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by

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This study investigates the relationship between cash and futures prices in the Brazilian agricultural market, focusing on the effects of trading activity on the price discovery mechanism of futures markets. The results are mixed, but several points begin to emerge. In general, higher trading activity is linked to the presence of long-run equilibrium relationships between cash and futures prices. In these cases, futures prices appear to play a more dominant role in the pricing process. In more lightly traded markets, neither long-run relationships nor short-run leads and lags can be found. Where short-run interactions exist, they are simultaneous in nature but weak. Overall, our findings suggest that the level of market activity necessary to develop interactive cash and futures markets is surprisingly small.

Keywords: price discovery, futures market, thin markets

INTRODUCTION

Price discovery is an important function performed by futures markets. Effective futures markets should generate prices that express consciously-formed opinions on cash prices in the future, and should transmit that information throughout the marketing system in a timely manner (Working, 1942; Tomek, 1980). Because of its importance, the effectiveness of futures markets in performing this function has been investigated extensively in the literature. The more recent studies have shown that futures prices play a dominant role in the discovery and transmission of price information. In the absence of effective price discovery, researchers have conjectured that limited trading volume associated with thin markets has adversely affected price discovery.

It is usually assumed that thin markets are inefficient and exhibit extensive price variability, i.e., low trading volume implies a relatively small amount of information and perhaps information of low quality (Tomek, 1980; Carter, 1989). The intuitive idea is that this poor flow of information might affect the price discovery function, but the extent to which trading activity affects the relationship between cash and futures has not been systematically addressed in the literature. The empirical work on price discovery that has indirectly discussed market performance in terms of trading volume provides mixed evidence regarding how price transmission is affected by trading activity (Garbade and Silber, 1983; Carter, 1989; Maynard et al., 2001; Yang et al., 2001).

The analysis of price discovery in agricultural futures markets has been primarily limited to U.S. or internationally traded commodity markets. However, over the last 15 years, the number of exchanges and agricultural future contracts that are traded in developing countries has grown. In this context, it is somewhat surprising that little research can be found that examines the effectiveness of price discovery of agricultural futures markets in the developing world, where thinness in market trading may be highly prevalent and have a significant impact on the transmission of market information.

The purpose of this paper is to analyze the effects of futures market trading activity on the price discovery mechanism of agricultural futures markets in Brazil. The Garbade-Silber framework provides the conceptual basis for the analysis, and cointegration and error correction models adopted in most recent literature are used to determine the relationships between cash and futures prices. The work focuses on Brazilian markets, but U.S. agricultural markets are also discussed for comparison.

Brazilian agricultural futures markets provide an informative case for examining price discovery in thinly traded markets in the developing world. Although futures trading in Brazil is among the largest in the world, the agricultural contracts are only responsible for approximately 1% of the total trading volume in the Brazilian Mercantile & Futures Exchange (BM&F). There are currently nine active agricultural contracts in Brazil: coffee (arabica and robusta), live cattle, feeder cattle, fuel alcohol (anhydrous), corn, sugar, soybeans, and cotton[1]. Some contracts have traded for numerous years (arabica coffee and sugar), while others have been temporarily stopped and/or modified in attempts to increase volume (corn and live cattle). Further, trading was stopped in two contracts (cotton and soybeans) during the period of analysis.

The volume of contracts traded on the BM&F varies by the commodity, but is much less than that found in exchanges in the developed world. In terms of volume, arabica coffee is by far the most liquid contract, followed by live cattle and fuel alcohol. The trading volume of the other contracts is very small, and sometimes on given days no transactions occur. For example, in the corn futures market, 96,500 million bushels were traded on the Chicago Board of Trade in 2003, whereas roughly 3 million bushels were traded on the BM&F. In the coffee futures market, which is the most liquid in Brazil, approximately 6 billion pounds were traded on the BM&F in 2003, while 120 billion pounds were traded on the New York Board of Trade (NYBOT)[2].

Three groups of agents should be particularly interested in understanding better the behavior of agricultural futures markets under thin trading, particularly in developing countries. Local hedgers/traders in these countries would be able to benefit from a more systematic and extensive research that could tell them what to expect when trading in these markets. Another group is formed by financial institutions looking for new opportunities to diversify their portfolios, and agricultural contracts traded in developing countries seem to be reasonable alternatives. There is an extensive literature showing the benefits of this kind of strategy, and interesting work can be found in Peters and Warwick (1997). Finally, regulators and policy makers must have accurate information about the trading behavior under low liquidity in order to design and regulate these markets.

