Crop Year Influences and Variability of the Agricultural Futures Spreads

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INTRODUCTION

Section 4a of the Commodity Exchange Act (CEA) provides limits on speculative trading on the premise that excessive speculation may lead to excessive price volatility. This section directs the Commodity Futures Trading Commission (CFTC) to set speculative position limits on futures and options contracts and explicitly exempts bona fide hedged positions. The CFTC directly sets limits on agricultural futures and options con-

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tracts and mandates the exchanges to adopt and enforce limits where the Commission has not established speculative position limits.[1]

The CFTC has assigned higher speculative position limits on intra-crop year spread positions than on inter-crop year spread positions. Exchanges have also set higher margin requirements on inter-crop year spread positions than intra-crop year spread positions. The CFTC's basis for different treatment of spread positions within and across crop years rests on the hypothesis that there can be a substantial difference in the market impact of spreads which are between months of the same crop year from those which are cross crop years.[2] A corollary which follows is that inter-month spreads across crop years may, under certain circumstances, act more like separate outright positions than spreads which are in the same crop year.

The purpose of this article is to examine this hypothesis considering both the relevant economic theory and empirical behavior of inter- versus intra-crop year spreads from July, 1983 to August, 1991. This study provides pertinent information to policy makers considering issues involving inter- and intra-crop year spread trading such as speculative position limits and margin requirements. Furthermore, the empirical results demonstrate that the crop year is another factor affecting agricultural futures spreads in addition to the length-of-month effect as suggested by Castelino and Vora (1984).

The major empirical findings are summarized as follows: (1) In general, futures price changes within and across crop years are highly correlated. However, the null hypothesis that the correlation between the legs of inter-crop year spreads equal that of intra-crop year spreads is rejected in most cases. (2) During the sample period, a few situations involving inter-crop year spreads are identified where price changes in the legs of spreads were statistically independent. (3) The intra-crop year spread volatility seems to differ from the volatility of its legs by an order of magnitude while inter-crop year spread volatility differs from the volatility of its legs only marginally. (4) The changes in inter-crop year spreads are often more volatile than those of intra-crop year spreads. (5) The mean values of most inter-crop year spreads are negative numbers (old crop prices are greater than new crop prices), while most of the mean values of intra-crop year spreads are positive or near zero.

These results are consistent with the theory of the price of storage and can be explained by differences in the marginal convenience yield of holding inventory of a commodity at different points in time.

[1]The CFTC determines the speculative position limits for corn, oats, wheat, soybean oil, soybean meal, and cotton.

[2]Further discussion can be found in the Federal Register / Vol. 53, No. 120, 23412.

The organization of this article is as follows. It briefly reviews the theory of the price of storage and then analyzes the behavior of inter-crop year spreads within the framework of the theory; describes the data and construction of spreads; and presents the statistical procedures employed. Empirical results are analyzed and the conclusions are presented in the final section.

THE THEORY OF THE PRICE OF STORAGE AND INTER-CROP YEAR SPREADS

The Theory of the Price of Storage and Spread Behavior

Working (1948, 1949) expanded the theory of the price of storage to explain inter-temporal price relationships between cash and futures as well as relationships between futures contracts of different delivery months. This theory has successfully explained the futures price behavior of seasonally harvested storable commodities. In essence, the theory states that the price difference between cash and futures or the difference between two futures contracts is equal to the cost of storage minus the marginal convenience yield of holding the current stock of a commodity at time t. The storage cost includes interest expense, insurance, and the direct cost associated with physical storage of the commodity. The incorporation of the marginal convenience yield is critical to explaining the existence of a negative price of storage. The marginal convenience yield is negatively related to the level of stock and rises at an increasing rate when stock levels are low. Conversely, the marginal convenience yield approaches zero when the level of inventory is high.[3]

According to the theory, when the current inventory level is adequate, the convenience yield from holding stocks is also negligible and arbitrage ensures that price differences (between cash and futures or two futures of different delivery months) have an upper limit, which is equal to the full cost of carry. Hence, when the level of inventory is adequate, temporal price relationships are closely linked by arbitrage to maintain the cost of storage relationship. When inventory levels of seasonally produced storable commodities are unusually low, sudden shifts in the demand for storage can be expected to generate large changes in the price

[3]Keynes (1930) and Hicks (1939) attribute a negative basis to the premium hedgers pay to speculators to shift price risk. Thus, there are several possible sources of a negative price spread: (1) Convenience yield; (2) risk premium; (3) asymmetric information [Khouny and Martel (1989)] and (4) aggregation [Wright and Williams (1991)]. For more literature on risk premiums and empirical evidence, see Kamara (1982), and others.

of storage. When shortages occur, the convenience yield from holding stocks becomes dominant, allowing the nearby price to be bid up. As a consequence, the difference between cash and futures or the difference between two futures becomes negative.

The theory of the price of storage cost provides an economic basis to predicate (analyze) a different behavior of inter- versus intra-crop year spreads. For example, it is expected that when the legs of intra-crop year spreads are priced off the same crop year's inventory, the legs will be closely linked whether inventory is adequate or low. On the other hand, the legs of inter-crop year spreads can be expected to behave differently when shortage conditions exist in the current period. Since there is generally no reason to believe that shortage conditions will exist in future crop years, those prices are relatively unaffected by the current crop shortage while the nearby prices will be bid up to reflect the current scarcity. Thus, the prices of the legs of the inter-crop year spreads will not move closely together and are therefore, less correlated relative to intra-crop year spreads. As a result, inter-crop year spread changes will be more volatile than intra-crop year spread changes.

In general, the literature dealing with improving and empirically testing the theory of storage is extensive.[4] However, only two previous studies have provided evidence that the legs of the spreads between inter-crop futures are less related than legs of the spreads between intra-crop year futures. Working (1933) demonstrated that the price differences for May–July futures contracts for wheat are less correlated in a period where spreads are negative than in a period where spreads are positive. Telser (1958) showed that the volatility of inter-crop year spreads is larger than that of intra-crop year spreads (for cotton and soybean futures in the period from 1926 to 1954).

This study extends the findings of previous studies by using recent data to perform large-scale empirical tests of the hypotheses that inter-crop year spreads are more violate than intra-crop year spreads for seven agricultural commodities within the framework of the theory of storage. Two proxy measures are employed which permit inferences on changes

[4]A major addition to the theory involves the measurement of the level of stock. Telser (1958) and Gray and Peck (1981) demonstrated that the price of storage is determined by the current stock available for delivery, rather than by the total level of current stock. Weymar (1966) made an additional contribution arguing that the expected level of stock between two futures' time periods is more of an influence than the current level of stock for the determination of the price of storage for two distant futures contracts. Additional literature with respect to the theory includes Tomek and Gray (1970) (soybeans), Ward and Dasse (1977) (frozen concentrated orange juice), Thompson (1986) (coffee, and cocoa), Fama and French (1989) (industrial and precious metals), and Cho and McDougall (1990) (crude oil and gasoline), and others.

in the inventory.[5] Two measures are used to demonstrate that each leg of the spread changes are equivalent and complement each other. The first measure is a correlation of each leg of spread changes and the second one is the volatility of corresponding spread changes.

