397 ***					
Wald F stat.	0.3761	1.3247	1.6860 ***	1.5899	1.7262 ***	4.7045 *	2.1077 **	1.2786

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

Table B6: Error-correction model parameter estimates for Rio Verde.

	RV-CME	CME-RV	RV-BM&F		BM&F-RV	
	ΔS_t 2005-2014	**ΔF_t 2005-2014**	**ΔS_t 1995-2004**	**ΔS_t 2005-2014**	**ΔF_t 1995-2004**	**ΔF_t 2005-2014**
C	0.0001	0.0003	0.0001	0.0002	0.0003	0.0001
Coint. Eq.	-0.0085 *	0.0084 **	-0.0113 *	-0.0376 *	0.0086 **	0.0092 ***
ΔS_{t-1}	-0.0644 *	-0.0022	-0.1669 *	-0.0764 *	0.0561 ***	0.0013
ΔS_{t-2}	0.0176	0.0216	-0.0592 *	0.0049	0.0531 ***	0.0228
ΔS_{t-3}	0.0425 **	0.0490 ***	0.0209	0.0276	0.0577 ***	0.0187
ΔS_{t-4}	0.0474 **	-0.0069	0.0417 ***	0.0303	0.0403	-0.0006
ΔS_{t-5}	-0.0897 *	-0.0072	0.0741 *	-0.1059 *	0.0734 **	0.0189
ΔS_{t-6}	0.0185	0.0068	0.0926 *	-0.0017	0.1386 *	-0.0024
ΔS_{t-7}	0.0698 *	0.0270	0.0978 *	0.0512 *	0.0550 ***	0.0138
ΔS_{t-8}	0.0446 **	0.0047	0.0496 **	0.0289	0.0555 ***	-0.0046
ΔS_{t-9}	0.0594 *	0.0546 **	0.0629 *	0.0442 **	-0.0429	-0.0055
ΔS_{t-10}	0.0170	0.0136	0.0268	0.0055	-0.0805 *	0.0115
ΔS_{t-11}			0.0419 ***		0.0028	
ΔS_{t-12}			0.0570 **		0.0128	
ΔS_{t-13}			0.0071		-0.0008	
ΔF_{t-1}	0.0082	0.0105	0.0099	0.0336	-0.0090	0.1081 *
ΔF_{t-2}	0.0356 **	-0.0216	0.0433 **	0.0118	0.0441 ***	0.0234
ΔF_{t-3}	0.0499 *	-0.0001	0.0232	-0.0018	0.0047	0.0384 ***
ΔF_{t-4}	0.0390 **	0.0107	0.0223	0.0131	-0.0263	0.0203
ΔF_{t-5}	0.0310 **	-0.0174	0.0219	0.0399 ***	0.0286	0.0332
ΔF_{t-6}	0.0315 **	-0.0347 ***	-0.0075	0.0440 **	0.0429 ***	0.0099
ΔF_{t-7}	0.0216	0.0106	0.0115	0.0269	-0.0350	-0.0180
ΔF_{t-8}	0.0375 **	-0.0066	0.0250	0.0200	-0.0013	0.0317
ΔF_{t-9}	-0.0097	0.0010	0.0266	-0.0251	-0.0089	-0.0244
ΔF_{t-10}	0.0206	0.0168	-0.0019	0.0436 **	0.0012	0.0651 *
ΔF_{t-11}			0.0400 **		0.0006	
ΔF_{t-12}			0.0363 **		-0.0013	
ΔF_{t-13}			-0.0089		-0.0128	
Wald F stat.	1.2411	0.7418	0.9923	1.1686	2.4686 *	3.3158 *

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

Table B7: Error-correction model parameter estimates for Mogiana.

