# Futures Expiration, Contract Switching, and Price Discovery


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*Futures contract switching in the weeks prior to expiration of the nearby contract produces some price and spread effects. An examination of daily and intraday prices in five commodity markets suggests contract switching has a greater impact on the volatility of nearby contract prices than on the volatility of next-to-nearby contract prices. The correlation between the nearby and next-to-nearby contracts remains fairly high throughout the switching period, but declines sharply in the last week of trading. The switching period witnesses fairly complex patterns of returns autocorrelation, cross-serial correlation, and leadership. Over the switching period, there is positive first-order autocorrelation and cross-correlation in daily returns, but negative first-order autocorrelation and cross-correlation for half-hourly returns.*

*Switching activity is found not to have an important impact on variation in price differences of the two contracts (the spread). Variation in the spread rises abnormally after the switching interval, in the days close to expiration. It is only in the last week of trading that the nearby contract is found to bear the burden of convergence to the spread. The evidence suggests that the nearby contract is not a lame duck until the last few days before expiration.*


One predictable pattern in futures markets is the sharp decline in trading activity and open interest in the nearby futures contract in the weeks prior to expiration as the vast majority of traders close out their positions by offsetting trades. Accompanying this decline is a comparably sharp and predictable rise in activity in the next-to-nearby contract, as many traders roll their positions over. Despite the scale of contract rollover, its effect on price patterns has not been closely studied.

We are interested in contract rollovers for two important reasons. We wish to know whether the inevitable changes in liquidity leadership at futures contract switching are accompanied by shifts in price leadership between the nearby and the next-to-nearby contracts. Such a question is intimately related to price discovery.

Studies on price discovery examine the information advantages of markets for single underlying assets or indexes; (see, for example, Garbade and Silber [1979], Harris et al. [1995], and Hasbrouck [1995]). Others investigate information flows across markets for similar but not identical assets or indexes. Conrad, Gultekin, and Kaul [1991] examine the flow of information between large and small stocks. Hamao, Masulis, and Ng [1990] and Karolyi and Stulz [1996] examine the spillovers between U.S. and foreign markets. The consensus has generally been that information travels from more liquid markets, where trading volume is concentrated, to less liquid markets.

Liquidity is critical to efficient price discovery (see, e.g., Barry and Jennings [1983] and Karpoff [1987]). A finding of simultaneity or near-simultaneity in liquidity switching and leadership switching would affirm many models related to this notion. Yet research on liquidity and leadership between nearby and next-to-nearby contracts is sparse. We attempt to provide such evidence. Futures markets provide some important advantages to this analysis. As the nearby and the next-to-nearby contracts are both written on the same underlying asset, we can carry out our analysis free from the confounding effects of firm-specific or market-specific news.

We would also like to determine how near to expiration the nearby contract loses its ability to reflect current information. Researchers and the media tend to follow the prices of the most liquid contract, which is typically the next-to-nearby contract by about the middle of the pre-delivery month. Our results will shed light on the importance of this practice.

To address these issues, we examine trading activity (number of trades, volume, and open interest), volatility, autocorrelation, and cross-correlation patterns in the nearby and next-to-nearby contracts in five commodity markets. We use daily and intraday data on three grains, wheat, oats, and corn, and on two soft commodities, coffee and cotton. We also conduct specific tests that examine leadership between the two contracts. Given the nature of the data, we take care not to overparameterize the tests.

Further, we use multiple methods, and are able to provide several tests of robustness. For instance, to evaluate intercontract price leadership, we use simple cross-correlations, cross-products of residuals from autoregressive models, and GARCH-standardized cross-products of residuals.

## I. BRIEF BACKGROUND

We posit that contract rollovers have identifiable effects on futures prices. Admittedly, the reasons for the switching from the nearby to the next-to-nearby contracts are mostly unrelated to information per se. Nonetheless, we still expect such switching to precipitate price changes.

Our reasoning has support in the literature. For instance, uninformed trading volume is found to be important in determining price patterns (see Kyle [1985] and O'Hara [1995]). Anecdotal evidence also provides support. The Commodities Report section of the *Wall Street Journal* reported the following on November 25, 2002:

> Huge spreads, which are the buying of one month simultaneously with the sale of another, cut the number of futures contracts outstanding in December and moved them into February, April, and June contracts, which helped those months reach new highs. . . . Crude oil futures rallied on the buying of futures to reverse previous sales ahead of the weekend. . . . On Friday, commercial accounts bought December contracts (for Cattle), which supported that month amid selling of previous purchased futures, mostly by large commodity fund speculators (p. C. 11).

Casual observation suggests that such reports on the effects of settlement or rollover occur on almost a daily basis in the last few weeks of the pre-expiration month.

Several authors examine the effects of futures contract maturity. Bessembinder et al. [1996] and Routledge, Seppi, and Spatt [2000] suggest that the term structure in futures price changes is related to speculative inventories. Bessembinder et al. suggest that the relatively high volatility closer to contract expiration (the "Samuelson effect") will be more prevalent in commodities, whose prices tend to revert to the mean. Studies also explain the presence of autocorrelation patterns via speculative storage models (Deaton and Laroque [1992] and Chambers and Bailey [1996]), or via uncontrollable factors, such as the weather (Roll [1984]).

Our focus is on futures contract switching, particularly on whether contract switching contributes to volatility and autocorrelation patterns in commodity futures. The analysis of intracommodity spread behavior is important in the case of rollover (switching) risk. If switching activity results in greater volatility differences between the prices of the nearby and next-to-nearby contracts, the concentration of rollover activity would result in higher rollover risk. This could have implications for hedgers who want to execute rollover trades, or for spread traders searching for arbitrage opportunities.

A useful first step is to establish the calendar intervals when switching is most prevalent. Our results suggest that the switching interval is fairly wide, covering the majority of the pre-expiration month. We examine various samples of the data—the pre-switching interval, the switching interval, and the post-switching interval—to test for changes in price and relative-price behavior.

Our main findings can be summarized as follows:

- Contract switching has more of an impact on the volatility of nearby prices than on more distant futures prices. The difference in return volatility of the nearby and next-to-nearby contracts rises during the contract-switching period for four of the five commodities.

- The correlation between nearby and next-to-nearby contracts remains fairly high throughout the switching period, but declines sharply in the last week of trading.
- The switching period exhibits fairly complex patterns of returns autocorrelation, cross-serial correlation, and leadership. Over the switching period, there is positive first-order autocorrelation and cross-correlation in daily returns, but negative first-order autocorrelation and cross-correlation for half-hourly returns.
- The switching activity is found not to have an important impact on the variation in the price difference between the two contracts (the spread). The variation in the spread rises abnormally *after* the switching interval, in the days close to expiration.
- It is only in the last week of trading that the nearby contract is found to bear the burden of convergence to the spread. The evidence suggests that the nearby contract is not a lame duck until the last few days prior to expiration.

## II. DESCRIPTION OF DATA AND RESEARCH DESIGN

### Data

We use daily settlement prices, volume, and open interest data as well as intraday data on three grains traded on the Chicago Board of Trade, wheat, oats, and corn, and on two soft commodities, coffee (traded on the Sugar, Coffee, and Cocoa Exchange), and cotton (traded on the New York Commodities Exchange). Corn, oats, coffee, and wheat have expiration cycles of March, May, July, September, and December, while cotton has an expiration cycle of March, May, July, October, and December. These are mature markets and actively traded contracts.

Our daily sample begins January 1986 and ends July 2001. The intraday sampling interval is December 1997 to July 2001. From the intraday sample, we extract prices and number of trades per period every half hour for the nearby and next-to-nearby contracts. Data series of finer intervals (such as 15 minutes) are found to be relatively discontinuous because of infrequent trading in the next-to-nearby contract in the months before the pre-expiration month. Thus, we cannot use the last 15 minutes of trading in the CBOT contracts, which trade from 9:30 am to 1:15 pm Central Standard Time. This exclusion is not expected to be materially important either to our testing procedures or to the test results.[1]

The nearby series is constructed by following a contract up to its expiration date, at which point the series switches to the next-to-nearby contract. For instance, the nearby (daily) series for oats for the first half of 1987 is constructed by following the March 1987 contract from December 20, 1986 (the day following the expiration of the December contract), until March 20, 1987 (the expiration of the March contract), and then picking up the May 1987 contract from March 21, 1987, until the May expiration date. The next-to-nearby contract series for the same period is constructed by following the May 1987 contract from December 20, 1986, until March 20, 1987, and then picking up the July contract from March 21, 1987. In this manner, we construct a pair of series, matched perfectly in time, but always different in maturity, for each of the five commodities.