In the next section we discuss the literature, and then present the methods used in the paper. We then present the results, our interpretations, conclusions.

[1] Data availability limited the analysis to six of the nine commodities (arabica coffee, corn, cotton, live cattle, soybeans, and sugar).

[2] Trading activity data were obtained in www.bmf.com.br, www.cbot.com, and www.nybot.com

REVIEW OF LITERATURE

Numerous studies on price discovery in agricultural futures markets have been conducted, but none has focused explicitly on how trading activity affects price discovery. Moreover, almost no work can be found on price discovery in developing countries, where market thinness is prevalent and might play an important role in the transmission of market information.

The literature on price discovery is extensive, and our discussion mainly focuses on more current works. Most recent studies of price discovery have used the Garbade-Silber framework along with cointegration and error correction models to determine the relationship between futures and cash prices. Garbade and Silber (1983) developed a model of simultaneous price dynamics in which changes in futures and spot prices on *t* are a function of the basis on *t-1*. They used the model to examine the characteristics of daily spot and futures prices for four storable agricultural commodities (wheat, corn, oats and orange juice)[3]. For wheat, corn and orange juice, they found that futures markets dominate cash markets. In contrast, they found that the pricing of oats is more evenly divided between cash and futures markets which led them to hypothesize that market size and liquidity might affect the price discovery role of futures markets.

Following Garbade and Silber, Oellermann et al. (1989) and Schroeder and Goodwin (1991) studied the price discovery mechanism for livestock in the periods 1979-1986 and 1975-1989, respectively. Both studies tested the extent of short-run price discovery, and found that information tends to be discovered first in futures markets and then transferred to cash markets. Both studies also adopted other procedures to verify their results in the long run. Oellerman et al. tested Granger-causality for the once-differenced prices and found that lagged changes in futures prices are statistically significant in explaining current changes in cash prices, but that lagged cash prices had little effect on futures prices. Schroeder and Goodwin used cointegration procedures to verify that daily cash and futures prices for live hogs didn't share a long-run relationship. They found a short-run relationship between cash and futures prices based on Garbade-Silber model, but failed to find a long-run relationship using either Granger-causality or cointegration procedures.

A slightly different approach was adopted by Koontz et al. (1990) to study price discovery in the livestock market. Using weekly U.S. cash and futures prices from 1973 through 1984, they investigated the spatial nature of the price discovery process. They adopted the procedure proposed by Geweke (1982) to generate causality tests and measures of interaction between major cash markets, and between cash and futures markets. In general, their findings suggested that there was a high degree of interaction between cash and futures prices. They also identified that the pricing relationships changed over time, reflecting changes in the industry which suggests that the price discovery process is dynamic and is influenced by the structure of the underlying markets.

Extending previous work, Yang et al. (2001) examined the price discovery performance of futures markets for storable (corn, oats, soybean, wheat, cotton, and pork bellies) and non-storable (hogs, live cattle, feeder cattle) commodities using daily data from 1992 to 1998. Based

[3] They also analyzed copper, gold, and silver, but we focus on the agricultural commodities.

on cointegration procedures and error correction models, their results showed that, in general, asset storability does not affect the price discovery function, although it may affect the magnitude of bias of futures markets' estimates. Moreover, the general conclusion in terms of discovery was that futures markets can be used as a price discovery tool in all of these markets. Although they didn't distinguish between thinly and heavily traded markets, the large differences in trading activity of the markets analyzed in their study suggests that it had little effect.

A few studies have examined specifically thinly traded markets. Brockman and Tse (1995) investigated the price discovery mechanism in four agricultural commodities markets in Canada (canola, barley, oats, and wheat). Using daily prices between 1978 and 1994, the four series were found to be cointegrated. Then they examined the significance of the error correction term in the error correction representation, finding for all commodities that this term was significant only in explaining cash prices. Their results suggested that price discovery was mainly performed in the futures market which was further confirmed using procedures proposed by Hasbrouck (1995).