	Mogi-CME	CME-Mogi	Mogi-BM&F		BM&F-Mogi	
	ΔS_t 2005-2014	ΔF_t 2005-2014	ΔS_t 1995-2004	ΔS_t 2005-2014	ΔF_t 1995-2004	ΔF_t 2005-2014
C	0.0001	0.0003	0.0001	0.0002	0.0004	0.0001
Coint. Eq.	-0.0083 *	0.0074 **	-0.0081 *	-0.0357 *	0.0064	0.0130 **
ΔS_{t-1}	-0.1273 *	0.0470 ***	-0.0460 **	-0.1707 *	0.1084 **	0.0210
ΔS_{t-2}	-0.0567 *	0.0160	0.0580 **	-0.1062 *	-0.0095	0.0242
ΔS_{t-3}	-0.0253	0.0186	0.1120 *	-0.0755 *	0.0653	0.0205
ΔS_{t-4}	0.0149	0.0017	0.0800 *	-0.0357 ***	0.0448	0.0082
ΔS_{t-5}	0.0636 *	0.0157	0.1011 *	0.0156	0.0776 ***	0.0141
ΔS_{t-6}	0.0670 *	0.0149	0.0450 ***	0.0241	0.0117	0.0115
ΔS_{t-7}	0.0480 **	0.0171	0.0343	0.0087	0.0131	0.0040
ΔS_{t-8}	0.0391 ***	0.0319	0.0493 **	0.0052	0.0713 ***	-0.0001
ΔS_{t-9}	0.0758 *	0.0104	0.0395 ***	0.0427 **	0.0068	-0.0045
ΔS_{t-10}	0.0376 ***	-0.0586 **	0.0027	0.0097	-0.0242	-0.0437 **
ΔS_{t-11}	0.0148	0.0016	-0.0341	-0.0076	0.0256	0.0244
ΔS_{t-12}	0.0756 *	-0.0134		0.0550 *		-0.0061
ΔS_{t-13}	-0.0020	-0.0019		-0.0133		-0.0131
ΔF_{t-1}	0.0035	0.0101	0.0071	0.0501 **	-0.0055	0.1124 *
ΔF_{t-2}	0.0401 *	-0.0194	0.0246 **	0.0875 *	0.0444 ***	0.0271
ΔF_{t-3}	0.0206	0.0009	0.0163	0.0527 **	-0.0001	0.0354 ***
ΔF_{t-4}	0.0396 **	0.0121	0.0254	0.0657 *	-0.0306	0.0215
ΔF_{t-5}	0.0210	-0.0173	0.0313 **	0.0296	0.0290	0.0311
ΔF_{t-6}	0.0169	-0.0340 ***	0.0162	0.0248	0.0449 ***	0.0099
ΔF_{t-7}	0.0246	0.0115	0.0261 **	0.0261	-0.0386 ***	-0.0164
ΔF_{t-8}	0.0389 **	-0.0065	0.0253 **	0.0346 ***	-0.0062	0.0325
ΔF_{t-9}	0.0150	0.0032	-0.0038	0.0277	-0.0091	-0.0233
ΔF_{t-10}	0.0123	0.0186	0.0187	-0.0113	0.0026	0.0659 *
ΔF_{t-11}	0.0063	-0.0099	0.0173	0.0305	-0.0060	0.0190
ΔF_{t-12}	0.0287	-0.0394 ***		0.0413 **		-0.0094
ΔF_{t-13}	0.0212	-0.0118		0.0530 *		0.0521 **
Wald F stat.	0.6032	0.8051	0.6964	1.5220	0.9858	0.7780

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

Table B8: Error-correction model parameter estimates for BM&FBOVESPA and CME.

	BMF-CME	CME-BMF
	2005-2014 ΔBMF_t	2005-2014 ΔCME_t
C	0.0004	0.0003
Coint. Eq.	-0.0073 *	0.0014
ΔBMF_{t-1}	-0.0004	-0.0221
ΔBMF_{t-2}	0.0509 **	0.0067
ΔCME_{t-1}	0.0786 *	0.0825 *
ΔCME_{t-2}	-0.0179	0.0059
Wald F stat.	7.8646 *	0.8917

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