Inventory Patterns over the Crop Year and Inventory Proxies

Inventories of seasonally-harvested, storable commodities exhibit the following pattern through the crop year. During the first quarter of the crop year, inventories build up as new-crop harvest is added to the inventory left over from the previous crop year. After reaching a peak, inventory slowly declines over the rest of the crop year.[6]

The inventory pattern over the crop year and the theory of the price of storage have implications regarding the construction of inventory proxies. In a world where this theory holds, low inventories are a necessary condition for price inversions. Therefore, the observance of negative spreads may be used as a proxy for periods of low inventory. Also, the assumption of the behavior of the inventory pattern over the crop year implies a crop year quarter may be used as a proxy for the inventory level.

Under these assumptions, it follows that the periods of greatest relative scarcity occur at the end of the crop year. Further, because shortage conditions influence the near leg but not the deferred leg, inter-crop year spreads are more likely to exhibit inverse carrying charges.

THE DATA SOURCES AND CONSTRUCTION OF THE SPREADS

The Data Sources

The seven commodities selected in this analysis are (1) corn, (2) oats, (3) wheat, (4) soybeans, (5) soybean oil, (6) soybean meal, and (7) cotton #2. The first six commodities are traded at the Chicago Board of Trade (CBOT) and cotton #2 is traded at the New York Cotton Exchange (NYCE).[7]

The sample period is from July, 1983 through August, 1991.[8] The 8 year sample period is considered to be of sufficient length to examine

[5]A discussion on the measurement of inventory problem can be found in Fama and French (1988).
[6]Further discussion can be found in Kolb (1991), Chapter 5.
[7]Wheat, corn, and soybeans are also traded on the Minneapolis Grain Exchange and MidAmerica Commodity Exchange.
[8]The daily data from CFTC futures data bank for periods before July, 1983 was not edited. Hence only data after July, 1983 is used in the analysis.

TABLE I

Specifics Used in the Construction of Crop Year Quarters for Seven Agricultural Commodities

Commodity	*First Future*	*Last Future*	*Transitional Month*	*Crop Season*
Cotton	Oct.	July	Oct.	Aug.–July
Corn	Dec.	Sept.	Sept.	Oct.–Sept.
Oats	July	May	None	June–May
Soybean	Sept.	Aug.	Sept.	Sept.–Aug.
Soybean meal	Oct.	Sept.	Sept.	Oct.–Sept.
Soybean oil	Oct.	Sept.	Sept.	Oct.–Sept.
Wheat	July	May	None	June–May

Construction of crop year quarters based upon the crop season instead of calendar year. For example cotton's crop year is devided as follows: quarter 1 includes August, September, October; quarter 2 includes November, December, January; quarter 3 includes February, March, April; and quarter 4 includes May, June, July.

recent inter-crop year spread behavior over various economic situations and provides an opportunity to identify the conditions, if any, under which prices across inter-crop years are independent.

As a result of changing inventories over the crop season, the crop year quarter is employed as an indicator variable to proxy changing levels of stock through the crop season. Table I presents definitions of crop-year and crop season (by quarters) for the seven agricultural commodities which are used in construction of the spreads.

Spreads are computed using daily settlement prices over the sample period for 3 intra- and 2 inter-crop year spreads based upon the following rationale.

Construction of Spreads

In choosing the intra- and inter-crop year spreads, it is believed that the spreads should possess the following characteristics: (1) the legs of the spread should have ample liquidity; (2) the spreads should be commonly traded; and (3) the legs of inter-crop year spreads should be situated at crucial points (points of maximum discontinuity of supply) in the crop years. Each of the five spreads analyzed include at least some of the desired characteristics, and when taken as a whole, include all of the characteristics.

- *The Nearby versus the First Deferred Old Crop Spread (Intra 1)*—It is probably the most commonly traded intra-crop year spread. This spread is actively used and is reflective of the fundamental factors of the old-crop year. However, this spread may be subject to factors that are peculiar to short-time-periods-to-expiration such as position concentrations rather than market to fundamentals.

- *First-Deferred versus Second-Deferred Old Crop Spread (Intra 2)*—This spread is less liquid than Intra 1, but still actively traded, and will be relatively unaffected by the concerns described above involving the nearby month.
- *First Delivery Month versus Second Delivery Month in New-Crop Spread (Intra 3)*—This spread, although relatively illiquid compared to old-crop spreads, is included to examine the behavior of spreads within the new crop.
- *Nearby Old-Crop Futures versus First Non-Transitional New-Crop Futures (Inter 1)*—This spread includes the most actively traded old-crop and new-crop futures, and is probably the most actively traded inter-crop year spread. In terms of fundamentals, it contrasts a price based upon nearby demand and supply factors versus a price based upon the market's current anticipation of future demand and supply factors prevailing just after the harvest of the new crop.
- *Last Futures in Old-Crop versus First Non-Transitional New-Crop Futures (Inter 2)*—This spread is believed to best illustrate the pricing consequences of the discontinuous supply resulting from the seasonal production cycle of agricultural commodities. Supplies are generally approaching the seasonal low as the last future of the old crop year approaches expiration, while supplies are at the seasonal high just as the first non-transitional new-crop futures approach expiration. Consequently, this spread is typically the most inverted and should most clearly demonstrate whether and under what conditions the prices of futures months in different crop years behave differently.

To avoid distortions due to congestion during the delivery period, no spot month contracts (nearby contracts on or after first notice day) are used in the analysis. Futures months that are transitional between the old crop and the new crop are excluded from the inter-crop year spreads but included in intra-crop year spreads so as to err on the side of conservatism in comparing the volatility of inter- versus intra-crop year spreads.

Since these spreads will not generally be of equal time intervals, the volatility of price changes will be greater for spreads of greater length.[9]

[9]This argument is based on the empirical evidence that future prices usually behave as a random walk.

Therefore, the spreads are standardized to reflect one month's equivalent spread changes.[10] It should be noted that some of the statistical measures report empty cells at times because one or both of the component prices of the spreads have expired.

STATISTICAL PROCEDURES

Direct and indirect statistical procedures proposed here are designed to measure the degree of dependence between price changes across and within crop years.

The first measure, the Spearman Rank correlation, is employed as a direct measure of the contemporaneous relationship between futures price changes of different delivery months.[11] If the correlation coefficient between price changes across crop years is nearly zero, it implies that price changes in each leg are nearly independent. On the other hand, when price changes across crop years are closely related, the correlation coefficient should be close to one.[12] Student t-statistics are used to test the null hypothesis that the correlation coefficient is equal to zero.[13] The Fisher's Z transformation is employed to test the equality of two correlation coefficients.[14]

The variance is used to indirectly measure the degree of dependence between price changes by: (1) comparing the variance of spread changes across and within crop years; and (2) comparing the variances of spread changes with the variances of the corresponding legs of the spread. These measures provide additional information on the risk behavior of spreads and their associated legs. Since the volatility of spreads per month is of interest in this study, spreads are adjusted by dividing by the square root

[10]This adjustment procedure depends upon the purpose of the study. If the researcher is interested in comparing the spread per month, the proper adjustment factor is found by dividing by the month length of the spread [see Williams (1986)]. This study is interested in the volatility of the spreads per month. The proper adjustment is, therefore, to divide by the square root of the month length. In the study by Dutt, Fenton, Smith, and Wang (1991), inter- and intra-crop year spreads with equal month length were constructed.

