LINKAGES BETWEEN AGRICULTURAL COMMODITY FUTURES CONTRACTS

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INTRODUCTION

Two distinct methodologies are used in price determination: partial equilibrium analysis and general equilibrium analysis. The former emphasizes supply and demand conditions for a specific good or service, assuming all other factors are the same, while the latter explicitly recognizes the interdependence of all prices. This study empirically tests the independence of the futures prices of the six agricultural commodities traded at the Chicago Board of Trade. The working hypothesis is that the prices of the six agricultural commodities move independently.

Although the null hypothesis is formulated in terms of price independence between any two of the six agricultural commodities (in the spirit of a partial equilibrium analysis) there are important economic reasons that would make one expect rejection of this hypothesis. These reasons are discussed next.

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Microeconomic theory postulates that there are two key economic linkages between any two commodities—substitutability and complementarity. For example, if the price of corn increases, cattle feeders may use soybean meal as a substitute, and vice versa. The relationship here is one of substitutability. On the other hand, if the price of soybean oil increases dramatically and soybeans are crushed to supply such oil, this process also produces soybean meal and may result in a drop in the price of soybean meal. The relationship here is one of complementarity. Substitutability and complementarity can be present simultaneously among the six agricultural commodities traded at the Chicago Board of Trade. For example, both corn and soybean meal are used for animal and chicken feeding. While substitutability exists between the two, some degree of complementarity is also at play. While soybean meal is high in protein, corn is high in nutrients and vitamins. Soybean meal and corn are usually mixed in certain proportions which are determined by economic and nutritional considerations. Oats and wheat can be used along with soybean meal and corn in various proportions. Thus, substitutability and complementarity are not strictly mutually exclusive among soybean meal, corn, oats, and wheat.

Given that corn, wheat, and soybeans are grown in a relatively concentrated geographical area, weather and general climatological factors affect the national supply of these crops in a similar way. Although corn is grown in over 40 of the contiguous United States, approximately 84% of the corn crop is grown in 17 states. Iowa, Illinois, Nebraska, Minnesota, Indiana, and Ohio produce the most corn. Figures vary somewhat from year to year. Total corn acres planted during the time period, 1981–1991, averaged 83 million acres per year; harvested corn acres averaged 73.7% to 89% of annual planted acreage for the 1981–1991 time period. Most of this acreage is concentrated in the "corn belt" where planting begins in early April and is completed in northern areas by late May. Following a period of slow growth, the corn plant grows rapidly provided that ample supply of moisture and soil nutrients are available.

Soybeans were grown in 20 states and planted on approximately 63 million acres of farmland per year during the 1981–1991 time period. In general, wheat is grown in more states than any other commodity and planted on approximately 76 million acres a year. Oats are grown in approximately 12 north central states and planted an average of 14 million acres per year.

The importance of the effects of weather on the futures prices of agricultural commodities is well documented. Stevens (1991) has found evidence for a weather persistence effect on corn, wheat, and soybean contract prices. Similar results are reported in Teigen and Singer (1989), Westcott (1989) and others. A much larger literature exists that relates weather conditions to seasonal price dynamics. Anderson and Danthine (1983) and Anderson (1985) review aspects of grain production seasonality effects.

As important as the weather and general climatological factors are, recall that every farmer (whether an individual or a large corporate entity) attempts to plant crops that allow maximization of profit under the uncertain conditions of weather and future spot prices. The farmer knows with some degree of accuracy when to plant and when to harvest, what and how much fertilizer to use, and what is the expected crop yield under certain conditions. For example, corn must be planted very early in June to have time to grow and mature during the hot late summer months. Cool weather delays maturity and a possible early frost could cause serious crop damage. On the other hand, soybeans can still be planted mid-to late June and are less sensitive to early fall frost damage than is corn. However, soybean yield is much less that corn yield. Thus, the supply of these crops is ultimately dependent on the profit-maximizing behavior of farmers under conditions of weather and price uncertainty.