Fortenberry and Zapata (1997) evaluated price linkages between futures and cash markets in the U.S. for cheddar cheese, diammonium phosphate (DAP) and anhydrous ammonia (NH3). For all three markets, they focused on the period immediately after the contracts were launched, using daily prices for DAP, and weekly prices for cheddar cheese and NH3[4]. Based on cointegration techniques, they found no evidence that futures and spot prices of cheddar cheese shared a long-run relationship, but did find the presence of cointegration for the DAP and NH3 markets even when examining only the first year of trading. The authors implicitly argue that even newly formed and thinly traded futures markets can be effective price discovery mechanisms.

Maynard et al. (2001) evaluated the performance of the thinly traded shrimp futures contract as a price discovery tool. Using weekly data from November 1994 through June 1998, thirteen varieties of shrimp in the cash market and two varieties in the futures market (traded at the Minneapolis Grain Exchange) were studied. They found that only one variety in the cash market was cointegrated with one of the futures contracts. All the other varieties in the cash markets failed to be cointegrated with any of the futures prices, which indicates that those prices showed no long-run relationship during the period 1994-1998. Further short-run analysis using Sims' two-sided distributed lag model provided evidence of only a weak relationships among spot and futures prices. They concluded that shrimp futures prices failed as a price discovery mechanism, and they identified that the lack of liquidity in this market might have been the cause of this deficiency.

In sum, the recent studies of price discovery tend to show that futures prices play a major role in the pricing process. But when the focus turns to thin markets, the results are mixed. Several papers suggest that the price discovery function might be well performed even in thinly traded markets (DAP and oats, for example). Nevertheless, empirical evidence also showed that some thinly traded contracts have failed to provide a price discovery mechanism. In the following sections we will discuss the procedures used to analyze price discovery in Brazil, and

[4] The cheddar cheese market had some unique characteristics during the period analyzed, i.e., the cash market functioned only once a week, and trading sessions in both cash and futures markets were quite short.

the results of this analysis.

RESEARCH METHODS

We investigate the price discovery process between agricultural futures markets and cash markets in Brazil using Johannsen and error-correction methods in the presence of cointegration. In its absence, we use the VAR procedures discussed by Geweke (1982) and Koontz et al. (1990). For storable commodities, following Garbade and Silber (1983) and Yang et al. (2001), we use a cash-equivalent price which is based on a no arbitrage assumption. The assumption of no arbitrage implies that the following relationship should hold: $F_{T/t} = \left(C_t + U\right) \cdot e^{r(T-t)}$, where $F_{T/t}$ is the futures price at time *t* of a contract expiring at time *T*, C_t is the cash price at time *t*, *U* is the present value of all storage costs other than interest rate, and *r* is the daily interest rate. Assuming that *U* is negligible over a reasonable period (Yang et al, 2001), we express the futures price as a cash-equivalent futures price. We follow this procedure because it best reflects the opportunity cost of holding positions in the cash market.[5] For the non-storable commodity, we simply use cash and futures prices.

We begin the empirical process by checking for stationarity of the series using the Augmented Dickey-Fuller (ADF) test, Pantula's procedure, and specifying the lag structure with the Schwarz Bayesian Criteria (SBC). The null hypothesis for this test is that there is a unit root in the series (i.e., the series is nonstationary), while the alternative hypothesis is that there is no unit root. If cash and futures prices are found to be integrated of the same order, cointegration tests using the Johansen procedure are performed. The basic idea is that futures and cash prices can share a long-run relationship if they are found to be cointegrated, i.e., if there is a linear combination of them which is stationary.

Provided the cash and futures prices are cointegrated, they are expected to return to the long-run equilibrium after possible short-run deviations. The cointegrated variables can be represented by an error correction model, in which the "error" refers to the disequilibrium responses. Since the residual $\{\hat{e}_{t-1}\}$ from $F_{t-1} = a + b \cdot C_{t-1} + e_{t-1}$ represents an estimation of the deviation from the long-run equilibrium in period *t-1*, it can be used in the error correction term in the model:

$$\Delta F_t = a + \Pi \cdot e_{t-1} + \sum_{i=1}^{q} b_i \Delta F_{t-i} + \sum_{j=1}^{q} g_j \Delta C_{t-j} + e_t \qquad (1)$$

$$\Delta C_t = a' + \Pi' \cdot e_{t-1} + \sum_{i=1}^{q} b'_i \Delta F_{t-i} + \sum_{j=1}^{q} g'_j \Delta C_{t-j} + e'_t \qquad (2)$$

where *F* and *C* stand for cash-equivalent futures prices and cash prices, respectively. Since each equation contains the same number of lagged regressors[6], OLS estimation can be used efficiently. The Breusch-Pagan and ARCH-LM tests for heteroskedasticity are performed, and if there is evidence of non-constant variance in the residuals, GARCH and White's procedures are