[11]Typical empirical distributions of inter-crop-year spreads are skewed to the left by a few large negative values. Given this situation, the perason correlation coefficient [Dutt, Fenton, Smith, and Wang (1991)] may be distorted due to its sensitivity to extreme values. For this reason, Spearman rank correlation is employed also.

[12]Residual cross correlation of price changes may be preferred if either of two futures price changes are still autocorrelated.

[13]For testing the null hypothesis that rho = 0, the following t-statistic with $(n - 2)$ degrees of freedom is used: $t = r/(n - 2)^{1/2}/(1 - r^2)^{1/2}$ where r is the estimated correlation coefficient and n is sample size.

[14]The Fisher's Z transformation is $Z = 1/2\text{Ln}((1 + r)/1 - r))$ were r is the estimated correlation coefficient. Z is distributed almost normally with a standard error approximately $\sigma_z = 1/(n - 3)^{1/2}$ and n is the sample size.

of the month length and subsequently computing the variance of the adjusted spreads. In this way, the sources of volatility due to different spread lengths are removed. For comparison purposes, variance of the spread changes within crop years is used as a benchmark with which to compare the relative dependence of price changes within a crop year versus the dependence across crop years.

To explain the relationship between these two measures, the spread is defined as $S_t = P_t, T_2 - P_t, T_1$ where P_t, T_2 and P_t, T_1 are futures prices at time t and maturity at T_2, T_1, respectively, and $T_2 > T_1$. For simpler presentation, let $T_2 = 2$ and $T_1 = 1$.

The change in the spread is defined as $\Delta S_t = S_t - S_{t-1} = \Delta P_{t2} - \Delta P_{t1}$ where Δ denotes $(1 - B)$ and B is a backward shift operator. The variance of the changes in an inter-crop spread can be written as:

$$\mathrm{Var}(\Delta S_t) = \mathrm{Var}(\Delta P_{t2}) + \mathrm{Var}(\Delta P_{t1}) - 2\mathrm{Cov}(\Delta P_{t2}, \Delta P_{t1})$$

In words, the variance of the spread changes is the sum of three components: (1) the variance of ΔP_{t2}; (2) the variance of ΔP_{t1}; and (3) the $\mathrm{Cov}(\Delta P_{t2}, \Delta P_{t1})$. If P_{t2} in the new crop year is independent of P_{t1} in the old crop year, then $\mathrm{Cov}(\Delta P_{t2}, \Delta P_{t1}) = 0$, and $\mathrm{Var}\,(\Delta S_t)$ is at a maximum.[15] On the other hand, if P_{t2} and P_{t1} are in the same market (the extreme opposite case), then $\mathrm{Var}(\Delta S_t) = 0$. Therefore, if the magnitude of $\mathrm{Var}(\Delta S_t)$ is close to the sum of $\mathrm{Var}(\Delta P_{t2})$ and $\mathrm{Var}(\Delta P_{t1})$, it implies that price changes across crop years are nearly independent. If the variance of the spread changes is significantly less than the sum of the variances of the price changes of the legs, it implies that the correlation of price changes is high. Hence, the two measures have a negative relationship.

EMPIRICAL RESULTS

The empirical analysis is conducted under two levels of data aggregation. The first method, a temporal disaggregate analysis, organizes and analyzes the data by the respective crop year quarters of each commodity. This is done by dividing each commodities' crop year into approximately four 12-week quarters and then constructing relevant statistics. This type of analysis provides an opportunity to identify particular time periods where the two legs of the spread are statistically independent. It also furnishes the empirical distribution of the various estimates. The major weakness of

[15]Certainly, if cov ($\Delta Pt2$, $\Delta Pt1$) is negative (i.e., two price move in totally different direction) then $\mathrm{Var}(\Delta \mathrm{St}) > \mathrm{Var}\,(\Delta \mathrm{Pt2}) + \mathrm{Var}(\Delta \mathrm{Pt1})$). However, the theory of the price of storage rules out this situation for a storable commodity with continuous inventories.

this approach is that the sample size for the crop year quarters are relatively small.

The temporal aggregate analysis, the second method employed, pools the crop year quarters across calendar years. This method utilizes larger sample sizes to deliver more reliable estimates, and allows an indirect test of the theory of the price of storage. Examination of the proportion of negative spreads throughout the crop year quarters indirectly tests observed behavior with expected behavior as implied by theory. Following the assumption of declining inventory in the latter part of the crop year, theory suggests an increase in the proportion of negative spreads throughout the corresponding period.

Temporal Disaggregate Analysis

The results of the temporal disaggregate method include:

1. A discussion of the summary statistics for the variances and correlations of the spread changes.
2. An analysis of correlations to identify those crop year quarters where statistical independence between the legs of the inter- and intra-crop year spreads exist.
3. A discussion of two hypothesis tests on the disaggregate data.

Table II presents summary statistics from empirical distributions of sample estimates of the variance of spread changes and the Spearman Rank Correlations of its legs for the seven commodities. These results suggest that the mean sample variance of the spread changes is generally higher for inter-crop year spreads. For example, soybean oil's mean sample variances of spread changes are 0.3817, 0.3174, and 0.4491 (for intra 1, intra 2, and intra 3, respectively) while the estimates of inter 4 and inter 5 are larger at 1.439 and 0.6602, respectively. The mean Spearman Rank Correlation estimates of inter-crop year spreads are also lower. Mean correlation estimates are generally in the 90% range for intra-crop year spreads and the 70 to 80% range for the inter-crop year spreads. The dispersion of inter-crop year spreads also appears to be greater.