Crop production costs are different from region to region, and from county to county. The farmer must determine the costs of seed, fertilizer, chemicals, fuel, land/rent, labor, taxes, and capital and weigh those costs against projected income based upon estimated yield and estimated futures prices. After land costs, fertilizer is the second greatest expense unique to corn production due to the nitrogen requirements of the corn plant. The nitrogen requirements contribute to corn's reputation for being the highest cost grain to produce. On the other hand, the corn plant has the highest yield per bushel of any of the grain or soy alternatives. During the 1981–1991 time period, the average corn yield was 129 bushels per acre; 2 times the yield of soybeans, 1.7 times the yield of wheat, and over 2.25 times the yield of oats.

Beyond the supply and demand considerations that affect the interdependence of agricultural commodities, one should mention exogenous shocks such as the Soviet Union grain policy shift of the early 1970s and the European Economic Community's emphasis on self-sufficiency in the 1980s. Reinhart and Wickham (1994) give an exhaustive list of factors affecting world commodity prices with emphasis on policy issues, such as stabilization funds, agricultural boards, international commodity agreements, external compensatory finance, and others. Furthermore, over a longer term, technological advances and population growth also affect agricultural prices.

Pindyck and Rotemberg (1990) offer numerous statistical tests which confirm that prices of several commodities such as wheat, cotton, copper, gold, crude oil, lumber and cocoa, have a persistent tendency to move together. They maintain that a possible explanation for such excess comovement "is that commodity price movements are to some extent the result of herd behavior." By herd behavior, they mean that traders are alternatively bullish or bearish across all commodity markets with no justification provided by economic fundamentals.

Finally, agricultural commodities are linked via the trading strategy called spreading. When traders find soybeans cheap, they buy soybeans and they sell soybean oil and soybean meal; or they buy corn and sell soybeans, often in various ratios. Their actions are motivated by perceived mispricings between the products. Spreading, as an arbitrage activity, acts as a mechanism that restores proper relationships.

DATA DESCRIPTION

This study uses daily settlement prices for the nearby contract for the six agricultural futures contracts traded at the Chicago Board of Trade (CBOT): corn, wheat, oats, soybean, soybean meal, and soybean oil. The time period is from January 2, 1981, to October 24, 1991, for a total of 2734 observations. The data are provided by the CBOT. A few daily prices are missing. Missing daily observations are replaced by the average of the previous and subsequent prices.

METHODOLOGY

The error correction model (ECM) of Engle and Granger (1987) is used. Since the ECM is based on the concept of Granger causality and the notion of cointegration, these two tests are described first.

Granger Causality Tests

Granger causality tests are tests of the prediction ability of time series models. Specifically, Y is said to cause or lead X provided some coefficient, a_i, is not zero in the following equation:

$$X_t = c_0 + \sum_{i=1}^{m} a_i Y_{t-i} + \sum_{j=1}^{m} b_j X_{t-j} + \varepsilon_t \tag{1}$$

Similarly, X is causing or leading Y if some coefficient, a_i, is not zero in eq. (2) below:

$$Y_t = \gamma_0 + \sum_{i=1}^{m} a_i X_{t-i} + \sum_{j=1}^{m} \beta_j Y_{t-j} + \mu_t \qquad (2)$$

If both of these events occur, there is feedback.[1] Regressions (1) and (2) can be used to test for the existence of a short-term relationship between the variables X and Y. The test for causality is based on an F-statistic that is computed by running the regressions in both the unconstrained form (full model) and the constrained form (reduced model). The reduced model is obtained from eqs. (1) and (2) by dropping the lagged values of the independent variables. The F-statistic is given by

$$F_1 = \frac{(\text{SSE}_r - \text{SSE}_f)/m}{\text{SSE}_f/(T - 2m - 1)} \qquad (3)$$

where SSE_r and SSE_f are the sum of squares of residuals of the reduced and full models, respectively; m is the number of lags; and T is the number of observations.