### Research Design

Intraday returns for the nearby (next-to-nearby) contract are given by 100 times the log relative of the closing prices in a given half-hour interval $i$ and the closing price of the preceding half-hour interval $(i - 1)$, or

$$r_{j,i} = \ln\left[\frac{p^c_{j,i}}{p^c_{j,i-1}}\right] * 100$$

where the superscript $c$ represents the closing price, and subscript $j$ represents either the nearby contract or the next-to-nearby contract.[2]

Similarly, daily returns are given by 100 times the log relative of daily $(t)$ settlement prices:

$$R_{j,t} = \ln\left[\frac{P_{j,t}}{P_{j,t-1}}\right] * 100$$

Return volatility is computed from the absolute value of returns. Intraday return volatility is estimated by:[3]

$$\hat{\sigma_i} = \sqrt{\tfrac{\pi}{2}}\left|\hat{e_i}\right|$$

where the estimate of $e_i$ is from the autoregressive model:

$$r_{j,i} = a_j + \sum_{k=1}^{K} b_{j,k} r_{j,i-k} + e_{j,i} \qquad \text{(1-A)}$$

Daily volatility is defined in similar fashion as:

$$\hat{\sigma_t} = \sqrt{\frac{\pi}{2}}\left|\hat{u_t}\right|$$

where the estimate of $u_t$ is from the autoregressive model:

$$R_{j,t} = c_j + \sum_{l=1}^{L} w_{j,l} R_{j,t-l} + u_{j,t} \qquad \text{(1-B)}$$

We measure leadership and spread behavior across the maturity of the nearby contract.

***Measuring leadership.*** We consider a range of tests to establish the patterns of comovement and leadership in the nearby and next-to-nearby contracts. Our first choice is the Pearson coefficient, which is typically used to test for the presence of serial cross-correlation. For instance, one could examine whether the day $t$ returns in the nearby contract are correlated with the day $t-1$, $t-2$, $t-l$ returns in the next-to-nearby contract. Yet limiting ourselves to such an analysis exposes us to a variety of problems.

First, the Pearson coefficient may lead to biased inferences in the presence of extreme observations. Therefore, for some tests we employ the Spearman rank correlation coefficient.

Second, the returns may themselves be autocorrelated, so that the serial cross-correlation may simply be a symptom of comovement rather than leadership. To assess comovements and leadership with more flexibility in their form, we use a simple extension of the serial cross-covariance measures employed in Lo and MacKinlay [1990] and Mech [1993]. If nearby daily returns ($R_N$) lead next-to-nearby daily returns ($R_X$) over a particular interval, perhaps due to greater liquidity, we have

$$Cov(R_{X,t}, R_{N,t-1}) > Cov(R_{X,t-1}, R_{N,t})$$

which can be written as

$$E(R_{X,t}R_{N,t-1}) - E(R_{X,t})E(R_{N,t-1}) >$$
$$E(R_{X,t-1}R_{N,t}) - E(R_{X,t-1})E(R_{N,t})$$

If expected returns are equal across the two maturities, this simplifies to

$$E(R_{X,t}R_{N,t-1}) > E(R_{X,t-1}R_{N,t})$$

Without loss of generality, the nearby contract leadership (with no feedback) can be captured by

$$\tilde{u}_{X,t}\tilde{u}_{N,t-1} > 0$$

and

$$\tilde{u}_{X,t-1}\tilde{u}_{N,t} = 0 \qquad \text{(2-A)}$$

where $\tilde{u}_j$ are the residuals from Equation (1-B). The test formulations in (2-A) directly control for possible autocorrelation in returns. This technique is easily extended to control for ARCH-type effects in the data. For instance, let $x_{N,t}$ and $x_{X,t}$ represent, respectively, the standardized residuals for the nearby and next-to-nearby returns from a GARCH model. Nearby-contract leadership would imply

$$x_{X,t}x_{N,t-1} > 0$$

and

$$x_{X,t-1}x_{N,t} = 0 \qquad \text{(2-B)}$$

Formulations (2-A) and (2-B) are particularly suited to this study since we assess leadership by employing pooled time series data with relatively short periodicity, such as five day intervals across the expiration cycle. We employ the notations $\omega$ and standardized $\omega$ for formulations (2-A) and (2-B), respectively. The standardized $\omega$ formulation has the added advantage of allowing for time-of-day controls in the variance of returns.[4]

***Measuring spread convergence.*** Augmented Dickey-Fuller tests (not reported here to save space) show that prices of the nearby and next-to-nearby contracts are cointegrated. In other words, the spread between the two prices is mean-reverting. An issue of interest, and one that is intuitively related to the broader issue of leadership, is whether the pressures of convergence undergo change during and after the switching period.

We use a near-VAR with error correction model for this purpose. The model is:

$$\Delta P_{X,t} = \alpha_X + \textstyle\sum_{l=1}^{L} \beta_{X,l}\Delta P_{X,t-l} +$$
$$\textstyle\sum_{l=1}^{L} \beta_{X,l}\Delta P_{X,t-l} + \sum_{m=1}^{M} \eta_{X,m}\Delta P_{N,t-m} +$$
$$\lambda_{X,2}z_{t-1}D_1 + \lambda_{X,3}z_{t-1}D_2 + \xi_{X,t} \qquad \text{(3-A)}$$

$$\Delta P_{N,t} = \alpha_N +$$
$$\textstyle\sum_{l=1}^{L} \beta_{N,l}\Delta P_{X,t-l} + \sum_{m=1}^{M} \eta_{N,m}\Delta P_{N,t-m} + \lambda_{N,1}z_{t-1}$$
$$\lambda_{N,1}z_{t-1} + \lambda_{N,2}z_{t-1}D_1 + \lambda_{N,3}z_{t-1}D_2 + \xi_{N,t} \qquad \text{(3-B)}$$

where $z_{t-1} = (P_X e^{-r_X X} - P_N e^{-r_N N})_{t-1}$ is the lagged adjusted spread, and represents the error correction term. $D_1$ ($D_2$) is a $\{0, 1\}$ dummy variable taking the value of 1 if $t$ falls in the switching (post-switching) interval.

Collectively, significant coefficients on lagged changes in the nearby prices in (3-A) would typically be interpreted as indicating information flows from the nearby contract to the next-to-nearby contract. Similarly, significant coefficients on lagged changes in the next-to-nearby prices in (3-B) would be interpreted as indicating information flows from the next-to-nearby contract.[5]

The $\lambda_{X,1}$, $\lambda_{N,1}$, coefficients indicate the burden of convergence between the two contracts. If, for instance, $\lambda_{X,1} < 0$ and $\lambda_{N,1} = 0$, following a widening of the spread, the next-to-nearby price falls in the process of convergence. Similarly, if $\lambda_{N,1} > 0$ and $\lambda_{X,1} = 0$, the nearby price converges to the next-to-nearby price. The $\lambda_2$ ($\lambda_3$) coefficients indicate the extent to which the convergence pressures are different in the switching (post-switching) interval. For instance, a positive $\lambda_{N,2}$ coefficient and a non-negative $\lambda_{X,2}$ coefficient would indicate that the nearby contract bears a higher-than-typical burden of convergence during the switching period.

## III. EMPIRICAL RESULTS

We describe results as to switching intervals and patterns of volatility, autocorrelation, leadership, and spreads.

### Switching Interval

To identify the switching interval, we examine volume and open interest for each of the five commodities. Exhibit 1 reports daily volume ($V$) and end-of-day open interest ($I$) averaged for the full sample and for five-day intervals defined by their proximity to the first trading day (denoted 0) of the delivery month. For instance, the interval (1 to 5) represents the second through the sixth trading day of the delivery month, and (–4 to 0) represents the first trading day of the delivery month and the last four trading days of the prior month.

To isolate the intervals when switching activities are high, we employ two algorithms. First, we note that periods with heavy switching activity will witness high negative correlation between the open interest of the nearby and next-to-nearby contracts, and high positive correlation between volume of the nearby and next-to-nearby contracts. Here we assume that the two transactions in contract switching—the offsetting in the nearby contract, and the positioning in the next-to-nearby contract—take place fairly simultaneously.

Second, we note that during the heavy switching period, most of the volume in the nearby contract will be dedicated to reduction of the open interest in this contract, and, simultaneously, much of the volume in the next-to-nearby contract will be dedicated to increasing the open interest in that contract. In other words, the variables ($-\Delta I/V$) for the nearby contract, termed the open interest ratio for the nearby contract [$IR(N)$], and ($\Delta I/V$) for the next-to-nearby contract, termed the open interest ratio for the next-to-nearby contract [$IR(X)$] will be relatively high over the switching period.

The two algorithms prove to be consistent in isolating the heavy switching periods. For instance, for wheat, the interval (–14 to 0) exhibits a strong negative correlation between the open interest and a strong positive correlation between the trading volume of the two contracts. Over this interval ($IR(N)$) is relatively high, and [$IR(X)$] is at its highest. Similarly, the intervals with symptoms of switching for the other commodities are: coffee (–19 to –5), oats (–19 to 0), corn (–19 to 0), and cotton (–14 to –5). We highlight the switching intervals in Exhibit 1 and in the tables that follow.

The trading activity in and around the switching period can best be characterized as patterns of waves. That is, *total* (combined) volume and open interest do not increase or decline monotonically as we approach expiration. For instance, for each of the five commodities, the period close to expiration is relatively quiet, with nearby volume approaching zero, and the next-to-nearby contract's volume also falling during this time. The volume for the next-to-nearby contract is highest sometime before expiration, particularly in the ten-day interval (–9 to 0). Total (combined) volume and open interest is highest during the (–29 to –25) period or earlier.

### Volatility Patterns

Exhibit 2 reports daily returns volatility for the full sample and for the five-day intervals. We report daily returns volatility for close-to-close prices. Volatility using open-to-close prices (trading volatility) and close-to-open prices (overnight volatility) shows no substantive differences, and is not reported to save space.[6] We also examine whether differences in volatility between the nearby and the next-to-nearby contracts are significant (i.e., whether the ratio $\sigma(N)/\sigma(X)$ is different from 1).