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[5] For storable commodities, the analysis was also performed using cash and futures prices including the interest charge as an exogenous variable. The results were practically identical to those reported in the text.

[6] The number of lags is determined by the SBC.

used.

In order to test for causality in the system represented by equations (1) and (2), the Wald test is used. The null hypothesis of non-causality is given by $H_0 : \Pi = g_1 = ... = g_q = 0$ in equation (1) and $H_0 : \Pi' = b_1' = ... = b_q' = 0$ in equation (2), and the test statistic follows a chi-square distribution with degrees of freedom equal to the number of restrictions.

In the absence of cointegration between futures and cash prices, short-run interactions between the markets can be assessed. In order to test for Granger causality, we follow the procedure suggested by Geweke (1982) and adopted by Koontz et al. (1990). Based on the system of equations,

$$\Delta F_t = a_F + \sum_{i=1}^{q} \breve{b}_i \Delta F_{t-i} + n_t \tag{3}$$

$$\Delta C_t = a_C + \sum_{j=1}^{q} \breve{g}_j \Delta C_{t-j} + n_t' \tag{4}$$

$$\Delta F_t = a + \sum_{i=1}^{q} b_i \Delta F_{t-i} + \sum_{j=1}^{q} g_j \Delta C_{t-j} + e_t \tag{5}$$

$$\Delta C_t = a' + \sum_{i=1}^{q} b_i' \Delta F_{t-i} + \sum_{j=1}^{q} g_j' \Delta C_{t-j} + e_t' \tag{6}$$

three measures of linear dependence between cash and futures prices are defined:

$$P_{F \to C} = \ln \left[\frac{Var(n_t')}{Var(e_t')} \right] \tag{7}$$

$$P_{C \to F} = \ln \left[\frac{Var(n_t)}{Var(e_t)} \right] \tag{8}$$

$$P_{C \cdot F} = \ln \left[\frac{Var(e_t) \cdot Var(e_t')}{|Y|} \right] \tag{9}$$

where $|Y|$ is the determinant of the covariance matrix of e_t and e_t'. Expression (7) measures the strength of linear feedback from futures prices to cash prices, expression (8) does the same from cash prices to futures prices, and expression (9) measures the instantaneous association between both price series.

A more intuitive notion of this measure can be developed by noting the following monotonic transformation of *P*, given by Pierce (1982):

$$S_{F \to C} = 1 - \exp\left(-P_{F \to C}\right) \tag{10}$$

$$S_{C \to F} = 1 - \exp\left(-P_{C \to F}\right) \tag{11}$$

$$S_{C \cdot F} = 1 - \exp\left(-P_{C \cdot F}\right) \tag{12}$$

where *S* measures the percentage of the variation in futures (cash) prices which is explained by cash (futures) prices.

DATA

The data consist of Brazilian futures and spot prices for coffee (arabica), corn, cotton, live cattle, soybeans, and sugar. The futures prices were obtained from the Brazilian Mercantile & Futures Exchange (BM&F), and are the daily closing prices. All futures prices are quoted in US$, except for corn and live cattle starting in 2001 when the exchange began to trade them in the local currency, *Reais*. The futures prices were taken from the nearby contract, and were rolled over to the next contract on the first day of the delivery month. The spot prices were also obtained from the BM&F, and reflect cash markets at delivery points. The interest rate used to calculate the cash-equivalent futures price was the 3-month Treasury bill rate.