Tests of Stationarity and Cointegration

If variables, X_t and Y_t, are both non-stationary in levels, but the first differences of the variables are stationary, then variables, X_t and Y_t are integrated of order one, denoted by $I(1)$. The ECM requires the variables to be $I(1)$. The stationarity of the time series is investigated with the Augmented Dickey–Fuller (1979) (ADF) test:

$$\ln X_t - \ln X_{t-1} = b_0 + b_1 \ln X_{t-1} + \sum_{i=1}^{m} c_i (\ln X_{t-i} - \ln X_{t-i-1}) + \varepsilon_t \qquad (4)$$

where X represents the level or the first difference of the variable. The null hypothesis of non-stationarity is $b_1 = 0$.

When two variables are $I(1)$, their linear combinations, $Z_t = X_t - aY_t$, is generally $I(1)$. However, if there is an a such that Z_t is integrated of order zero, $I(0)$, the linear combination of X_t and Y_t is stationary, and it is said that the two variables are cointegrated. Cointegration is a property of two non-stationary time series and the relationship, $Z_t = X_t - aY_t$, represents a long-run equilibrium relationship. Thus, the cointegra-

[1]The several testable forms of Granger's causality are described in Pierce and Haugh (1977), Guilkey and Salemi (1982), and Geweke, Meese, and Dent (1983).

tion factor, Z_t, can be used to measure long-term linkages between variables, X_t and Y_t.

Engle and Granger suggest the following method for estimating the value of a. First run the regression:

$$X_t = a + aY_t + \varepsilon_t \tag{5}$$

Then, the estimate of a obtained from (5) is plugged into eq. (6):

$$\hat{Z}_t = X_t - (\hat{a} + \hat{a}Y_t), \tag{6}$$

where $\hat{Z}_t$ represents an estimate of the cointegration factor.

Error Correction Model

By integrating the concept of causality in the Granger sense with the notion of cointegration, it is possible to develop a model which tests for the presence of both short-term and long-term relationships between the variables, X_t and Y_t. This model is the ECM, proposed by Engle and Granger. In (7), the ECM model investigates the potential long-run and short-run impact of the variable, Y_t, on the variable, X_t:

$$\begin{aligned} X_t - X_{t-1} &= a_0 + a_1\hat{Z}_{t-1} + \sum_{i=1}^{m} c_i(Y_{t-i} - Y_{t-i-1}) \\ &+ \sum_{j=1}^{m} d_j(X_{t-j} + X_{t-j-1}) + \varepsilon_t. \end{aligned} \tag{7}$$

The ECM represented by eq. (7) decomposes the dynamic adjustments of the dependent variable, X_t, to changes in the independent variable, Y_t, into two components: first, a long-run component given by the cointegration term, $a_1\hat{Z}_{t-1}$, also known as the error-correction term; and, second, a short-term component given by the first summation term in the right-hand side of eq. (7). In other words, a long-run relationship refers to one established by (7) during the entire sample of January 2, 1981, to October 24, 1991. On the other hand, a short-term relationship is shown in (7) by the lagged values of the dependent and independent variables. Three lags are used in this study.

Similarly, the long-run and short-run impact of X_t on Y_t can be captured by the following ECM:

$$Y_t - Y_{t-1} = \beta_0 + \beta_1 \hat{Z}_{t-1} + \sum_{i=1}^{m} \phi_i (X_{t-i} - X_{t-i-1})$$

$$+ \sum_{j=1}^{m} \theta_j (Y_{t-j} + Y_{t-j-1}) + \varepsilon_t. \tag{8}$$

From eqs. (7) and (8) one may deduce that the variables, X_t and Y_t, exhibit long-run movements when at least one of the coefficients, a_1 or β_1, is different from zero. If a_1 is statistically different from zero, but β_1 is not; then, the implication is that X_t follows and adjusts to Y_t in the long run. The opposite occurs when β_1 is statistically different from zero but a_1 is not. If both coefficients, a_1 and β_1, are statistically different from zero, a feedback relationship exists, implying that variables, X_t and Y_t, adjust to one another over the long run.