The evidence also suggests that switching activity impacts volatility in the nearby contract more than in the next-to-nearby contract. The intraday ratio of $\sigma(N)/\sigma(X)$ is significantly greater than 1 in at least one of the switching intervals for each commodity.[7]

# EXHIBIT 1
## Trading Activity

| Interval | $V(N)$ | $V(X)$ | $\frac{V(N)}{V(X)}$ | $\rho(\Delta V)$ | $I(N)$ | $I(X)$ | $\frac{I(N)}{I(X)}$ | $\rho(\Delta I)$ | $IR(N)$ | $IR(X)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | | | | | | | | | | |
| Full Sample | 4173 | 4869 | .86** | .394 | 14901 | 19414 | 0.77** | -.349 | 0.241 | 0.044 |
| $\leq$ -30 | 7046 | 1840 | 3.83** | .712 | 30040 | 10798 | 2.78** | .563 | 0.065 | -0.009 |
| -29 to -25 | 6111 | 3549 | 1.72** | .559 | 22824 | 15915 | 1.43** | .049 | -0.169 | -0.129 |
| -24 to -20 | 5562 | 3779 | 1.47** | .505 | 21066 | 17055 | 1.24** | -.016 | 0.069 | 0.064 |
| -19 to -15 | 5114 | 4228 | 1.21** | .630 | 19121 | 18143 | 1.05 | -.012 | 0.097 | 0.084 |
| -14 to -10 | 4642 | 4889 | 0.95 | .589 | 16414 | 19765 | 0.83** | -.165 | 0.152 | 0.087 |
| -9 to -5 | 4126 | 5393 | 0.77** | .445 | 12507 | 21273 | 0.59** | -.235 | 0.258 | 0.088 |
| -4 to 0 | 3556 | 7291 | 0.49** | .473 | 6225 | 23768 | 0.26** | -.387 | 0.378 | 0.086 |
| 1 to 5 | 1058 | 7176 | 0.15** | .312 | 2526 | 25255 | 0.10** | -.112 | 0.416 | 0.015 |
| 6 to 10 | 482 | 6749 | 0.07** | .221 | 1229 | 25654 | 0.05** | -.110 | 0.635 | -0.001 |
| 11 to $T$ | 313 | 6291 | 0.05** | .237 | 490 | 24011 | 0.02** | -.015 | 0.910 | -0.011 |
| Coffee | | | | | | | | | | |
| Full Sample | 2818 | 3432 | 0.82** | .414 | 9665 | 14414 | 0.67** | -.506 | 0.391 | 0.071 |
| $\leq$ -30 | 4922 | 1316 | 3.74** | .763 | 19641 | 8658 | 2.27** | .202 | 0.028 | 0.086 |
| -29 to -25 | 4672 | 1701 | 2.75** | .753 | 17397 | 9903 | 1.76** | -.015 | -0.100 | -0.194 |
| -24 to -20 | 4317 | 1900 | 2.27** | .796 | 16141 | 10727 | 1.51** | -0.014 | 0.081 | 0.094 |
| -19 to -15 | 4205 | 2575 | 1.63** | .846 | 14072 | 12016 | 1.17** | -.226 | 0.145 | 0.120 |
| -14 to -10 | 3610 | 3769 | 0.96 | .772 | 10029 | 14372 | 0.70** | -.504 | 0.272 | 0.155 |
| -9 to -5 | 2442 | 5367 | 0.46** | .573 | 3465 | 18419 | 0.19** | -.662 | 0.607 | 0.120 |
| -4 to 0 | 306 | 4886 | 0.06** | .513 | 1373 | 19256 | 0.07** | -.001 | 0.659 | 0.001 |
| 1 to 5 | 156 | 5111 | 0.03** | .272 | 743 | 19638 | 0.04** | .055 | 0.914 | -0.001 |
| 6 to 10 | 96 | 5178 | 0.02** | .277 | 358 | 19327 | 0.02** | .071 | 0.967 | -0.013 |
| 11 to $T$ | 86 | 4822 | 0.02** | .109 | 180 | 17834 | 0.01** | -.022 | 1.000 | -0.011 |
| | | | | | | | | | | |

| Interval | $V(N)$ | $V(X)$ | $\frac{V(N)}{V(X)}$ | $\rho(\Delta V)$ | $I(N)$ | $I(X)$ | $\frac{I(N)}{I(X)}$ | $\rho(\Delta I)$ | $IR(N)$ | $IR(X)$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Oats | | | | | | | | | | |
| Full Sample | 541 | 585 | 0.93** | .552 | 5346 | 3952 | 1.35** | -.479 | 0.385 | 0.095 |
| $\leq$ -30 | 724 | 193 | 3.75** | .639 | 6297 | 1824 | 3.45** | .502 | 0.166 | 0.054 |
| -29 to -25 | 632 | 310 | 2.04** | .641 | 5259 | 2661 | 1.98** | .112 | -0.425 | -0.488 |
| -24 to -20 | 639 | 397 | 1.61** | .582 | 5028 | 2930 | 1.72** | -.042 | 0.113 | 0.127 |
| -19 to -15 | 621 | 478 | 1.30** | .656 | 4594 | 3257 | 1.41** | -.310 | 0.148 | 0.151 |
| -14 to-10 | 638 | 654 | 0.98 | .672 | 3965 | 3730 | 1.06 | -.255 | 0.238 | 0.162 |
| -9 to -5 | 651 | 792 | 0.82** | .704 | 2994 | 4396 | 0.68** | -.609 | 0.341 | 0.172 |
| -4 to 0 | 853 | 1119 | 0.76** | .707 | 1318 | 5389 | 0.25** | -.802 | 0.505 | 0.162 |
| 1 to 5 | 138 | 708 | 0.20** | .375 | 339 | 5929 | 0.06** | -.100 | 0.737 | 0.029 |
| 6 to 10 | 77 | 757 | 0.10** | .347 | 161 | 5906 | 0.03** | -.061 | 0.990 | -0.013 |
| 11 to $T$ | 63 | 726 | 0.09** | .224 | 84 | 5484 | 0.02** | .051 | 0.930 | -0.022 |
| Corn | | | | | | | | | | |
| Full Sample | 4317 | 13554 | 1.06** | .469 | 54408 | 73262 | 0.74** | .029 | 0.183 | 0.066 |
| $\leq$ -30 | 22290 | 5823 | 3.83** | .739 | 111390 | 45790 | 2.43** | .790 | 0.065 | 0.075 |
| -29 to -25 | 17961 | 9666 | 1.86** | .615 | 80755 | 62728 | 1.29** | .083 | -0.230 | -0.298 |
| -24 to -20 | 17934 | 10140 | 1.77** | .538 | 76487 | 66092 | 1.16** | -.068 | 0.065 | 0.069 |
| -19 to -15 | 16503 | 10443 | 1.58** | .555 | 69587 | 69335 | 1.00 | -.326 | 0.091 | 0.098 |
| -14 to -10 | 16496 | 13132 | 1.26** | .729 | 60443 | 74023 | 0.82** | -.293 | 0.132 | 0.096 |
| -9 to -5 | 14544 | 14418 | 1.01 | .605 | 46493 | 78936 | 0.59** | -.310 | 0.216 | 0.100 |
| -4 to 0 | 16616 | 20400 | 0.82** | .515 | 23668 | 87342 | 0.27** | -.643 | 0.288 | 0.098 |
| 1 to 5 | 5299 | 19729 | 0.27** | .363 | 9087 | 91719 | 0.10** | -.241 | 0.312 | 0.019 |
| 6 to 10 | 2371 | 19962 | 0.12** | .185 | 3931 | 92340 | 0.04** | -.105 | 0.370 | -0.003 |
| 11 to $T$ | 1608 | 18826 | 0.09** | .042 | 1407 | 86462 | 0.02** | -.062 | 0.468 | -0.011 |
| Cotton | | | | | | | | | | |
| Full Sample | 2682 | 3088 | 0.87** | .426 | 11623 | 16527 | 0.70** | -.256 | 0.324 | 0.058 |
| $\leq$ -30 | 3023 | 2374 | 1.27** | .428 | 16174 | 15373 | 1.05* | .152 | 0.053 | 0.053 |
| -29 to -25 | 3640 | 2203 | 1.65** | .521 | 17045 | 14088 | 1.21** | .170 | 0.066 | 0.064 |
| -24 to -20 | 3711 | 2662 | 1.39** | .538 | 15949 | 14690 | 1.09* | .101 | 0.096 | 0.067 |
| -19 to -15 | 3289 | 2784 | 1.18** | .565 | 13983 | 15376 | 0.91* | -.031 | 0.171 | 0.068 |
| -14 to -10 | 3061 | 3621 | 0.85** | .603 | 10750 | 16541 | 0.65** | -.344 | 0.316 | 0.097 |
| -9 to -5 | 2811 | 4840 | 0.58 | .575 | 4774 | 19144 | 0.25** | -.717 | 0.543 | 0.110 |
| -4 to 0 | 321 | 3918 | 0.08** | .276 | 1026 | 20197 | 0.05** | -.066 | 1.000 | -0.008 |
| 1 to $T$ | 157 | 4079 | 0.04** | .028 | 541 | 20328 | 0.03** | .294 | 1.000 | 0.034 |