The sample period used in the analysis varies for each commodity based on the availability of data and the characteristics of the contracts (Table 1). A change in the Brazilian exchange rate policy in January 1999 caused all the series to drop sharply during that month. Consequently, all series were divided into a period before January 1999, and after this change in government policy. The coffee price series was only divided into these two periods, but the price series for the other commodities were further segmented to reflect the following changes in their contracts:

(a) The corn futures contract stopped trading in February 2001, but was reinitiated in October 2001 with prices quoted in the local currency, *Reais;*
(b) The cotton contract stopped trading in December 1998[7];
(c) The live cattle contract began to be traded in the local currency, *Reais*, on the first trading day 2001;
(d) The soybean contract stopped trading in April 2001[7];
(e) Delivery specifications were changed in the sugar contract resulting in a structural break in the cash price series in 1997.

As a final point, although these markets were thinly traded, not many non-trading days were observed in the sample. The most active contracts – coffee and live cattle – were traded every day. For the other contracts, only a small fraction of the sample corresponded to days with no trades except for soybeans which were not traded approximately 14% of the time.

RESULTS

The first step is to test the price series for stationarity using the Augmented Dickey-Fuller (ADF) test under the null hypothesis of existence of unit root. The results of the ADF test[8] indicate that all price series are integrated of order 1 in all time periods at the 5% significance level, i.e., they are non-stationary in levels but stationary in first differences. Given that all price series are integrated of the same order, it is possible that futures and cash prices are also cointegrated.

The results of trace tests are reported in Table 3 and Table 4, and show that: (i) no

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[7] The contract was modified and trading was recently reinitiated.
[8] These results are not reported for purpose of brevity but are available from the authors. The Phillips-Perron test was also performed yielding similar results as the ADF test

cointegration can be found for cotton, corn, and soybeans for any of the time periods analyzed; (ii) a cointegration relationship can be found for live cattle and sugar in 2 out of 3 periods; and (iii) coffee prices are cointegrated in all periods.

Error correction models are estimated for the markets where cash and futures prices are cointegrated. The lead-lag relations between futures and cash prices can be analyzed by testing the error correction term and the lagged changes in prices[9] for significance. For almost all cases reported in Table 5, the hypothesis that the estimated coefficient of the error correction term is equal to zero cannot be rejected when the change in futures prices is the dependent variable, whereas it is rejected when the change in cash prices is the dependent variable. The only exception is found in the live cattle market during the 1996-1998 period, when the error correction term is significant in both cases. Thus, there is evidence that when a long-run relationship between futures and cash prices exists the adjustment towards the equilibrium is generally made by the cash prices. Regarding the influence on changes in futures (cash) prices from lagged changes in cash (futures) prices, the results are mixed (Table 5). In most cases, bivariate short-run causality existed in both directions– i.e. lagged cash prices affecting futures prices and lagged futures prices affecting cash prices – or no effect at all. The two exceptions showed contrasting results: (i) for coffee in the second period, lagged cash prices don't affect futures prices, but lagged futures price affect cash prices, and (ii) for live cattle in the first period, lagged cash prices affect futures prices, but lagged futures prices have no effect on cash prices.

For the cases in which no cointegration was found between futures and cash prices, vector autoregressive models were estimated and feedback relationships between prices were assessed procedure suggested by Geweke (1982). The results indicated the absence of lagged feedback for any market in any time period (Table 6). However, the measure of instantaneous association was found to be significant but small for cotton, live cattle, soybean, and corn (but only in one out of three periods). This evidence suggests that these markets interact weakly in the short run without establishing lead-lag relationships.

SUMMARY AND CONCLUSIONS

The findings of empirical work are summarized in Table 7 along with the daily average trading volume and number of trades. In general, it appears that the more actively traded contracts – coffee and live cattle – are more likely to show a long-run relationship between futures and cash prices. In the presence of cointegration, futures prices play the dominant role in the long-run price discovery process. In the absence of cointegration, no lead-lag relationships in the short run exist, but there is evidence of weak instantaneous interactions between futures and cash prices.

The findings that the coffee contract - the most actively traded contract in Brazilian agricultural futures markets (the average number of trades and volume per trade also have increased over time) – provides evidence of a long-run relationship between futures and cash prices with the futures market playing the more dominant role in the pricing process should not

[9] When the change in futures (cash) price is the dependent variable, the lagged changes in cash (futures) prices are tested for significance.

be surprising. Coffee is by far the most liquid contract traded in Brazil, and is one of the oldest contracts listed in the Brazilian Mercantile & Futures Exchange (BM&F). This commodity has represented one of the largest and most important sectors of Brazilian agriculture for the last 100 years, and traders on the exchange should understand how the market functions and respond quickly to changes in information. Moreover, there is an active international market for coffee, and Brazil also is a major player in this market.