The coefficients, c_i's and ϕ_i's, in eqs. (7) and (8), respectively, represent the short-term relationships between the variables, X_t and Y_t. If the c_i's are not all zero in a statistical sense but all ϕ_i's are; then, Y_t is leading or causing X_t in the short run. The reverse case occurs when the ϕ_i's are not all zero in a statistical sense, but all c_i's are. If both events occur, then there is a feedback relationship and the variables, X_t and Y_t, affect each other in the short run.

The empirical results of this study's investigation of short-term and long-term relationships between the six agricultural futures contracts are discussed next.

RESULTS OF THE TESTS OF STATIONARITY

The results of the ADF tests of stationarity for the level and first difference of the natural logarithm of the agricultural futures prices are presented in Tables I and II, respectively. For the price level, the null hypothesis of non-stationarity cannot be rejected for all contracts at the 5% of confidence level. However, the null of non-stationarity is rejected for all contracts for the price first difference. Thus, the prices of the six agricultural futures contracts under analysis are integrated of order one, $I(1)$.

RESULTS OF THE TESTS OF COINTEGRATION

Since the several tests of cointegration suggested by Engle and Granger differ in terms of power and sensitivity, three different tests are conducted: the Durbin Watson, the Dickey and Fuller (DF), and the ADF.

TABLE I

Augmented Dickey–Fuller Tests
Agricultural Futures Price Levels

Commodity	b_0	b_1	b_2	b_3	b_4	R^2
Corn	0.032	−0.003	0.057	0.024	0.007	0.006
	(2.391)[a]	(−2.402)	(2.954)[a]	(−1.230)	(0.365)	(3.876)[a]
Wheat	0.061	−0.006	−0.018	−0.052	0.001	0.007
	(3.066)[a]	(2.400)	(−0.947)	(−2.718)[a]	(0.070)	(4.629)[a]
Oats	0.039	−0.004	0.056	−0.027	0.030	0.007
	(2.470)[a]	(−2.483)	(2.932)[a]	(−1.384)	(1.569)	(4.441)[a]
Soybean	0.048	−0.004	0.006	−0.035	0.009	0.004
	(2.507)[a]	(−2.515)	(0.296)	(−1.816)	(0.485)	(2.548)[a]
Soybean meal	0.040	−0.004	0.016	−0.033	0.006	0.004
	(2.469)[a]	(−2.475)	(0.842)	(−1.715)	(0.302)	(2.489)[a]
Soybean oil	0.024	−0.003	0.073	−0.054	0.009	0.009
	(2.095)[a]	(−2.105)	(3.823)[a]	(−2.813)[a]	(0.451)	(6.353)[a]

Notes: The model is:

$$\ln P_t - \ln P_{t-1} = b_0 + b_1 \ln P_{t-1} + b_2 (\ln P_{t-1} - \ln P_{t-2}) + b_3 (\ln P_{t-2} - \ln P_{t-3}) + b_4 (\ln P_{t-3} - \ln P_{t-4}) + \varepsilon_t$$

The null hypothesis is $b_1 = 0$ (price levels are non-stationary) and is not rejected. The critical t-statistic for the b_1 coefficient at the 5% level is −2.86 [from Dickey–Fuller (1979), Table 8.5.2].
[a]Indicates the individual regression coefficient is statistically significantly different from zero at the 5% level.

The results presented in Table III indicate that cointegration is rejected by the Durbin Watson test but it is strongly confirmed by the more powerful tests of DF and ADF. Therefore, it is concluded that the time series of agricultural commodity futures prices are cointegrated and the use of the error correction model is appropriate in testing for short-term and long-term relationships between agricultural commodities.