*Intervals with strong symptoms of rollover are in boldface. * and ** represent significance levels of 5% and 1% against the null that the nearby and next-to-nearby contracts are equal.*

# Exhibit 2
**Return Volatility**

| Interval | $\sigma(N)_D^{CTC}$ | $\sigma(X)_D^{CTC}$ | $\frac{\sigma(N)_D^{CTC}}{\sigma(X)_D^{CTC}}$ | Interval | $\sigma(N)_D^{CTC}$ | $\sigma(X)_D^{CTC}$ | $\frac{\sigma(N)_D^{CTC}}{\sigma(X)_D^{CTC}}$ |
|---|---|---|---|---|---|---|---|
| **Wheat** | | | | **Oats** | | | |
| Full Sample | 1.065 | 0.971 | 1.10** | Full Sample | 1.401 | 1.282 | 1.09** |
| $\leq$ -30 | 0.914 | 0.827 | 1.11 | $\leq$ -30 | 1.088 | 0.993 | 1.10* |
| -29 to -25 | 1.249 | 1.146 | 1.09** | -29 to -25 | 1.350 | 1.331 | 1.02 |
| -24 to -20 | 1.036 | 0.922 | 1.12* | -24 to -20 | 1.445 | 1.372 | 1.05 |
| -19 to -15 | 1.039 | 0.904 | 1.15** | **-19 to -15** | **1.403** | **1.270** | **1.11** |
| **-14 to -10** | **1.102** | **1.022** | **1.08** | **-14 to -10** | **1.605** | **1.459** | **1.10** |
| **-9 to -5** | **1.061** | **0.960** | **1.11*** | **-9 to -5** | **1.408** | **1.358** | **1.04** |
| **-4 to 0** | **1.212** | **1.105** | **1.10** | **-4 to 0** | **1.761** | **1.480** | **1.19**** |
| 1 to 5 | 1.179 | 1.092 | 1.08 | 1 to 5 | 1.462 | 1.291 | 1.13 |
| 6 to 10 | 1.089 | 1.046 | 1.04 | 6 to 10 | 1.439 | 1.372 | 1.05 |
| 11 to | 1.143 | 0.954 | 1.20 | 11 to | 1.214 | 1.147 | 1.06 |
| $\text{Test}\frac{-14\text{ to }0}{< -15}$ | 3.691** | 4.005** | | $\text{Test}\frac{-19\text{ to }0}{< -20}$ | 5.971** | 5.228** | |
| $\text{Test}\frac{-14\text{ to }0}{1\text{ to }T}$ | -0.253 | -0.488 | | $\text{Test}\frac{-19\text{ to }0}{1\text{ to }T}$ | 2.355* | 1.777 | |
| **Coffee** | | | | **Corn** | | | |
| Full Sample | 1.731 | 1.590 | 1.09** | Full Sample | 0.949 | 0.903 | 1.05* |
| $\leq$ -30 | 1.707 | 1.551 | 1.10* | $\leq$ -30 | 0.827 | 0.785 | 1.05 |
| -29 to -25 | 1.657 | 1.527 | 1.09 | -29 to -25 | 1.084 | 1.057 | 1.03 |
| -24 to -20 | 1.692 | 1.520 | 1.11 | -24 to -20 | 0.919 | 0.898 | 1.02 |
| **-19 to -15** | **1.706** | **1.490** | **1.14*** | **-19 to -15** | **0.879** | **0.857** | **1.03** |
| **-14 to -10** | **1.750** | **1.563** | **1.12** | **-14 to -10** | **0.949** | **0.940** | **1.01** |
| **-9 to -5** | **1.852** | **1.669** | **1.11** | **-9 to -5** | **0.925** | **0.908** | **1.02** |
| -4 to 0 | 1.689 | 1.671 | 1.01 | **-4 to 0** | **1.128** | **0.996** | **1.13*** |
| 1 to 5 | 1.759 | 1.691 | 1.04 | 1 to 5 | 0.982 | 0.929 | 1.06 |
| 6 to 10 | 1.768 | 1.685 | 1.05 | 6 to 10 | 1.056 | 0.986 | 1.07 |
| 11 to | 1.803 | 1.626 | 1.11 | 11 to | 1.057 | 0.939 | 1.13 |
| $\text{Test}\frac{-19\text{ to }-5}{< -20}$ | 1.083 | 0.773 | | $\text{Test}\frac{-24\text{ to }0}{< -25}$ | 2.671** | 2.421* | |
| $\text{Test}\frac{-19\text{ to }-5}{-4\text{ to }T}$ | 0.327 | -1.421 | | $\text{Test}\frac{-24\text{ to }0}{1\text{ to }T}$ | -1.330 | -0.765 | |
| | | | | **Cotton** | | | |
| | | | | Full Sample | 1.039 | 0.959 | 1.08** |
| | | | | $\leq$ -30 | 0.953 | 0.916 | 1.04 |
| | | | | -29 to -25 | 0.912 | 0.856 | 1.07 |
| | | | | -24 to -20 | 1.078 | 1.008 | 1.07 |
| | | | | -19 to -15 | 1.024 | 0.968 | 1.06 |
| | | | | **-14 to -10** | **1.105** | **1.037** | **1.07** |
| | | | | **-9 to -5** | **1.220** | **1.028** | **1.19**** |
| | | | | -4 to 0 | 1.172 | 0.993 | 1.18* |
| | | | | 1 to | 1.009 | 0.962 | 1.05 |
| | | | | $\text{Test}\frac{-24\text{ to }0}{< -25}$ | 4.197** | 2.570** | |
| | | | | $\text{Test}\frac{-24\text{ to }0}{1\text{ to }T}$ | 1.040 | 1.025 | |

*Switching periods (boldfaced) are determined from Exhibit 1. * and ** represent significance levels of 5% and 1%.*

## Autocorrelation Patterns

Exhibit 3 reports the Spearman rank correlation, autocorrelation, and cross-correlation patterns for daily returns in the nearby and next-to-nearby contracts. Pearson correlation coefficients are fairly similar, and are omitted to save space. Given the sharp drop in trading in the days close to expiration, we pool the data for intervals (6 to 10) and (11 to *T*), where *T* indicates contract maturity, and report statistics for the combined interval (6 to *T*) for the commodities except cotton. For cotton, for the same reason, we report the (1 to *T*) interval.

The results indicate that the correlation between the daily returns in the two contracts (*NX*) remains fairly

# Exhibit 3
**Correlation, Serial Correlation, and Cross-Correlation in Daily Returns**

| Interval | $NX$ | $NN_{-1}$ | $XX_{-1}$ | $NX_{-1}$ | $XN_{-1}$ | Interval | $NX$ | $NN_{-1}$ | $XX_{-1}$ | $NX_{-1}$ | $XN_{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wheat** | | | | | | **Corn** | | | | | |
| $\leq$ -30 | .887 | -.003 | -.033 | -.016 | .002 | $\leq$ -30 | .917 | -.027 | -.029 | .056 | .042 |
| -29 to -25 | .882 | -.007 | .052 | .012 | .050 | -29 to -25 | .905 | .054 | .089 | .096 | .081 |
| -24 to -20 | .930 | .019 | .005 | .013 | .011 | -24 to -20 | .950 | .049 | .017 | .028 | .032 |
| -19 to -15 | .928 | .024 | .058 | .052 | .042 | **-19 to -15** | **.959** | **.149** | **.106** | **.121** | **.137** |
| **-14 to -10** | **.935** | **.018** | **.010** | **.009** | **-018** | **-14 to -10** | **.952** | **.057** | **.077** | **.067** | **.060** |
| **-9 to -5** | **.907** | **.137** | **.102** | **.124** | **.126** | **-9 to -5** | **.928** | **.126** | **.096** | **.122** | **.086** |
| **-4 to 0** | **.906** | **.165** | **.142** | **.179** | **.117** | **-4 to 0** | **.939** | **.128** | **.082** | **.118** | **.058** |
| 1 to 5 | .915 | .059 | .049 | .073 | .033 | 1 to 5 | .930 | .056 | .043 | .045 | .037 |
| 6 to $T$ | .836 | .036 | -.013 | .052 | .012 | 6 to $T$ | .843 | .039 | .013 | .036 | .023 |
| **Coffee** | | | | | | **Cotton** | | | | | |
| $\leq$ -30 | .949 | -.020 | .014 | -.009 | .009 | $\leq$ -30 | .926 | -.004 | -.008 | .001 | .028 |
| -29 to -25 | .944 | -.040 | -.031 | -.012 | -.055 | -29 to -25 | .940 | -.032 | -.046 | -.035 | -.057 |
| -24 to -20 | .960 | -.039 | -.024 | -.008 | -.045 | -24 to -20 | .942 | .086 | .084 | .081 | 1.09 |
| **-19 to -15** | **.954** | **-.049** | **-.021** | **-.024** | **-.049** | -19 to -15 | .940 | .029 | -.042 | .031 | .038 |
| **-14 to -10** | **.960** | **.077** | **.022** | **.056** | **.038** | **-14 to -10** | **.935** | **.033** | **.015** | **.024** | **.025** |
| **-9 to -5** | **.941** | **.025** | **.011** | **.066** | **.016** | **-9 to -5** | **.876** | **.163** | **.108** | **.120** | **.067** |
| -4 to 0 | .942 | .149 | .139 | .173 | .136 | -4 to 0 | .848 | .103 | .062 | .068 | .093 |
| 1 to 5 | .926 | -.045 | .004 | .035 | -.049 | 1 to $T$ | .795 | -.043 | -.132 | -.012 | -.124 |
| 6 to $T$ | .882 | -.052 | -.069 | .032 | -.169 | | | | | | |
| **Oats** | | | | | | | | | | | |
| $\leq$ -30 | .929 | -.010 | .009 | -.002 | .003 | | | | | | |
| -29 to -25 | .914 | .904 | .042 | .084 | .053 | | | | | | |
| -24 to -20 | .973 | .116 | .105 | .132 | .108 | | | | | | |
| **-19 to -15** | **.945** | **.192** | **.132** | **.149** | **.156** | | | | | | |
| **-14 to -10** | **.956** | **.082** | **.086** | **.048** | **.049** | | | | | | |
| **-9 to -5** | **.926** | **.142** | **.075** | **.096** | **.073** | | | | | | |
| **-4 to 0** | **.918** | **.062** | **.050** | **.028** | **.074** | | | | | | |
| 1 to 5 | .882 | .106 | .077 | .092 | .137 | | | | | | |
| 6 to $T$ | .840 | .063 | .075 | .168 | .075 | | | | | | |