The live cattle market also appears to be a rather interactive with relatively high trading activity that has fluctuated to some degree. Live cattle is one of the largest and most important sectors of Brazilian agriculture. While the market is primarily domestic in nature, firms have recently begun to increase the participation in the international market for processed meat products. Except for the 2^{nd} period where no long-run relationship existed and the average of number of trades declined by about 50%, the cash and futures markets interact considerably in a long-run context with the futures market becoming more dominant in the most recent period. There also appears to be a high level of interaction between the short-run movements in cash and futures. The relatively high degree of interaction is consistent with Koontz et al.'s findings for the U.S. live cattle market.

A somewhat surprising result is that the thinly traded sugar contract, similar to the more active coffee and live cattle contracts, demonstrated some degree of cointegration with futures prices playing the dominant role. Further, in the most recent period, short-run cash and futures interactions have increased along the trading activity. Part of the explanation for the degree of interaction even in the absence of high trading activity maybe the presence of a rather highly concentrated cash market structure where relatively few firms are actively involved in processing sugar and domestic alcohol. These processors actively take market positions to hedge against adverse price movements.

In contrast to these three markets, the lightly-traded corn contract shows almost no interaction between futures and cash prices. There is evidence of an instantaneous relationship between cash and futures in the 2^{nd} period, but the correlation coefficient although statistically significant is quite close to zero. While production is relatively large when compared to other commodities in Brazil, the domestic consumption also is quite large, which implies that international trade plays only a minor role in price formation. The domestic nature of the market may be one reason to explain the low trading volume and the lack of relationship between prices.

Finally, the two contracts which stopped trading – cotton and soybeans – showed small volume and no long-run relationship during the sample period. The short-term interactions that existed were simultaneous in nature but weak. In the case of cotton, the absence a strong relationship between futures and cash prices can be explained by the severe crisis and decline in the sector during the 1990's. A sharp reduction of import tariffs, together with an economic policy based on an over-valued exchange rate, caused a large increase in the imports of cotton, fibers and textile products. The Brazilian cotton sector was just unable to compete with the much cheaper imported products, and the industry began to shrink. Moreover, domestic firms began to take advantage of subsidized interest rates to import cotton whose quality and fiber differed from that of the existing cotton contract.

The case for the Brazilian soybean market is rather different. This market has lately been one of the most important and rapid growing sectors in Brazilian agriculture. The substantial increase in production and exports in recent years has made Brazil a major player in the international market, but soybean futures trading in Brazil has never expanded. In all likelihood, most processors operating in Brazil, who in large part export the processed oil and meal, use the futures contracts traded in the soybean complex on Chicago Board of Trade to establish their crush margins and hedge their export activities. In this case, the U.S. futures markets should play a major role in the pricing process of the Brazilian soybeans as both cash and futures prices in Brazil should be influenced by U.S. prices. However, limited trading volume appears to have reduced the degree of interaction between Brazilian cash and futures prices.

In sum, although the results in terms of price discovery are somewhat mixed, several points emerge with respect to the affect of trading activity and the price discovery process. Higher trading volume is linked to the presence of long-run equilibrium relationships between cash and futures prices as demonstrated in the live cattle and coffee markets. In these cases, the futures market appears to play the more dominant role in the price discovery process. In the lightly traded markets (i.e., corn, cotton, soybeans), no long-run relationship exists, and the short-run interactions found were simultaneous in nature and weak. For the sugar contract, while it is clear that the concentration in the cash market has an influence, it appears that trading activity during the last period reached a sufficient level to permit a more effective transmission of price information. Overall, our findings suggest that the level of trading activity necessary to promote the transmission of price information between the cash and futures markets is remarkably small.