ECM RESULTS

The results of the ECM are reported in Table IV. The main rows contain the regression coefficients, a_1's and c_i's, given by eq. (7), or the regression coefficients, β_1's and ϕ_i's, given by eq. (8). The corresponding t-statistics are given in parenthesis in the second rows. The last three columns to the right of Table IV contain the F-statistics which test for long-term, short-term, and long-term or short-term relationships, respectively. There is unidirectional long-term causality from corn to: wheat, oats, soybean, soybean meal, and soybean oil; from wheat to oats, soybean and soybean meal; from soybean to wheat and soybean meal; from soybean oil to

TABLE II

Augmented Dickey–Fuller Tests
First Difference of Agricultural Futures Prices

Commodity	b_0	b_1	b_2	b_3	b_4	R^2
Corn	−0.013	−0.982	−0.037	0.012	0.019	0.474
	(−0.474)	(−26.428)[a]	(1.158)	(0.462)	(0.994)	(611.526)[b]
Wheat	−0.013	−1.089	0.069	0.014	0.013	0.511
	(−0.424)	(−27.268)[a]	(2.003)[b]	(6.505)[b]	(0.671)	(711.704)[b]
Oats	−0.019	−0.974	0.029	−0.001	0.029	0.475
	(−0.493)	(−26.279)[a]	(0.898)	(−0.007)	(1.538)	(614.976)[b]
Soybean	−0.015	−1.013	0.016	−0.020	−0.013	0.499
	(−0.535)	(−26.056)[a]	(0.479)	(−0.736)	(−0.660)	(678.137)[b]
Soybean meal	−0.010	−1.036	0.050	0.015	0.020	0.494
	(−0.340)	(−26.889)[a]	(1.511)	(0.575)	(1.036)	(664.829)[b]
Soybean oil	−0.09	−0.953	0.025	−0.029	−0.023	0.468
	(−0.298)	(−25.584)[a]	(0.783)	(−1.104)	(−1.218)	(598.205)[b]

Notes: The model is:

$$R_t - R_{t-1} = b_0 + b_1 R_{t-1} + b_2 (R_{t-1} - R_{t-2}) + b_3 (R_{t-2} - R_{t-3}) + b_4 (R_{t-3} - R_{t-4}) + \varepsilon_t$$

where

$$R_t = 100 \ln (P_t/P_{t-1})$$

The null hypothesis is $b_1 = 0$ (Price first differences are non-stationary). The critical t-statistic for the b_1 coefficient at the 5% level is −2.88 [from Dickey–Fuller (1979), Table 8.5.2].

[a]Indicates rejection of the null hypothesis of non-stationarity.

[b]Indicates the individual regression coefficient is statistically significantly different from zero at the 5% level.

wheat, oats, soybean and soybean meal; and from oats to soybean meal. There is feedback in the long-term relationship between wheat and oats, wheat and soybean, and soybean and oats. The long-term linkages are strong and present in almost every pair of contracts. On the other hand, little short-term causality is detected. Finally, the hypothesis of neither long-term nor short-term unidirectional causality is rejected in 20 of the 30 cases.

In general, the results of the ECM reported in Table IV confirm the long-term interdependence of agricultural commodity futures. The economic rationale for this long-term interdependence can be found in the several theoretical reasons described in the introduction. That is, the substitutability and complementarity of the agricultural commodities, geographical and climatological factors, global demand shocks due to government policies both at home and abroad, and the excess comovement hypothesis.