Table III presents a summary of the occurrences of statistical independence between the legs of the spreads for each type of spread at a 5% level of significance. Over the sample period, there are 11 cases where the legs of the inter-crop year spreads are independent, while there are no cases of statistical independence for intra-crop year spreads. Wheat, soybean oil, and soybean meal are free from independence in both intra-

TABLE II

Summary Statatistics for: Variance of Spread Changes (× 100 Except Soymeal) Spearman Correlations of Spread Legs

Intra-Crop Year Spread (Intra 1): Nearby—1st Deferred

	Spread Change Variance			*Spearman*		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Cotton	2.401	7.381	0.6014	0.9391	0.9890	0.7182
Corn	0.0034	0.0188	0.0005	0.9389	0.9872	0.7805
Oats	0.0030	0.0214	0.0003	0.9301	0.9903	0.7660
Wheat	0.0053	0.0228	0.0017	0.9436	0.9843	0.8010
Soybeans	0.0388	0.7611	0.0013	0.9764	0.9970	0.8538
Soymeal	0.3451	3.0341	0.0069	0.9652	0.9972	0.8329
Soyoil	0.3817	2.83	0.0249	0.9821	0.9947	0.9361

Intra-Crop Year Spread (Intra 2): 1st Deferred—2nd Deferred

	Spread Change Variance			*Spearman*		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Cotton	2.346	15.19	0.7158	0.9290	0.9887	0.6545
Corn	0.0020	0.0073	0.0006	0.9428	0.9835	0.8174
Oats	0.0020	0.0094	0.0005	0.9486	0.9879	0.8353
Wheat	0.0060	0.212	0.0015	0.9359	0.9789	0.7521
Soybeans	0.0075	0.0316	0.0012	0.9811	0.9953	0.9471
Soymeal	0.1703	0.6387	0.0179	0.9690	0.9939	0.8823
Soyoil	0.3174	3.11	0.0234	0.9863	0.9960	0.9628

Intra-Crop Year Spread (Intra 3): 1st Month in New Year—2nd Month in New Year

	Spread Change Variance			*Spearman*		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Cotton	2.303	13.42	0.4855	0.9089	0.9768	0.7503
Corn	0.0008	0.0026	0.0002	0.9671	0.9921	0.9090
Oats	0.0030	0.0117	0.0007	0.8886	0.9769	0.6523
Wheat	0.0034	0.0079	0.0010	0.9412	1	0.6820
Soybeans	0.0213	0.1019	0.0024	0.9473	0.9875	0.7993
Soymeal	0.3732	1.063	0.0306	0.9491	1	0.8350
Soyoil	0.4491	1.992	0.0909	0.9630	0.9949	0.8680

Inter-Crop Year Spread (Inter 4): Last Month in Old Year—1st Non-Transitional Month in New Year

	Spread Change Variance			*Spearman*		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Cotton	4.717	17.92	0.5201	0.6927	0.9594	−0.027
Corn	0.0084	0.0532	0.0010	0.7418	0.9856	0.0870
Oats	0.0059	0.0886	0.0005	0.8963	0.9809	0.6752

TABLE II (Continued)

Summary Statatistics for: Variance of Spread Changes (× 100 Except Soymeal)
Spearman Correlations of Spread Legs

Intra-Crop Year Spread (Intra 1): Nearby—1st Deferred

	Spread Change Variance			Spearman		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Wheat	0.0166	0.0721	0.0026	0.8562	0.9536	0.5521
Soybeans	0.0571	0.2176	0.0052	0.8691	0.9733	0.6241
Soymeal	0.9739	4.220	0.0501	0.8308	0.9749	0.5030
Soyoil	1.439	7.355	0.0505	0.9141	0.9944	0.7840

Inter-Crop Year Spread (Inter 5): Nearby—1st Non-Transitional Month in New Year

	Spread Change Variance			Spearman		
	Mean	*Max*	*Min*	*Mean*	*Max*	*Min*
Cotton	3.586	11.04	0.7262	0.6751	0.9330	0.0786
Corn	0.0049	0.0232	0.0012	0.7090	0.9758	0.2729
Oats	0.0043	0.0540	0.0004	0.8170	0.9751	0.2248
Wheat	0.0138	0.0823	0.0025	0.7705	0.9792	0.5224
Soybeans	0.0434	0.2027	0.0045	0.8231	0.9883	0.5447
Soymeal	0.5043	1.714	0.0291	0.7725	0.9867	0.3789
Soyoil	0.6602	4.372	0.0707	0.8850	0.9909	0.5248

TABLE III

Number of Times Spread Legs are Statistically Independent Measured by Spearman Correlation Estimates Temporal Disaggregate Analysis (Five Percent Level of Significance)

Type	*Corn*	*Cotton*	*Oats*	*Wheat*	*Soybean Meal*	*Soybean Oil*	*Soybean*
Intra 1	0/22	0/22	0/24	0/24	0/30	0/30	0/30
Intra 2	0/22	0/18	0/16	0/16	0/21	0/22	0/23
Intra 3	0/30	0/30	0/23	0/31	0/29	0/29	0/31
Inter 4	0/30	3/30	0/31	0/31	0/30	0/30	0/30
Inter 5	2/30	4/22	1/31	0/31	1/30	0/30	0/31

Out of about 940 quarterly estimates of correlations of various spread construct legs, 3% (28) of the time the null hypothesis that the spread legs are uncorrelated holds. The preponderance of these events occur in the inter-crop year spread constructs. However, many of these are associated with large standard errors which due apparently driven by unusually low numbers of observations (typically 12 to 16). In general, most correlation estimates are calculated from 50–60 observations.

To avoid independent occurrences due to sampling fluctuations, only estimates of greater than 20 observations are reported. This reduces the number of independent occurrences to 11. All occur in the inter-crop year spread constructs.
The numerator indicates the number of times the null hypothesis that rho-0 holds. The denominator indicates the number of sample estimates.

TABLE IV

Number of Times Inter-Crop-Year Spread Volatility Greater Than Intra-Crop-Year Spread Volatility[a] Disaggregate Analysis
(Five Percent Level of Significance)

Type	*Corn*	*Cotton*	*Oats*	*Wheat*	*Soymeal*	*Soyoil*	*'Beans*
Inter4/Intra1	12/22	12/22	10/24	15/24	21/30	23/30	24/30
Inter5/Intra1	10/22	10/22	6/24	13/24	15/30	16/30	24/30
Inter4/Intra2	17/22	9/15	11/16	10/16	18/22	17/22	20/23
Inter5/Intra2	17/22	7/15	5/16	6/16	18/22	16/22	19/23
Inter4/Intra3	30/30	22/30	4/23	22/30	15/26	14/28	27/31
Inter5/Intra3	29/30	16/22	4/23	21/30	10/26	8/28	18/31

There are 1024 crop-year quarters where inter-crop and intra-crop year variances (of spread changes) can be directly compared to determine whether inter-crop-year spreads are more volatile than intra-crop-year spreads, 641 times the null hypothesis that the two are equal is rejected.
The numerator is the number of times the null hypothesis that the volatility of the inter-crop year spread is equal to that of the intra-crop-year spread is rejected. The denominator is the total number of possible comparisons.
[a]Combined overall level of significance tests suggested by Fisher are performed. The test statistic is distributed chi-squared-$2\Sigma \ln P_i$ (i = 1 to n_i) where P_i is the P value of the significance level for each case and n_i is the number of cases. The degrees of freedom is ($2 \times n_i$). All chi-squared tests are significant at the 5% level.

and inter-crop year spreads. Cotton was found to exhibit the greatest number of occurrences. However, most of these cases (6) correspond to a change in the government's price support program of cotton during the 1985–1986 crop year which may have reduced available stocks for delivery.[16] For example, in the third crop year quarter of 1985 to 1986, inter-crop year spread # 4's spread legs correlation is estimated to be 0.027 (0.2084 standard error).