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Table 1: Sample periods for each commodity

	1st period	2nd period	3rd period
Coffee (arabica)	6/23/97 – 12/30/98	2/1/99 – 10/6/03	-
# trading days	380	1,162	
Corn	11/29/96 – 12/30/98	2/1/99 – 2/28/01	10/26/01 – 10/31/03
# trading days	515	514	501
Cotton	11/22/96 – 12/30/98	-	-
# trading days	520		
Live cattle	1/8/96 – 12/30/98	2/1/99 – 12/28/00	1/2/01 – 10/31/03
# trading days	739	475	705
Soybeans	10/31/95 – 5/29/98	2/1/99 – 4/30/01	-
# trading days	637	556	
Sugar	10/31/95 – 4/14/97	4/15/97 – 12/30/98	2/1/99 – 10/31/03
# trading days	357	426	1,177

Table 2: Contract specifications

	Price quotation	Contract size
Coffee (arabica)	US$ per 60-net kilogram bag to two decimal places	100 bags weighing 60-net kilograms each
Corn	R$ per 60-net kilograms to two decimal places	27 metric tons, each one weighing 60 net kilograms
Cotton	Cents of US$ per pound to two decimal places	28,108.65 pounds, or 12,750 kilograms
Live cattle	R$ per unit of 15 kilograms to two decimal places	330 units of 15 kilograms
Soybeans	US$ per metric ton to two decimal places (free from any taxes or charges)	100 metric tons of soybeans in bulk
Sugar	US$ per 50-net kilogram bag to two decimal places (free of any charge)	270 bags of 50 net kilograms each

Table 3: Trace tests for futures and cash prices – coffee, corn, and cotton

	l_{trace}	Critical value (5%)	
Coffee			
06/97 – 12/98 (1 lag)			
$r \leq 0$	22.881	12.53	Cointegration
$r \leq 1$	0.985	3.84	
02/99 – 10/03 (2 lags)			
$r \leq 0$	30.055	12.53	Cointegration
$r \leq 1$	1.312	3.84	
Corn			
11/96 – 12/98 (3 lags)			
$r \leq 0$	10.599	12.53	No cointegration
$r \leq 1$	0.102	3.84	
02/99 – 02/01 (1 lag)			
$r \leq 0$	12.342	12.53	No cointegration
$r \leq 1$	0.276	3.84	
10/01 – 10/03 (3 lags)			
$r \leq 0$	17.047	19.96	No cointegration
$r \leq 1$	3.782	9.24	
Cotton			
11/96 – 12/98 (3 lags)			
$r \leq 0$	9.708	12.53	No cointegration
$r \leq 1$	2.199	3.84	

(*) The lag structures are determined by the SBC

Table 4: Trace tests for futures and cash prices – live cattle, soybeans, and sugar

	l_{trace}	Critical value (5%)	
Live cattle			
01/96 – 12/98 (1 lag)			
$r \leq 0$	15.927	12.53	Cointegration
$r \leq 1$	0.062	3.84	
02/99 – 12/00 (1 lag)			
$r \leq 0$	12.839	19.96	No cointegration
$r \leq 1$	3.222	9.24	
01/01 – 10/03 (2 lags)			
$r \leq 0$	40.559	12.53	Cointegration
$r \leq 1$	1.164	3.84	
Soybeans			
10/95 – 05/98 (2 lags)			
$r \leq 0$	8.512	12.53	No cointegration
$r \leq 1$	0.031	3.84	
02/99 – 04/01 (1 lag)			
$r \leq 0$	5.032	12.53	No cointegration
$r \leq 1$	0.518	3.84	
Sugar			
10/95 – 04/97 (1 lag)			
$r \leq 0$	30.700	12.53	Cointegration
$r \leq 1$	1.212	3.84	
04/97 – 12/98 (2 lags)			
$r \leq 0$	8.042	12.53	No cointegration
$r \leq 1$	0.070	3.84	
02/99 – 10/03 (1 lag)			
$r \leq 0$	47.374	12.53	Cointegration
$r \leq 1$	0.401	3.84	