TABLE III

Tests of Cointegration

Dependent Variable	*Independent Variable*	*Durbin Watson Test (1)*	*Dickey Fuller Test (2)*	*Augmented Dickey Fuller Test (3)*
Wheat	Corn	0.014369	−52.26189[a]	−30.12145[a]
Corn	Wheat	0.009165	−52.21620[a]	−29.91296[a]
Oats	Corn	0.007707	−52.20759[a]	−29.28114[a]
Corn	Oats	0.005001	−52.22821[a]	−29.95998[a]
Soybean	Corn	0.001845	−52.23562[a]	−29.93037[a]
Corn	Soybean	0.008373	−52.24120[a]	−29.95983[a]
Soybean meal	Corn	0.008724	−52.17515[a]	−29.58511[a]
Corn	Soybean meal	0.006034	−52.10741[a]	−29.49466[a]
Soybean oil	Corn	0.010841	−52.22683[a]	−29.96488[a]
Corn	Soybean oil	0.009368	−52.22040[a]	−29.93878[a]
Oats	Wheat	0.015934	−52.15556[a]	−29.22252[a]
Wheat	Oats	0.018432	−52.22925[a]	−30.12490[a]
Soybean	Wheat	0.013952	−52.19921[a]	−29.91429[a]
Wheat	Soybean	0.015684	−52.22321[a]	−30.05781[a]
Soybean meal	Wheat	0.013595	−52.17447[a]	−30.02778[a]
Wheat	Soybean meal	0.016112	−52.17388[a]	−29.97973[a]
Soybean oil	Wheat	0.006891	−52.118435[a]	−29.98776[a]
Wheat	Soybean oil	0.010623	−52.21108[a]	−30.06295[a]
Soybean	Oats	0.013572	−52.21487[a]	−29.90226[a]
Oats	Soybean	0.012806	−52.16034[a]	−29.20106[a]
Soybean meal	Oats	0.014519	−52.17772[a]	−30.15126[a]
Oats	Soybean meal	0.014530	−52.16615[a]	−29.21062[a]
Soybean oil	Oats	0.006183	−52.22409[a]	−29.98051[a]
Oats	Soybean oil	0.007417	−52.15125[a]	−29.26256[a]
Soybean meal	Soybean	0.026209	−52.61152[a]	−30.90135[a]
Soybean	Soybean meal	0.26995	−52.21353[a]	−30.38700[a]
Soybean oil	Soybean	0.006119	−52.19815[a]	−29.95631[a]
Soybean	Soybean oil	0.008118	−52.19837[a]	−29.94611[a]

Among the various statistically significant relationships presented in Table IV, it is worth noticing that the highest significant statistics in the last column of the table involve corn as the independent variable. This leading role of corn can be explained by noting that the average annual corn crop during the period, 1981–1991 was the highest among the other crops; 7.3 billion bushels of corn was produced versus 1.9 billion bushels of soybeans, and even lower quantities of wheat and oats. During the period, 1981–1991, corn exports amounted to 1.8 billion bushels, followed by soybean exports that totaled 716 million bushels. The leading

TABLE III (Continued)

Tests of Cointegration

Dependent Variable	*Independent Variable*	*Durbin Watson Test (1)*	*Dickey Fuller Test (2)*	*Augmented Dickey Fuller Test (3)*
Soybean oil	Soybean meal	0.006216	−52.22677[a]	−30.07316[a]
Soybean meal	Soybean oil	0.007432	−52.16634[a]	−30.13913[a]

Notes: (1) The cointegration equation is:

$$\ln Y_t = a + b \ln X_t + \varepsilon_t$$

The null hypothesis is: $H_0{:}b = 0$ (No cointegration).
The Durbin Watson critical value for rejection of the null hypothesis of no cointegration, at the 5% level, is 0.386 (Engle and Granger 1987).
(2) The model is the following:

$$\ln Y_t = c_0 + \sum_{i=1}^{3} a_i \ln Y_{t-i} + \sum_{j=1}^{3} b_j \ln X_{t-j} + \mu_t$$
$$\mu_t - \mu_{t-1} = a + \phi\mu_{t-1} + \varepsilon_t$$