*Switching periods are boldfaced.*

high over the switching interval, while there is a perceptible drop in the last interval prior to expiration. There is also an elevation in the first-order autocorrelation ($NN_{-1}$) and ($XX_{-1}$) in daily returns. For instance, the serial correlation in wheat is as high as 0.165 for the nearby contract ($NN_{-1}$) and 0.142 for the next-to-nearby contract ($XX_{-1}$). Such levels of autocorrelation are generally not apparent over the non-switching intervals.

We also find elevated levels of first-order cross-serial correlation over the switching intervals. The switching-period cross correlation ($NX_{-1}$) is a maximum of 0.179 for wheat, 0.066 for coffee, 0.149 for oats, 0.118 for corn, and 0.120 for cotton. The corresponding cross-correlation ($XN_{-1}$) is fairly similar: 0.117 for wheat, 0.016 for coffee, 0.156 for oats, 0.086 for corn, and 0.067 for cotton. Thus, there appears to be higher positive feedback between the two contracts over the switching interval.

We provide correlation, autocorrelation, and cross-serial correlation patterns for half-hourly returns in Exhibit 4. These results are strikingly different from those reported in Exhibit 3 in several respects.

First, the intraday correlation between the nearby and next-to-nearby contract returns falls more sharply in the expiration month (1 to 5) and (6 to $T$). The intraday correlation over the last days of trading is only 0.682 for wheat, 0.528 for coffee, 0.599 for oats, 0.717 for corn, and 0.422 for cotton.

Second, the switching period witnesses a rise in the negative autocorrelation for wheat, coffee, and cotton. For instance, over the switching period, the first-order autocorrelation for wheat ranges between –0.085 and –0.137

## EXHIBIT 4
**Correlation, Serial Correlation, and Cross-Correlation in Half-Hourly Returns**

| Interval | $NX$ | $NN_{-1}$ | $XX_{-1}$ | $NX_{-1}$ | $XN_{-1}$ | Interval | $NX$ | $NN_{-1}$ | $XX_{-1}$ | $NX_{-1}$ | $XN_{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wheat** | | | | | | **Corn** | | | | | |
| $\leq$ -30 | .923 | .074 | .023 | .090 | .023 | $\leq$ - 30 | .803 | .079 | .066 | .044 | .099 |
| -29 to -25 | .902 | -.043 | -.083 | -.061 | -.083 | -29 to -25 | .856 | -.021 | -.016 | -.055 | -.001 |
| -24 to -20 | .885 | -.095 | -.120 | -.109 | -.120 | -24 to -20 | .841 | .035 | -.010 | .025 | -.001 |
| -19 to -15 | .872 | -.098 | -.061 | -.087 | -.061 | **-19 to -15** | **.813** | **-.003** | **-.056** | **-.020** | **-.039** |
| **-14 to -10** | **.890** | **-.112** | **-.137** | **-.137** | **-.137** | **-14 to -10** | **.790** | **.088** | **.027** | **.074** | **.039** |
| **-9 to -5** | **.859** | **-.137** | **-.046** | **-.109** | **-.046** | **-9 to -5** | **.766** | **.019** | **-.070** | **-.019** | **-.016** |
| **-4 to 0** | **.850** | **-.085** | **-.140** | **-.114** | **-.140** | **-4 to 0** | **.840** | **.059** | **.087** | **.059** | **.090** |
| 1 to 5 | .792 | -.042 | -.067 | .032 | -.067 | 1 to 5 | .847 | -.021 | -.027 | .015 | .023 |
| 6 to $T$ | .682 | -.094 | -.033 | .079 | -.033 | 6 to $T$ | .717 | -.034 | .025 | .002 | -.004 |
| **Coffee** | | | | | | **Cotton** | | | | | |
| $\leq$ -30 | .888 | .002 | -.003 | .012 | -.010 | $\leq$ -30 | .847 | -.021 | -.045 | -.037 | -.011 |
| -29 to -25 | .932 | -.058 | -.051 | -.045 | -.054 | -29 to -25 | .821 | -.040 | .048 | .011 | .026 |
| -24 to -20 | .901 | .035 | .030 | .008 | .061 | -24 to -20 | .853 | .007 | .013 | .002 | .032 |
| **-19 to -15** | **.855** | **-.057** | **-.046** | **-.075** | **-.022** | -19 to -15 | .819 | -.005 | -.029 | .004 | -.052 |
| **-14 to -10** | **.864** | **-.064** | **-.083** | **-.093** | **-.080** | **-14 to-10** | **.731** | **-.052** | **-.035** | **-.035** | **-.020** |
| **-9 to -5** | **.881** | **-.069** | **-.064** | **-.060** | **-.078** | **-9 to -5** | **.757** | **-.069** | **-.022** | **-.018** | **-.027** |
| -4 to 0 | .834 | -.010 | -.069 | -.035 | -.021 | -4 to 0 | .622 | .100 | .058 | .063 | .056 |
| 1 to 5 | .762 | -.073 | -.009 | -.038 | -.056 | 1 to $T$ | .422 | -.029 | .007 | .029 | -.026 |
| 6 to $T$ | .528 | .118 | .088 | .067 | .059 | | | | | | |
| **Oats** | | | | | | | | | | | |
| $\leq$ -30 | .812 | .-013 | -.018 | -.004 | .019 | | | | | | |
| -29 to -25 | .879 | .058 | .026 | .033 | .056 | | | | | | |
| -24 to -20 | .915 | .064 | .026 | .053 | .049 | | | | | | |
| **-19 to -15** | **.833** | **-.017** | **-.005** | **-.025** | **-.014** | | | | | | |
| **-14 to -10** | **.872** | **-.065** | **-.094** | **-.085** | **-.070** | | | | | | |
| **-9 to -5** | **.823** | **.003** | **.016** | **.004** | **.017** | | | | | | |
| **-4 to 0** | **.798** | **.002** | **-.003** | **.001** | **.048** | | | | | | |
| 1 to 5 | .728 | .040 | -.044 | -.003 | .012 | | | | | | |
| 6 to $T$ | .599 | .037 | .060 | .052 | -.002 | | | | | | |

*Switching periods are boldfaced.*

in the nearby contract ($NN_{-1}$), and between –0.046 and –0.140 in the next-to-nearby contract ($XX_{-1}$). This is different from the finding of positive first-order correlation in close-to-close returns, but the pattern of negative intraday autocorrelation is consistent with the switching process. If simultaneous selling in one contract and buying in the other results in a rise or compression of the spread, a negative first-order autocorrelation will follow from the process of reversion to the spread (via arbitrage pressures).

Third, the first-order cross-serial correlation, ($NX_{-1}$) and ($XN_{-1}$), is generally negative over the switching period, unlike the results in Exhibit 3. This too is consistent with spread divergence (and ultimately convergence) over the switching process.