Most cases (8) of statistical independence occur in inter-crop year five (last futures in the old-crop first nontransitional new-crop futures). Since this inter-crop year spread incorporates futures months where the difference in the supply condition is at its most extreme, the results are consistent with previously stated expectations in (3.2).

F-tests are conducted comparing the variance of the spread changes of inter- and intra-crop years by quarter for each inter/intra combination. Table IV reports the number of times the null hypothesis is rejected. In general, Table IV showed that the null hypothesis was rejected about 62%

[16]Telser (1958), Gray and Peck (1981), and others provide arguments and evidences that government price supports (or loan programs) reduce current stock available for delivery and, hence, increase spread volatility.

of the time.[17] The Chi-square test suggested by Fisher is conducted.[18] This test provides a single test result for the null hypothesis over all crop year quarters. All but two of the chi-square test results are significant at the 1% level. In sum, the statistical tests support the assertion that inter-crop year spreads are more volatile than intra-crop year spreads.

In short, summary statistics of empirical distributions illustrate apparent differences on correlations and volatility of spread changes within and across crop years. The disaggregate temporal analysis identifies few crop year quarters where there is statistical independence between the spread legs for inter-crop year spreads. Finally, hypothesis tests confirm that inter-crop year spread volatility is greater than intra-crop year spread volatility.

Temporal Aggregate Analysis

The results of the temporal aggregate method include:

1. Analysis of correlations and spread averages segregated by the signs of the spread.
2. Analysis of the proportion of negative spreads occurring in inter- and intra-crop year spreads.
3. Analysis of correlations for inter- and intra-crop year spreads.
4. Analysis of volatility for the inter- and intra-crop year spreads changes and their legs.

Table V reports a summary of (1) correlations between the legs of the spreads; (2) mean values of all spreads and mean values of positive spreads and negative spreads as well as (3) the number of observations segmented by the sign of the spreads. For a given commodity, it appears that the correlations between futures price changes in the negative spreads are less than the correlations when the spread is greater than zero. Furthermore, most mean values of inter-crop years are negative and a greater proportion of observations of inter-crop years fall into the region of negative values. The converse is true for intra-crop year spreads. If the inventory pattern over the crop year behaves as assumed in (2.2), it would be consistent with the theory of the price of storage to state that these results indicating current levels of inventory are usually lower for inter-

[17]The tables containing p-values and degrees of freedom from which Table IV is derived are available from the authors.

[18]This test is described to some degree at the bottom of Table IV. Further discussion on this test can be found in Fisher (1970).

TABLE V

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					*Positive Spreads*					*Negative Spreads*				
QTR	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*
Cotton: Spearman Correlations															
1	0.969	0.961	0.925	0.803	0.746	0.976	0.965	0.946	0.943	0.846	0.921	0.947	0.912	0.733	0.693
2	0.966	0.930	0.923	0.708	0.668	0.970	0.951	0.914	0.709	0.700	0.957	0.890	0.925	0.710	0.666
3	0.905	*	0.950	0.750	0.697	0.898	*	0.952	0.851	0.836	0.895	*	0.950	0.733	0.675
4	*	*	0.910	0.714	*	*	*	0.917	0.870	*	*	*	0.904	0.675	*
Cotton: Mean Values of Standardized Spread															
1	0.445	0.236	−0.739	−1.960	−1.020	0.558	0.409	0.185	0.375	0.668	−0.252	−0.522	−1.140	−2.770	−1.830
2	0.193	−0.115	−0.533	−1.780	−1.470	0.468	0.291	0.094	0.235	0.558	−0.560	−0.688	−0.726	−2.130	−1.960
3	−0.382	*	−0.695	−2.260	−3.150	0.538	*	0.168	0.445	0.410	−0.805	*	−1.070	−2.770	−3.750
4	*	*	0.109	−1.610	*	*	*	1.100	0.794	*	*	*	−1.100	−2.040	*
Cotton: Number of Observations															
1	605	611	627	624	617	469	591	275	272	314	136	20	352	352	303
2	605	603	615	615	600	523	454	228	151	223	82	149	387	464	367
3	554	*	613	584	590	357	*	200	146	167	97	*	413	438	423
4	*	*	624	527	376	*	*	294	138	114	*	*	330	369	262
Corn: Spearman Correlations															
1	0.960	0.975	0.954	0.736	0.592	0.960	0.975	0.954	0.874	0.646	0.953	0.977	*	0.694	0.540
2	0.968	0.945	0.980	0.767	0.666	0.972	0.968	0.980	0.880	0.784	0.921	0.886	*	0.704	0.533
3	0.918	0.942	0.984	0.815	0.797	0.967	0.935	0.964	0.894	0.896	0.872	0.942	*	0.773	0.745
4	*	*	0.985	0.766	0.888	*	*	0.985	0.886	0.940	*	*	*	0.762	0.826

TABLE V (Continued)

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					*Positive Spreads*					*Negative Spreads*				
QTR	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*
Corn: Mean Values of Standardized Spread															
1	0.037	0.027	0.043	−0.060	−0.007	0.039	0.031	0.043	0.016	0.036	−0.009	−0.008	*	−0.081	−0.080
2	0.027	−0.010	0.045	−0.053	−0.023	0.034	0.023	0.045	0.033	0.038	−0.018	−0.070	*	−0.88	−0.078
3	−0.053	−0.063	0.044	−0.063	−0.059	0.033	0.031	0.044	0.055	0.059	−0.106	−0.101	*	−0.109	−0.105
4	*	*	0.046	−0.096	−0.018	*	*	0.046	0.014	0.029	*	*	*	−0.105	−0.053
Corn: Number of Observations															
1	615	612	500	635	606	594	571	500	265	425	21	41	*	370	181
2	612	608	618	618	606	560	427	618	253	365	52	181	*	365	243
3	613	196	633	631	613	288	79	633	252	238	325	117	*	379	375
4	*	*	638	589	206	*	*	638	320	106	*	*	*	269	100
Oats: Spearman Correlations															
1	0.959	0.976	*	0.885	0.775	0.967	0.977	*	0.979	0.853	0.875	0.982	*	0.828	0.684
2	0.949	0.953	0.875	0.919	0.837	0.968	0.970	0.912	0.955	0.896	0.804	0.915	0.845	0.885	0.751
3	0.938	*	0.921	0.925	0.859	0.961	*	0.944	0.963	0.935	0.901	*	0.910	0.896	0.793
4	*	*	0.946	0.935	0.935	*	*	0.961	0.989	0.969	*	*	0.915	0.884	0.884

TABLE V (Continued)