(*) The lag structures are determined by the SBC

Table 5: Error correction representation for the cointegrated prices

	Error correction term			Wald tests [a]	
	coefficient Π_i	standard error	$H_0 : \Pi_i = 0$	$H_0 : b_i = 0$	$H_0 : \Pi_i = b_i = 0$
Coffee					
06/97 – 12/98					
futures	0.045	0.037	don't reject	don't reject	don't reject
cash	0.129	0.027	reject	don't reject	reject
02/99 – 10/03					
futures	-0.019	0.068	don't reject	don't reject	don't reject
cash	0.049	0.021	reject	reject	reject
Live cattle					
01/96 – 12/98					
futures	-0.011	0.005	reject	reject	reject
cash	0.011	0.003	reject	don't reject	reject
01/01 – 10/03					
futures	0.007	0.008	don't reject	reject	reject
cash	0.017	0.003	reject	reject	reject
Sugar					
10/95 – 04/97					
futures	-0.006	0.010	don't reject	don't reject	don't reject
cash	0.019	0.004	reject	don't reject	reject
02/99 – 10/03					
futures	-0.004	0.005	don't reject	reject	reject
cash	0.022	0.003	reject	reject	reject

(*) Tests are performed at 5% significance level

(a) The b_i represents the coefficient associated with the lagged covariates; when the change in futures (cash) prices is the dependent variable, this coefficient refers to the lagged changes in cash (futures) prices

Table 6: Measures of interaction for the non-cointegrated prices

	$S_{F \to C}$	$S_{C \to F}$	$S_{C \cdot F}$
Corn			
11/96 – 12/98	0.004	0.109	0.003
02/99 – 02/01	0.002	0.003	0.051 *
10/01 – 10/03	0.047	0.041	0.001
Cotton			
11/96 – 12/98	0.024	0.070	0.014 *
Live cattle			
02/99 – 12/00	-0.000	0.041	0.154 *
Soybeans			
10/95 – 05/98	0.033	0.016	0.023 *
02/99 – 04/01	0.002	0.016	0.126 *
Sugar			
04/97 – 12/98	-0.002	0.038	0.000

(*) Denotes statistical significance at 5%

Table 7: General results for each commodity

	1^{st} period	2^{nd} period	3^{rd} period
Coffee (arabica)	6/23/97 – 12/30/98	2/1/99 – 10/6/03	
Long-run interaction	*F ® C*	*F ® C*	
Short-run interaction	*no*	*F ® C*	
Avg. trading volume (a)	698	1,686	
Avg. # of trades (b)	167	415	
Futures / production (c)	87%	179%	
Corn	11/29/96 – 12/30/98	2/1/99 – 2/28/01	10/26/01 – 10/31/03
Long-run interaction	*no*	*no*	*no*
Short-run interaction	*no*	*F « C*	*no*
Avg. trading volume (a)	75	35 (d)	108
Avg. # of trades (b)	46	20 (d)	34
Futures / production (c)	2%	1%	1%
Cotton	11/22/96 – 12/30/98		
Long-run interaction	*no*		
Short-run interaction	*F « C*		
Avg. trading volume (a)	63		
Avg. # of trades (b)	31		
Futures / production (c)	0%		
Live cattle	1/8/96 – 12/30/98	2/1/99 – 12/28/00	1/2/01 – 10/31/03
Long-run interaction	*F « C*	*no*	*F ® C*
Short-run interaction	*C ® F*	*F « C*	*F « C*
Avg. trading volume (a)	428	500 (e)	481
Avg. # of trades (b)	98	44 (e)	94
Futures / production (c)	6%	8%	7%
Soybeans	10/31/95 – 5/29/98	2/1/99 – 4/30/01	
Long-run interaction	*no*	*no*	
Short-run interaction	*F « C*	*F « C*	
Avg. trading volume (a)	69	26	
Avg. # of trades (b)	25	13	
Futures / production (c)	0%	0%	
Sugar	10/31/95 – 4/14/97	4/15/97 – 12/30/98	2/1/99 – 10/31/03
Long-run interaction	*F ® C*	*no*	*F ® C*
Short-run interaction	*no*	*no*	*F « C*
Avg. trading volume (a)	29	84	206
Avg. # of trades (b)	6	16	19
Futures / production (c)	1%	2%	4%

(a) Average number of contracts traded daily
(b) Average number of trades executed daily
(c) Total quantity traded in futures markets divided by the total quantity produced
(d) The average refers to half of the sample in this 2^{nd} period; data for the rest of the sample could not be obtained
(e) The average refers only to 1999; data for 2000 could not be obtained