Finally, there is generally a rise in cross-correlation $NX_{-1}$ in the last days prior to expiration (i.e., the (6 to $T$) interval). For instance, the final $NX_{-1}$ is 0.079 for wheat, 0.067 for coffee, and 0.052 for oats. This may suggest that the nearby contract lags the price changes in the next-to-nearby contract near expiration when there is extremely low trading activity in the nearby contract.[8]

### Intra-Commodity Leadership Patterns

Exhibit 5 presents the standardized $\omega$ statistics across the maturity of the nearby contract.[9] For half-hourly returns, like the cross-serial correlation results in Exhibit 4, there is evidence of positive feedback from the next-to-nearby

# EXHIBIT 5
**Leadership Patterns in Daily and Half-Hourly Returns**

| Interval | $NX_{-1}$ | $XN_{-1}$ | $NX_{-1}$ | $XN_{-1}$ | Interval | $NX_{-1}$ | $XN_{-1}$ | $NX_{-1}$ | $XN_{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| **Wheat** | Daily | | Half-Hourly | | **Oats** | Daily | | Half-Hourly | |
| to -30 | -.008 | -.074* | .096** | .085** | to -30 | -.046 | -.056 | .004 | .011 |
| -29 to -25 | .049 | .018 | -.005 | .031 | -29 to -25 | .019 | -.009 | .056 | .097 |
| -24 to -20 | .019 | .028 | -.076 | -.081 | -24 to -20 | .079* | .069 | .026 | -.064 |
| -19 to -15 | .047 | .039 | -.002 | -.038 | **-19 to -15** | .080* | .078* | -.042 | -.077* |
| **-14 to -10** | .005 | -.029 | -.122** | -.108* | **-14 to -10** | -.027 | -.024 | -.074** | -.099** |
| **-9 to -5** | .063* | .063* | -.091* | -.034 | **-9 to -5** | -.008 | -.024 | -.009 | -.058* |
| **-4 to 0** | .095* | .124** | -.086* | -.093* | **-4 to 0** | .022 | .025 | .136** | .116* |
| 1 to 5 | .057 | .045 | .030 | -.020 | 1 to 5 | -.027 | -.027 | .309** | .121* |
| 6 to $T$ | .038 | .003 | .129** | -.100 | 6 to $T$ | .020 | .030 | .211** | -.020 |
| **Coffee** | Daily | | Half-Hourly | | **Corn** | Daily | | Half-Hourly | |
| to -30 | .015 | .020 | .069* | .058* | to -30 | .017 | -.014 | .064* | .088* |
| -29 to -25 | .026 | -.045 | -.003 | .001 | -29 to -25 | .154* | -.018 | -.079* | .002 |
| -24 to -20 | .036 | .021 | .042 | .046 | -24 to -20 | .029 | .020 | .011 | -.008 |
| **-19 to -15** | .042 | .014 | -.025 | -.031 | **-19 t0 -15** | .027 | .020 | .045 | -.013 |
| **-14 to -10** | .033 | .009 | .024 | .075* | **-14 to -10** | .037 | .011 | .050 | .076* |
| **-9 to -5** | .037 | -.017 | .061 | .100* | **-9 to -5** | -.022 | -.097** | .037 | .058 |
| -4 to 0 | .056 | .028 | -.019 | -.030 | **-4 to 0** | .114** | .061 | -.036 | .003 |
| 1 to 5 | .077 | -.001 | .250** | .140* | 1 to 5 | .043 | .053 | -.048 | .008 |
| 6 to $T$ | .005 | -.060 | .147* | -.012 | 6 to $T$ | .062 | .006 | .087** | -.034 |
| | | | | | **Cotton** | Daily | | Half-Hourly | |
| | | | | | to -30 | .008 | .004 | -.014 | .011 |
| | | | | | -29 to -25 | -.022 | -.052 | .054* | .056* |
| | | | | | -24 to -20 | .085* | .120** | .076* | .073* |
| | | | | | -19 to -15 | .012 | .026 | .065* | -.024 |
| | | | | | **-14 to -10** | -.013 | -.009 | .045 | .041 |
| | | | | | **-9 to -5** | .069 | .060 | .024 | -.016 |
| | | | | | -4 to 0 | .042 | .096 | .042 | .053 |
| | | | | | 1 to $T$ | -.023 | -.087 | .114** | -.079 |

*Switching periods are boldfaced. * and ** represent significance levels of 5% and 1%.*

contract in the last weeks of trading. The $NX_{-1}$ statistic is positive and significant in the final interval for each commodity. The $XN_{-1}$ statistic is insignificant during this period. Thus, there is evidence of intraday leadership of the next-to-nearby contract in the final days prior to expiration. There is no evidence of leadership in daily returns.

There are no clear patterns of leadership over the switching periods. For instance, with half-hourly returns, we find considerable dual negative intraday feedback or causality over the switching intervals for wheat and oats. In daily returns, there is evidence of dual causality in wheat and oats over the switching period, and for cotton in a pre-switching interval.

Overall, the patterns of leadership across the nearby and next-to-nearby contracts do not seem to be strongly related to the switching period. Yet we consistently find that the next-to-nearby contract leads the nearby contract in the last weeks of trading. Spread convergence patterns discussed below reveal more evidence.

We also test for seasonality in leadership between the nearby and next-to-nearby contracts. It is plausible that the nearby and next-to-nearby contracts are more closely tied in late November, when hedgers switch their attention from the harvest or old crop (December contract) to the new crop (March contract). Regressions of $x_{X,t}x_{N,t-1}$ and $x_{X,t-1}x_{N,t}$ on dummy variables representing

# EXHIBIT 6

## Spread Patterns in Daily and Half-Hourly Returns

| Interval | $Spd_{adj}$ | $t$ | $\sigma^2(Spd_{adj})$ | $t$ | $Spd_{adj}$ | $t$ | $\sigma^2(Spd_{adj})$ | $t$ |
|---|---|---|---|---|---|---|---|---|
| Wheat | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| Constant | -1.478** | (-9.40) | 0.496** | (18.46) | 1.173* | (2.16) | 0.138** | (8.12) |
| D{-24 to -20} | 0.418 | (-1.43) | -0.199** | (-3.84) | -0.588 | (-1.74) | -0.042 | (-1.28) |
| D{-19 to -15} | 0.693* | (2.36) | -0.185** | (-3.59) | 0.114 | (0.35) | 0.016 | (0.42) |
| D{-14 to -10} | 0.854** | (2.91) | -0.203** | (-3.94) | 0.621 | (1.89) | 0.010 | (0.32) |
| D{-9 to -5} | 0.994** | (2.71) | -0.160** | (-3.11) | 0.754* | (2.30) | -0.031 | (-0.92) |
| D{-4 to 0} | 0.912** | (3.11) | -0.067 | (-1.31) | 1.320** | (4.04) | 0.018 | (0.53) |
| D{1 to 5 } | 0.587* | (2.00) | -0.083 | (-1.61) | 2.109** | (6.37) | 0.018 | (0.55) |
| D{6 to $T$ } | 0.034 | (0.13) | 0.097** | (2.07) | 2.559** | (7.81) | 0.081* | (2.44) |
| $\chi^2$ | 54.46** | | 48.13** | | 61.03** | | 5.87 | |
| $R^2_{adj}$ | .007 | | .010 | | .032 | | .003 | |
| Coffee | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| Constant | -0.469** | (-3.69) | 0.433** | (19.50) | -1.446** | (-32.44) | 0.116** | (12.88) |
| D{-24 to -20} | -0.095 | (-0.38) | -0.089* | (-2.08) | -0.244** | (-2.58) | 0.033 | (1.81) |
| D{-19 to -15} | -0.259 | (-1.05) | -0.033 | (-0.78) | -0.953** | (-11.04) | 0.003 | (0.16) |
| D{-14 to -10} | 0.047 | (0.19) | -0.022 | (-0.02) | -0.055 | (-0.63) | 0.015 | (0.88) |
| D{-9 to -5} | 0.179 | (0.72) | 0.111** | (2.58) | 0.181* | (2.09) | 0.009 | (0.48) |
| D{-4 to 0} | -0.288 | (-1.16) | 0.027 | (0.62) | -0.067 | (-0.74) | 0.006 | (0.33) |
| D{1 to 5} | -0.569* | (-2.28) | 0.065 | (1.51) | -0.278** | (-2.60) | 0.030 | (1.43) |
| D{6 to $T$ } | -0.739** | (-3.23) | 0.129** | (3.24) | -0.414** | (-3.77) | 0.195** | (8.83) |
| $\chi^2$ | 28.51** | | 31.51** | | 37.10** | | 27.76** | |
| $R^2_{adj}$ | 0.006 | | 0.010 | | 0.032 | | 0.017 | |
| Oats | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| Constant | 1.824** | (13.27) | 0.482** | (18.28) | 0.874** | (6.88) | 0.127** | (11.38) |
| D{-24 to -20} | -0.158 | (-0.60) | -0.200** | (-3.96) | -0.522* | (-2.08) | -0.014 | (-0.61) |
| D{-19 to -15} | -0.128 | (-0.48) | -0.123* | (-2.44) | 0.373 | (1.55) | -0.036* | (-2.18) |
| D{-14 to -10} | -0.076 | (-0.28) | -0.128* | (-2.53) | 0.166 | (0.07) | -0.033 | (-1.56) |
| D{-9 to -5} | -0.219 | (-0.83) | -0.086 | (-1.70) | 0.288 | (1.18) | -0.015 | (-0.63) |
| D{-4 t0 0} | 0.151 | (0.57) | 0.118* | (2.33) | 0.956** | (3.96) | -0.001 | (-0.09) |
| D{1 to 5} | -0.492 | (-1.66) | 0.099* | (1.96) | 1.745** | (5.78) | 0.080** | (3.07) |
| D{6 to $T$} | -1.496** | (-6.43) | 0.152** | (3.40) | 4.365** | (13.55) | 0.173** | (6.35) |
| $\chi^2$ | 52.26** | | 72.32** | | 42.84** | | 26.87** | |
| $R^2_{adj}$ | .012 | | .021 | | .056 | | .015 | |