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					*Positive Spreads*					*Negative Spreads*				
QTR	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*
							Oats: Mean Values of Standardized Spread								
1	0.036	0.031	*	−0.051	0.010	0.046	0.035	*	0.023	0.064	−0.028	−0.023	*	−0.096	−0.111
2	0.030	0.010	0.000	−0.024	0.013	0.040	0.034	0.024	0.031	0.063	−0.020	−0.023	−0.027	−0.059	−0.047
3	−0.004	*	−0.013	−0.018	−0.015	0.028	*	0.028	0.033	0.042	−0.041	*	−0.029	−0.043	−0.054
4	*	*	0.003	−0.001	−0.001	*	*	0.028	0.037	0.037	*	*	−0.031	−0.039	−0.039
							Oats: Number of Observations								
1	617	608	*	258	245	508	576	*	113	179	109	32	*	145	66
2	602	604	405	610	594	460	347	189	245	322	142	257	216	365	272
3	595	*	602	602	592	322	*	200	206	249	273	*	402	396	343
4	*	*	636	414	414	*	*	344	188	188	*	*	292	226	226
							Wheat: Spearman Correlations								
1	0.972	0.959	0.968	0.873	0.736	0.973	0.964	0.968	0.930	0.711	0.950	0.909	*	0.866	0.749
2	0.957	0.924	0.942	0.907	0.801	0.965	0.970	0.943	0.951	0.916	0.931	0.904	0.850	0.899	0.760
3	0.901	*	0.946	0.849	0.747	0.923	*	0.944	0.836	0.687	0.897	*	0.989	0.848	0.748
4	*	*	0.968	0.768	0.782	*	*	0.971	0.977	0.977	*	*	0.905	0.740	0.753
							Wheat: Mean Values of Standardized Spread								
1	0.061	0.036	0.031	−0.114	−0.018	0.063	0.044	0.031	0.017	0.047	−0.014	−0.016	*	−0.123	−0.068
2	0.031	−0.056	0.027	−0.112	−0.070	0.050	0.038	0.028	0.036	0.073	−0.040	−0.087	−0.002	−0.134	−0.109
3	−0.077	*	0.023	−0.114	−0.135	0.028	*	0.027	0.028	0.041	−0.097	*	−0.004	−0.124	−0.153
4	*	*	0.025	−0.125	−0.125	*	*	0.028	0.052	0.052	*	*	−0.007	−0.150	−0.156

TABLE V (Continued)

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					*Positive Spreads*					*Negative Spreads*				
QTR	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*
Wheat: Number of Observations															
1	616	613	217	648	611	607	553	217	94	350	9	60	*	554	261
2	619	619	629	629	619	517	248	621	127	231	102	371	8	502	388
3	602	*	608	606	598	228	*	561	142	175	374	*	47	466	423
4	*	*	638	470	416	*	*	599	174	166	*	*	39	296	250
Soybeans: Spearman Correlations															
1	0.992	0.989	0.930	0.850	0.805	0.992	0.989	0.951	0.946	0.805	*	1.000	0.929	0.850	0.819
2	0.991	0.989	0.942	0.847	0.769	0.991	0.989	0.968	0.902	0.844	0.984	0.945	0.930	0.834	0.720
3	0.978	0.961	0.959	0.894	0.837	0.989	0.962	0.982	0.967	0.945	0.916	0.981	0.927	0.830	0.727
4	0.974	*	0.975	0.866	0.893	0.994	*	0.988	0.971	0.971	0.936	*	0.960	0.829	0.843
Soybeans: Mean Values of Standardized Spread															
1	0.079	0.069	−0.100	−0.228	−0.053	0.079	0.069	0.010	0.007	0.054	*	−0.007	−0.129	−0.234	−0.262
2	0.074	0.058	−0.052	−0.139	−0.017	0.079	0.062	0.026	0.023	0.081	−0.009	−0.012	−0.102	−0.188	−0.109
3	0.027	−0.010	−0.026	−0.086	−0.053	0.057	0.027	0.042	0.045	0.069	−0.056	−0.041	−0.100	−0.175	−0.159
4	−0.043	*	−0.003	−0.135	−0.070	0.052	*	0.056	0.076	0.063	−0.125	*	−0.067	−0.200	−0.163
Soybeans: Number of Observations															
1	608	609	612	621	600	608	606	199	94	434	*	3	413	527	166
2	592	588	609	609	588	569	566	324	232	363	23	22	285	377	225
3	628	416	638	630	628	514	262	426	363	394	114	154	212	267	234
4	205	*	648	577	414	128	*	413	207	215	77	*	235	370	199

TABLE V (Continued)

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					*Positive Spreads*					*Negative Spreads*				
QTR	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*	*INTRA1*	*INTRA2*	*INTRA3*	*INTER4*	*INTER5*
	Soybean Meal: Spearman Correlations														
1	0.979	0.975	0.869	0.667	0.596	0.965	0.977	0.902	0.750	0.630	0.962	0.971	0.867	0.658	0.586
2	0.975	0.982	0.926	0.868	0.787	0.964	0.982	0.929	0.934	0.848	0.963	0.979	0.946	0.823	0.738
3	0.984	0.972	0.984	0.915	0.867	0.989	0.986	0.982	0.966	0.943	0.978	0.953	0.967	0.867	0.812
4	0.975	*	0.986	0.888	0.951	0.985	*	0.987	0.973	0.982	0.956	*	0.964	0.838	0.916
	Soybean Meal: Mean Values of Standardized Spread														
1	0.269	0.422	−0.670	−5.230	−2.670	1.788	1.817	0.432	0.809	3.065	−2.480	−1.890	−1.100	−7.150	−6.920
2	0.872	0.785	0.771	−2.290	−0.380	2.297	1.752	1.032	1.963	3.626	−1.420	−1.350	−0.579	−5.330	−3.730
3	0.288	−0.219	0.881	−1.120	−0.603	2.187	1.555	1.324	2.162	3.023	−2.140	−2.510	−1.220	−4.330	−3.910
4	−1.090	*	0.597	−2.130	−1.030	2.300	*	1.513	2.757	2.213	−4.470	*	−1.530	−5.840	−4.160
	Soybean Meal: Number of Observations														
1	604	608	167	616	599	425	426	66	186	319	179	182	101	430	260
2	609	605	579	619	603	443	471	505	345	369	166	134	74	274	234
3	612	809	631	633	609	423	423	554	409	386	189	186	77	224	223
4	206	*	634	226	395	115	*	481	110	217	93	*	153	116	178
	Soybean Oil: Spearman Correlations														
1	0.985	0.985	0.941	0.879	0.800	0.992	0.989	0.965	0.901	0.822	0.948	0.971	0.927	0.871	0.751
2	0.988	0.985	0.961	0.912	0.859	0.990	0.991	0.970	0.967	0.934	0.981	0.970	0.952	0.871	0.769
3	0.989	0.963	0.963	0.951	0.926	0.992	0.992	0.991	0.983	0.974	0.984	0.976	0.976	0.917	0.879
4	0.983	*	0.987	0.873	0.969	0.992	*	0.987	0.985	0.989	0.973	9	0.987	0.765	0.936

TABLE V (Continued)

Mean Values of Standardized Spreads by Quarter Classified by Sign of Standardized Spread Intra1: Nearby—1st Deferred Intra2: 1st Deferred—2nd Deferred Intra3: 1st Month in new crop year—2nd Month in new crop year Inter4: Last month in old crop year—1st Non-transitioinal month in new crop year Inter5: Nearby—1st Non-transitional month in new crop year

	All Spreads					Positive Spreads					Negative Spreads				
QTR	INTRA1	INTRA2	INTRA3	INTER4	INTER5	INTRA1	INTRA2	INTRA3	INTER4	INTER5	INTRA1	INTRA2	INTRA3	INTER4	INTER5
Soybean Oil: Mean Values of Standardized Spread															
1	0.088	0.170	−0.050	−0.317	0.023	0.235	0.265	0.014	0.079	0.340	−0.891	−0.384	−0.105	−0.543	−0.903
2	0.115	0.004	−0.022	−0.283	−0.108	0.250	0.180	0.057	0.127	0.314	−0.454	−0.507	−0.113	−0.665	−0.838
3	−0.138	−0.249	−0.083	−0.434	−0.471	0.214	0.174	0.087	0.202	0.311	−0.737	−0.807	−0.267	−1.270	−1.510
4	−0.130	*	0.088	−0.428	−0.116	0.166	*	0.150	0.224	0.191	−0.791	*	−0.170	−1.200	−0.728
Soybean Oil: Number of Observations															
1	595	596	223	615	596	533	527	119	299	473	62	69	114	316	123
2	603	597	572	613	599	522	490	380	390	446	81	107	192	223	153
3	613	613	633	625	613	455	428	420	438	429	158	185	213	187	184
4	208	*	600	233	397	156	*	508	146	287	52	*	92	87	110

crop year spreads. Hence, most of the inter-crop year spreads have negative values and the correlations of its legs in the inter-crop year spreads is less than those of its legs in the intra-crop year spreads.[19]

Table VI reports the results of hypothesis tests where the null hypothesis that inter-crop year correlation of the futures price changes are equal to that of the correlation of intra-crop year futures price changes. The null is rejected most of the time. This suggests that intra-crop year correlation of the legs of the spread are greater than inter-crop year correlations.

Table VII provides a summary of the variances of spread changes and their corresponding legs for the five spread types in the analysis over all seven commodities. The data is aggregated by the crop-year quarter across calendar years. Table VII illustrates that spread volatility is less than the volatility of its associated legs. However, the intra-crop-year spread volatility seems to differ from the volatility of its legs by an order of magnitude while inter-crop-year spread volatility differs from the volatility of its legs only marginally. While this result indicates that spread trading is a lower risk trading technique, it also suggests that intra-crop-year spreading is considerably less risky than inter-crop-year spreading.

From Tables V and VII, one can see that the variance of price changes for the first leg is roughly equal to the variance of the price changes for the second leg when the spreads are positive or near zero. In the region of negative spreads, the variance of the first leg price changes is often greater than the variance of the second leg price changes. These results can be explained as follows:

In cases where inventory is adequate, the spread will reflect the carrying cost of inventory between the two time periods and are, therefore, positive. Under circumstances where current inventory is in short supply, the demand and supply of the price of the first leg are relatively more inelastic than the second leg and are, thus, more volatile. Also, the realization of a shortage will force the near price to increase and produce a negative spread.

Finally, from Table VII, it can be observed that there is some seasonal variation in the volatility of spreads. In general, price volatility increases from the first to the fourth quarter.

[19]In Table V, the purpose of classification of all daily spreads into subsets of positive and negative spreads by pooled crop year quarters is to provide additional empirical evidences to support the hypothesis on spread behaviors in metal markets observed by Fama and French (1988). Their hypothesis states that there is a negative relationship between level of stock of inventory and the number of positive daily spreads during a given period. This study's statistical analyses and tests are based on all daily spreads by pooled crop-year quarters. They are not based on observations from subsets of positive or negative spreads by crop year quarters.

TABLE VI

Summary of Aggregate Hypothesis Tests of Spearman Correlations Across Crop Years

	Comparisons of (Intra, Inter) Combinations					
Commodity	(1,4)	(2,4)	(3,4)	(1,5)	(2,5)	(3,5)
Corn	2/3	2/3	4/4	3/3	3/3	4/4
Cotton	3/3	2/2	4/4	3/3	2/2	3/3
Oats	3/3	2/2	0/3	3/3	2/2	2/3
Wheat	3/3	1/2	4/4	3/3	2/2	4/4
Soybean meal	4/4	3/3	4/4	4/4	3/3	4/4
Soybean oil	4/4	3/3	4/4	3/4	3/3	4/4
Soybeans	4/4	3/3	4/4	4/4	3/3	4/4

Notes: Null: Equality of correlations of inter-/intra- crop-year spread changes Alt: Intra-crop-year spread change correlations are greater than inter-crop-year spread change correlations.
(1) The definitions of intra1–3 and inter4–5 are defined in Table VI, (2) The level of significance α is equal to .01 and the test is one-sided, (3) The numerator is the number of times the null hypothesis is rejected and the denominator is the number of cases considered, (4) Fisher Z tests is used in the hypothesis tests.

The results of hypothesis tests of the equality of the variance of spread changes for intra-/inter-crop years are reported in Table VIII. The null hypothesis is rejected most of the time. These results are consistent with the results of hypothesis testing based on temporal disaggregate data. This study supports the hypothesis that changes in inter-crop-year spreads are often more volatile than changes in intra-crop-year spreads.

In sum, the aggregate temporal analysis confirms the empirical findings and are consistent with the price of storage, but also reveal a seasonal volatility pattern. Such lower correlations are associated with a greater proportion of negative spreads.

CONCLUSIONS

To test the hypothesis that spreads whose legs cross crop-years may behave differently than spreads whose legs are within the same crop-year, an empirical analysis of the temporal relationships between futures price changes within and across crop years is conducted within the framework of the theory of the price of storage. The analysis is conducted on seven storable, agricultural, commodity markets.

Empirical results suggest that the movements of futures price changes within and across crop years are highly correlated, but correlations between inter-crop year price changes are less than those of intra-crop year prices changes. Further, volatility of inter-crop year spread changes are often greater than intra-crop year change volatility. These

TABLE VII

Variances of the Change in Spread and its Legs Analysis by Quarter

Intra1 = *Nearby—1st*
Intra2 = *1st Deferred—2nd Deferred*
Intra3 = *1st Month in Few Year—2nd Month in New Year*
Inter4 = *Last Month yr Old Year—1st Non-Transitional in New Year*

Inters = *Nearby—1st Non-Transitional Month in New Year*
$V(\Delta S)$ = *Variance of the Change in the Spread*
$V(\Delta F1)$ = *Variance of the Change in the First Leg*
$V(\Delta F2)$ = *Variance in the Change in the Second Leg*

Cotton

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	1.292	25.65	23.26	1.395	29.09	27.25	1.534	15.39	13.85	3.649	21.13	14.86	2.365	6.084	2.622
2	1.364	24.2	22.46	3.476	28.81	28.4	1.45	14.34	12.75	4.316	9.035	5.037	3.077	5.783	3.053
3	4.657	30.85	26.23				2.208	29.34	26.79	5.174	14.05	10.25	5.485	12.71	10.02
4							5.007	39.09	35.27	4.832	11.14	6.619			