| Interval | $Spd_{adj}$ | $t$ | $\sigma^2(Spd_{adj})$ | $t$ | $Spd_{adj}$ | $t$ | $\sigma^2(Spd_{adj})$ | $t$ |
|---|---|---|---|---|---|---|---|---|
| Corn | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| Conatant | 1.309** | (9.84) | 0.387** | (14.97) | 4.149** | (33.42) | 0.131** | (11.33) |
| D{-24 to -20} | -1.246** | (-4.89) | -0.157** | (-3.17) | -0.329 | (-1.33) | -0.002 | (-0.08) |
| D{-19 to -15} | -1.050** | (-4.11) | -0.163** | (-3.29) | 0.134 | (0.55) | -0.037 | (-1.48) |
| D{-14 to -10} | -0.972** | (-3.86) | -0.162** | (-3.26) | 0.379 | (1.46) | -0.041* | (-1.99) |
| D{-9 to -5} | -1.062** | (-4.16) | -0.160** | (-3.20) | 0.436 | (1.81) | -0.039 | (-1.36) |
| D{-4 to 0} | -0.973** | (-3.82) | -0.029 | (-0.59) | 1.025** | (4.28) | 0.008 | (0.04) |
| D{1 to 5} | -1.190** | (-4.67) | -0.038 | (-0.76) | 1.523** | (6.49) | -0.024 | (-0.94) |
| D{6 to $T$} | -1.729** | (-7.66) | 0.086* | (1.98) | 1.832** | (8.45) | 0.049* | (2.18) |
| $\chi^2$ | 72.02** | | 41.63** | | 39.59** | | 9.51 | |
| $R^2_{adj}$ | .021 | | .012 | | .023 | | .002 | |
| Cotton | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| Constant | -0.912** | (-11.73) | 0.328** | (20.08) | 0.365** | (4.62) | 0.140** | (14.13) |
| D{-24 to -20} | 0.012 | (0.07) | -0.059 | (-1.58) | 0.191 | (1.18) | -0.012 | (-0.60) |
| D{-19 to -15} | 0.107 | (0.57) | -0.015 | (-1.45) | 0.536** | (3.36) | -0.018 | (-0.93) |
| D{-14 to -10} | 0.247 | (1.39) | -0.024 | (-0.64) | 0.840** | (5.20) | -0.009 | (-0.47) |
| D{-9 to -5} | 0.367* | (2.07) | 0.163* | (2.36) | 0.730** | (4.62) | -0.069* | (-2.16) |
| D{-4 to 0} | 0.168 | (0.95) | 0.228** | (6.09) | 0.235 | (1.37) | 0.192** | (9.33) |
| D{1 to $T$ } | -0.041 | (-0.19) | 0.227** | (5.25) | -1.055** | (-4.37) | 0.518** | (16.98) |
| $\chi^2$ | 6.27 | | 92.56** | | 35.40** | | 88.28** | |
| $R^2_{adj}$ | .002 | | .031 | | .016 | | .071 | |

** and ** represent significance levels of 5% and 1%.*

the five contracts reveal only limited seasonality in leadership. We document no seasonal trends over the switching intervals (results available from the authors).

### Spread Patterns and the Burden of Convergence

Results of the regression of the standardized adjusted price spread ($SPR_{adj}$) on a constant and dummy variables representing the pre-switching, switching, and post-switching intervals are shown in Exhibit 6. We evaluate the coefficients in the respective intervals against an interval of all days at least 25 days preceding the first trading day of the delivery month [i.e., (*all days* ≤ –25), or more simply (≤ –25)]. The standardized adjusted spread is given by

$$100 * \left(\frac{P_X e^{-r_X X} - P_N e^{-r_N N}}{P_N e^{-r_N N}}\right)$$

where $r_X X$ represents the product of the six-month fixed-maturity Treasury bill rate and time to expiration of the next-to-nearby contract, and $r_N N$ represents the product of the three-month fixed-maturity Treasury rate and time to expiration of the nearby contract.[10]

Exhibit 6 also reports the results from regressions of the absolute changes in this variable [i.e., $\sigma(SPR_{adj})$] on a constant and dummy variables (denoted $D\{\}$). The coefficients from the two sets of regressions will indicate the extent to which the spread and the variance of the spread differ from the control interval (≤ –25 interval). A priori, while there is no clear expectation on the coefficients from the ($SPR_{adj}$), there are grounds to expect positive coefficients for the switching period in the $\sigma(SPR_{adj})$ regressions. Following anecdotal evidence, one would expect to find a rise in the variation in the spread during the switching period.

The results of the $SPR_{adj}$ regressions suggest that the spread does undergo changes from the control interval to the switch period, especially when evaluated over half-hourly intervals. For instance, the coefficients for dummy variables representing the switching intervals are generally positive and significant for the intraday regressions, suggesting that the spread widens within the day over the switching period.

There is weaker evidence of spread patterns evaluated over settlement prices. This may simply be the result of settlement prices closer to their theoretical (cost-of-carry-adjusted) values relative to the intraday prices. For corn, we find $SPR_{adj}$ computed from settlement prices to actually shrink over contract maturity.

The $\sigma(SPR_{adj})$ regressions fail to suggest that the switching activity increases variation in the spread. The switching period coefficients are never positive for the intraday regressions and only sporadically positive for daily regressions. The results, however, clearly indicate that $\sigma(SPR_{adj})$ is significantly higher in the last weeks of trading. The coefficient estimates for $D\{6 \text{ to } T\}$ are consistently significant and positive for both the daily and half-hourly regressions. Thus, there is substantial evidence that the variability in the spread rises only in the expiration month, after the majority of switching activity has already occurred.

We also assess the role contract switching might have on the burden of spread convergence for the two contracts. In Exhibit 7 we report the coefficients for the decomposed error correction terms in the error correction model [Equations (3-A) and (3-B)]. We report results for both half-hourly and daily data.

The F-values suggest that the next-to-nearby contract Granger-causes the nearby contract in oats and corn, and there is dual causality in cotton. The $\lambda_{N,3}$ coefficient is consistently positive, suggesting that the nearby contract bears an abnormally high burden of convergence to the spread in the final days of trading. Note also that the $\lambda_{X,3}$ coefficient is either positive or zero, suggesting that the next-to-nearby contract bears a less-than-normal convergence burden during this period. The $\lambda_{N,2}$ coefficient is generally non-positive (coffee is an exception), which would suggest that the nearby contract does not bear an abnormally high burden of convergence during the switching period.

Overall, there is little evidence to indicate that the sharp change in liquidity dominance over the switching period results in a major change in convergence patterns. Yet there is evidence to indicate that the burden of convergence shifts strongly to the nearby contract in the last few days of trading. When we use the unadjusted spread, $(P_X - P_N)_{t-1}$, as the error-correction ($z_{t-1}$) variable, the results are similar.

## IV. SUMMARY AND CONCLUSIONS

We employ daily and intraday data on three grains and two soft commodities to examine whether contract-switching periods show price and spread patterns that are notably different from other periods.

We demonstrate the problem of establishing the switching point itself, and suggest that for the markets we examine it falls approximately between the first day of the delivery month and 20 trading days prior. The main findings relating to intracommodity behavior may be summarized as follows.

## EXHIBIT 7
**Spread Convergence**

| Interval | $\Delta P_N$ | $t$ | $\Delta P_X$ | $t$ | $\Delta P_N$ | $t$ | $\Delta P_X$ | $t$ |
|---|---|---|---|---|---|---|---|---|
| **Wheat** | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| $\lambda_1$ | 0.013 | (1.29) | 0.003 | (0.31) | 0.003 | (0.99) | 0.001 | (0.35) |
| $\lambda_2$ | -0.22 | (-1.36) | -0.008 | (-0.57) | -0.005 | (-1.53) | -0.004 | (-1.30) |
| $\lambda_3$ | 0.070** | (4.81) | 0.025* | (2.03) | 0.006 | (1.99) | -0.003) | (-1.07) |
| $F_N$ | 1.75 | | 3.72* | | 3.06* | | 0.05 | |
| $F_X$ | 0.18 | | 1.62 | | 1.77 | | 0.71 | |
| **Coffee** | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| $\lambda_1$ | -0.003 | (-0.17) | -0.018 | (-1.15) | -0.008 | (-0.82) | -0.008 | (-0.93) |
| $\lambda_2$ | 0.049 | (1.71) | 0.032 | (1.27) | 0.028* | (2.34) | 0.009 | (0.76) |
| $\lambda_3$ | 0.069** | (2.68) | 0.061** | (2.68) | 0.063** | (3.63) | 0.031* | (1.99) |
| $F_N$ | 15.63** | | 2.52 | | 3.78** | | 6.59** | |
| $F_X$ | 17.86** | | 3.03* | | 1.20 | | 11.83** | |
| **Oats** | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| $\lambda_1$ | -0.007 | (-0.41) | -0.013 | (-0.79) | -0.002 | (-0.35) | -0.004 | (-0.64) |
| $\lambda_2$ | -0.003 | (-0.15) | 0.005 | (0.25) | -0.008 | (-1.18) | -0.005 | (-0.68) |
| $\lambda_3$ | 0.104** | (4.50) | 0.035 | (1.69) | 0.010* | (1.97) | 0.001 | (0.25) |
| $F_N$ | 1.65 | | 5.81** | | 2.40 | | 2.741* | |
| $F_X$ | 5.13** | | 4.91** | | 4.98** | | 0.99 | |
| **Corn** | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| $\lambda_1$ | 0.045** | (3.76) | 0.029** | (2.77) | 0.005 | (1.59) | 0.003 | (1.27) |
| $\lambda_2$ | -0.090** | (5.84) | -0.049** | (3.65) | -0.007* | (-2.14) | -0.006** | (-2.90) |
| $\lambda_3$ | 0.057** | (3.87) | 0.021 | (1.64) | 0.006 | (1.95) | -0.004 | (-1.42) |
| $F_N$ | 6.20** | | 0.91 | | 12.07** | | 0.325 | |
| $F_X$ | 14.65** | | 5.68** | | 5.80** | | 2.00 | |
| **Cotton** | Daily | | Daily | | Half-Hourly | | Half-Hourly | |
| $\lambda_1$ | 0.045** | (3.15) | 0.22 | (1.76) | -0.004 | (-0.71) | -0.006 | (-1.30) |
| $\lambda_2$ | -0.063** | (-2.87) | -0.054** | (-2.80) | -0.001 | (-0.14) | 0.003 | (0.53) |
| $\lambda_3$ | 0.261** | (7.47) | 0.144** | (4.69) | 0.057** | (5.30) | 0.004 | (0.52) |
| $F_N$ | 21.25** | | 13.49** | | 20.25** | | 6.64** | |
| $F_X$ | 12.39** | | 9.46** | | 15.38** | | 10.97** | |

** and ** represent significance levels of 5% and 1%.*

First, contract switching has more of an impact on the volatility in nearby contract prices. The difference in the return volatility of the nearby and next-to-nearby contracts rises during the contract-switching period for most commodities.

Second, the correlation between the nearby and next-to-nearby contract remains fairly high through the switching period, and declines sharply in the last week of trading.

Third, there is little evidence to indicate that the sharp decline in trading activity in the nearby contract over the switching period is accompanied by a rise in leadership (in the causality sense) in the more liquid next-to-nearby contract. The nearby contract's returns are determined to lag the next-to-nearby contract only in the last few days prior to expiration.

Fourth, the switching activity is found not to have an important impact on the variation in the difference in prices of the two contracts (the spread). The variation in the spread rises abnormally after the switching interval in the few days prior to expiration.

Fifth, it is only in the last week of trading that the nearby contract is found to bear the burden of convergence to the spread.

Taken together, the evidence in our intracommodity analysis suggests that the nearby contract is not a lame duck until the last few days of trading, if we define lame duck as the market that lags the other, or one in which there is no price discovery. To some extent, this is unexpected, as media attention and (more important) trader attention generally turn to the next-to-nearby contract weeks prior to the first notice day. The focus on the next-to-nearby contract at this stage might signal the emergence of this contract as the contract of choice.

What we do find is that the switching process lasts for several days and that the nearby contract continues to trade actively until close to expiration. Our results also indicate that the link between liquidity and price discovery may be somewhat tenuous in futures markets, where the value in arbitrage is fairly well defined.

## ENDNOTES

[1]The data are obtained from Tick Data, Inc., which screens the data for gaps and bad ticks.

[2]The return for the first intraday half-hour is computed by taking the price relatives of the closing and opening price of that interval. The formulation for daily returns is for close-to-close (CTC) prices. Some tests also use daily returns computed from open-to-close (OTC) prices and close-to-open prices (CTO).

[3]A standard result for normally distributed variables is $E(|x|) = (2/\pi)^{0.5}\sigma$ (see, e.g., Ane and Geman [2000]).

[4]Specifically, we use the univariate GARCH model in estimation of the intraday standardized $\omega$ statistic:

$$h_{N,i} = \delta_0 + \delta_1 h_{N,i-1} + \delta_2 \hat{e}^2_{N,i-1} + \delta_3 e^2_{N,i-1} D^o_i + \delta_4 e^2_{N,i-1} D^c_i + \psi_{N,i}$$

where $h_{N,i}$ is the variance of the variable $\hat{e}_{N,i}$ and $D^o_t$ ($D^c_t$) is a dummy variable taking a value of 1 if $i$ falls at the market's open (close). The motivation for such controls is the presence of deeply U-shaped volatility patterns in half-hourly returns in each commodity.

[5]We also use the lagged unadjusted spread, $(P_X - P_N)_{t-1}$, for the $z_{t-1}$ variable in these tests.

[6]Daily volatility reported in Exhibit 2 is computed using the mean of the absolute return. Volatility statistics using an alternative measure do not differ materially.

[7]Examining results for trading volatility, we note that switching activity results in elevated levels of trading volatility, particularly for the nearby contract. The hypothesis that trading volatility in the switching period is equal to that in the pre-switching period is rejected for all commodities. At first blush, one should not construe this as proof of switching activity leading to increased volatility, since the test may be biased to reject the null too often. According to Samuelson [1965], futures return volatility is expected to increase as one gets closer to expiration for reasons other than switching activity (see Bessembinder et al. [1996]). Further examination also reveals that trading volatility for coffee and oats in the switching period is greater than in the post-switching period, contrary to Samuelson. Additionally, there is no evidence that post-switching period volatility is greater than switching period volatility for the other three markets. Thus, it appears that the switching activity increases trading volatility.

[8]It is also possible that the bouncing of the two contracts' half-hourly prices between mostly stationary bid and ask prices will induce (artificial) negative serial correlations and negative lead-lag correlations in both directions. Thus, our inferences must be tempered to the extent that this is manifest. We thank the reviewer for pointing this out.

[9]The patterns in the $\omega$ statistics are similar to those in the standardized $\omega$. Thus, we do not report the $\omega$ statistics, but these results are available on request.

[10]The Treasury yields are extracted from the Federal Reserve Statistical Release H.15.

## REFERENCES


Ane, Thierry, and Helyette Geman. "Order Flow, Transaction Clock, and Normality of Asset Returns." *Journal of Finance*, v. 55 (October 2000), pp. 2259-2284.

Barry, Christopher B., and Robert H. Jennings. "The Opening Price Performance of Initial Public Offerings of Common Stock." *Financial Management*, v. 22(1) (1993), pp. 54-63.

Bessembinder, Hendrik, Jay F. Coughenour, Paul J. Seguin, and Margaret Monroe Smoller. "Is There a Term Structure of Futures Volatilities? Reevaluating the Samuelson Hypothesis." *The Journal of Derivatives*, v. 4 (Winter 1996), pp. 45-58.

Chambers, Marcus J., and Roy E. Bailey. "A Theory of Commodity Price Fluctuations." *Journal of Political Economy*, v. 104, (5) (October 1996), pp. 924-957.

Conrad, Jennifer, Mustafa N. Gultekin, and Gautam Kaul. "Asymmetric Predictability of Conditional Variances." *Review of Financial Studies*, v. 4(4) (1991), pp. 597-622.

Deaton, Angus, and Guy Laroque. "On the Behavior of Commodity Prices." *Review of Economic Studies*, v. 59(198) (1992), pp. 1-24.

Garbade, Kenneth D., and William Silber. "Dominant and Satellite Markets: A Study of Dually-Traded Securities." *Review of Economics and Statistics*, v. 61(3) (1979), pp. 455-460.

Hamao, Yasushi, Ronald W. Masulis, and Victor Ng. "Correlations in Price Changes and Volatility Across International Stock Markets." *Review of Financial Studies*, v. 3(2) (1990), pp. 281-308.

Harris, Frederick deB., Thomas H. McInish, Gary L. Shoesmith, and Robert A. Wood. "Cointegration, Error Correction, and Price Discovery on Informationally Linked Security

Markets." *Journal of Financial and Quantitative Analysis*, v. 30(4), (1995), pp. 563-579.

Hasbrouck, Joel. "One Security, Many Markets: Determining the Contributions to Price Discovery." *Journal of Finance*, v. 50(4) (1995), pp. 1175-1199.

Karolyi, G. Andrew, and René M. Stulz. "Why Do Markets Move Together? An Investigation of U.S.-Japan Stock Return Comovements." *Journal of Finance*, v. 51(3) (July 1996), pp. 951-986.

Karpoff, Jonathan M. "The Relation Between Price Changes and Trading Volume: A Survey." *Journal of Financial and Quantitative Analysis*, v. 22(1) (1987), pp. 109-126.

Kyle, Albert S. "Continuous Auctions and Insider Trading." *Econometrica*, v. 53(6) (1985), pp. 1315-1336.

Lo, Andrew W., and A. Craig MacKinlay. "When Are Contrarian Profits Due To Stock Market Overreaction?" *Review of Financial Studies*, v. 3(2) (1990), pp. 175-206.

Mech, Timothy S. "Portfolio Return Autocorrelation." *Journal of Financial Economics*, v. 34(3) (1993), pp. 307-344.

O'Hara, Maureen. *Market Microstructure Theory.* Malden, MA: Blackwell Publishing, 1997.

Roll, Richard. "Orange Juice and Weather." *American Economic Review*, v. 74(5) (1984), pp. 861-880.

Routledge, Bryan R., Duane J. Seppi, and Chester S. Spatt. "Equilibrium Forward Curves For Commodities." *Journal of Finance*, v. 55(3) (June 2000), pp. 1297-1338.

Samuelson, Paul. "Proof that Properly Anticipated Prices Fluctuate Randomly." *Industrial Management Review*, v. 6 (1965), pp. 41-63.