Corn

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	0.0016	0.0213	0.0186	0.0012	0.0248	0.0227	0.0007	0.0097	0.0093	0.0056	0.0163	0.0100	0.0031	0.0051	0.0027
2	0.0011	0.0222	0.0215	0.0016	0.0215	0.0205	0.0005	0.0124	0.0122	0.0036	0.0086	0.0075	0.0030	0.0053	0.0045
3	0.0078	0.0659	0.0626	0.0031	0.0300	0.0284	0.0009	0.0437	0.0425	0.0066	0.0254	0.0239	0.0066	0.0254	0.0242
4							0.0011	0.0612	0.0596	0.0258	0.0722	0.0483	0.0103	0.0847	0.0940

Oats

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	0.0054	0.0918	0.0828	0.0021	0.0692	0.0641				0.0236	0.1236	0.1107	0.0146	0.0315	0.0209
2	0.0016	0.0229	0.0196	0.0019	0.0295	0.0264	0.0046	0.0256	0.0226	0.0033	0.0261	0.0243	0.0024	0.0097	0.0070
3	0.0021	0.0258	0.0227				0.0022	0.0198	0.0180	0.0024	0.0230	0.0198	0.0026	0.0129	0.0098
4							0.0027	0.0354	0.0312	0.0037	0.0314	0.0264	0.0037	0.0314	0.0264

TABLE VII (Continued)

Variances of the Change in Spread and its Legs Analysis by Quarter

Intra1 = Nearby—1st
Intra2 = 1st Deferred—2nd Deferred
Intra3 = 1st Month in Few Year—2nd Month in New Year
Inter4 = Last Month yr Old Year—1st Non-Transitional in New Year

Inters = Nearby—1st Non-Transitional Month in New Year
$V(\Delta S)$ = Variance of the Change in the Spread
$V(\Delta F1)$ = Variance of the Change in the First Leg
$V(\Delta F2)$ = Variance in the Change in the Second Leg

Wheat

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	0.0037	0.1057	0.0995	0.0040	0.0853	0.0834	0.0039	0.0757	0.0621	0.0165	0.1168	0.0975	0.0075	0.0239	0.0161
2	0.0034	0.0431	0.0362	0.0080	0.0542	0.0455	0.0038	0.0373	0.0369	0.0072	0.0454	0.0373	0.0069	0.0185	0.0107
3	0.0094	0.0551	0.0444				0.0023	0.0289	0.0270	0.0123	0.0442	0.0289	0.0123	0.0276	0.0145
4							0.0035	0.0791	0.0763	0.0328	0.0801	0.0525	0.0310	0.0818	0.0508

Soybeans

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	0.0044	0.4006	0.4047	0.0054	0.4049	0.3952	0.0259	0.2347	0.1774	0.0599	0.2374	0.1222	0.239	0.0705	0.0311
2	0.0035	0.2865	0.2882	0.0046	0.2882	0.2747	0.0170	0.1776	0.1465	0.0463	0.1700	0.0977	0.0252	0.0670	0.0341
3	0.0119	0.4586	0.4590	0.0131	0.4409	0.4336	0.0153	0.2591	0.2530	0.0379	0.2043	0.1770	0.0356	0.1283	0.1130
4	0.1464	2.255	1.872				0.0250	0.8873	0.8810	0.0969	0.5398	0.4596	0.0906	0.6599	0.5993

TABLE VII (Continued)

Variances of the Change in Spread and its Legs Analysis by Quarter

Intra1 = *Nearby—1st*
Intra2 = *1st Deferred—2nd Deferred*
Intra3 = *1st Month in Few Year—2nd Month in New Year*
Inter4 = *Last Month yr Old Year—1st Non-Transitional in New Year*

Inters = *Nearby—1st Non-Transitional Month in New Year*
$V(\Delta S)$ = *Variance of the Change in the Spread*
$V(\Delta F1)$ = *Variance of the Change in the First Leg*
$V(\Delta F2)$ = *Variance in the Change in the Second Leg*

Soymeal

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	14.96	604.4	548.8	11.35	316.5	284.7	82.02	374.7	328.5	141.6	241.7	181.4	65.08	72.3	35.69
2	9.906	266.2	245.9	8.625	319.4	301.7	43.97	367	366.8	68.03	237.9	172.1	32.33	82.05	53.48
3	57.6	1056	921.4	31.74	968	981.6	20.1	1019	1011	54.34	497	510.9	67.1	349.3	311.4
4	51.03	1837	1867				21.97	1509	1485	124.7	950.1	1009	51.92	1178	1199

Soyoil

	Intra1			*Intra2*			*Intra3*			*Inter4*			*Inter5*		
Qtr	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$	$V(\Delta S)$	$V(\Delta P1)$	$V(\Delta P2)$
1	0.3069	9.557	9.221	0.1631	5.511	5.272	0.5005	5.106	6.343	1.694	5.904	3.619	0.4454	1.165	0.6977
2	0.1699	6.059	5.346	0.1947	6.963	6.445	0.4445	6.507	6.055	0.7859	4.763	3.738	0.5806	1.952	1.167
3	0.3786	16.52	16.01	0.6107	18.08	16.95	0.4439	14.01	13.53	0.9157	9.118	7.924	0.8605	5.642	4.674
4	0.6342	27.76	27.39				0.2653	18.61	18.32	3.421	14.49	14.67	0.8061	19.52	18.76

TABLE VIII

Summary of Aggregate Hypothesis F-Tests for the Equality of Inter- and Intra-Crop-Year Spreads by Commodity and Crop-Year Quarters

	Comparisons of (Intra, Inter) Combinations					
Commodity	(1,4)	(2,4)	(3,4)	(1,5)	(2,5)	(3,5)
Corn	2/3	3/3	4/4	2/3	3/3	4/4
Cotton	2/3	1/2	3/4	2/3	1/2	3/3
Oats	2/3	2/2	2/3	2/3	1/2	1/3
Wheat	2/3	1/2	4/4	2/3	1/2	4/4
Soybean Meal	3/4	3/3	4/4	3/4	3/3	2/4
Soybean Oil	3/4	3/3	4/4	2/4	3/3	2/4
Soybeans	4/4	3/3	4/4	2/4	2/3	2/4

Notes: Null: Equality of variances of inter-/intra-crop-year spread changes Alt: Inter-crop-year spread change variances greater than intra-crop-year spread change variances.
(1) The definitions of intra1–3 and inter4–5 are defined in Table VI, (2) the level of significance α is equal to 0.01 and the test is one-sided, (3) the numerator is the number of times the null hypothesis is rejected and the denominator is the number of cases considered.

results are consistent with the implications from the theory of storage. This is because the levels of inventory of inter-crop year spreads are often lower than the inventory levels of intra-crop year spreads.

These results provide justification for regulators to set tighter speculative position limits and exchanges to set higher margin requirements for inter-crop year spread positions relative to intra-crop-year spread positions. The results of the analysis also have implications regarding the relative degree of risk involved in trading agricultural spreads within and across crop years.

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