The null hypothesis is: H_o: $\phi = 0$ (No cointegration).
The critical value for rejection of the null hypothesis of no cointegration, at the 5% level, is −3.37. (Engle and Granger, 1987).
(3) The model is the following:

$$\ln Y_t = c_0 + \sum_{i=1}^{3} a_i \ln Y_{t-i} + \sum_{j=1}^{3} b_j \ln X_{t-j} + \mu_t$$
$$\mu_t - \mu_{t-1} = a + \phi_1\mu_{t-1} + \phi_2 (\mu_{t-1} - \mu_{t-2}) + \phi_3 (\mu_{t-2} - \mu_{t-3}) + \varepsilon_t$$

The null hypothesis is: H_o: $\phi_1 = 0$ (No cointegration).
The critical value for rejection of the null hypothesis of no cointegration, at the 5% level, is −3.17. [Engle and Granger (1987)]
[a]Indicates rejection of the null hypothesis.

role of corn is also evidenced by the decision of the Chicago Board of Trade to introduce new products tied to corn contracts, such as the Iowa Corn Crop Yield Insurance futures and option contracts.

SUMMARY AND CONCLUSIONS

This study investigates long-term and short-term relationships among the six agricultural futures contracts traded at the CBOT: corn, wheat, oats, soybean, soybean meal, and soybean oil. The data correspond to daily settlement prices for the nearby contract. The time period under analysis extends from January 2, 1981, to October 24, 1991, and involves 2734 observations for each contract.

Tests of stationarity find that prices are non-stationary in levels but stationary in the first differences. That is, prices are integrated of order

TABLE IV

Error Correction Model (ECM) for Testing for Long-Term (LT) and Short-Term (ST) Relationship for Prices of Agricultural Futures Contracts

						H_0: *No Relationship*		
Dependent Variable	*Independent Variable*	a_1, β_1	c_1, ϕ_1	c_2, ϕ_2	c_3, ϕ_3	*No LT Impact*	*No ST Impact*	*No LT or ST Impact*
Wheat	Corn	0.0092	−0.0130	−0.0191	−0.0518			
		(3.632)[c]	(−0.579)	(−0.854)	(−2.319)[c]	13.220[a]	2.224	5.005[a]
Corn	Wheat	0.0001	0.356	−0.0013	0.0273			
		(0.051)	(1.763)	(−0.065)	(1.371)	0.005	1.603	1.206
Oats	Corn	0.0049	−0.0873	0.0048	0.0361			
		(2.684)[c]	(−3.094)[c]	(0.171)	(1.278)	7.219[a]	3.796[a]	4.648[a]
Corn	Oats	0.0006	0.0395	−0.0107	−0.0007			
		(0.387)	(2.575)[c]	(−0.698)	(−0.048)	0.147	2.324	1.766
Soybean	Corn	0.0091	0.0037	0.0310	0.0246			
		(3.461)[c]	(0.160)	(1.327)	(1.057)	12.006[a]	1.013	3.726[a]
Corn	Soybean	−0.0010	0.0251	−0.0417	−0.0098			
		(−0.488)	(1.011)	(−1.681)	(−0.393)	0.239	1.359	1.067
Soybean meal	Corn	0.0049	0.0013	0.0033	0.0082			
		(2.677)[c]	(0.054)	(0.134)	(0.337)	7.179[a]	0.046	3.846[a]
Corn	Soybean meal	−0.0001	0.0038	−0.0567	−0.0120			
		(−0.048)	(0.179)	(−2.650)[c]	(−0.561)	0.001	2.469	1.854
Soybean oil	Corn	0.0047	−0.0104	0.0200	0.0373			
		(2.127)[c]	(−0.431)	(0.828)	(1.541)	4.534[b]	1.120	3.915[a]
Corn	Soybean oil	0.0023	0.0420	−0.0284	0.018			
		(1.196)	(2.160)[c]	(−1.456)	(0.094)	1.433	2.162	1.963
Oats	Wheat	0.0067	−0.0129	−0.0333	0.0353			
		(2.945)[c]	(−0.498)	(−1.290)	(1.366)	8.693[a]	1.307	3.192[b]
Wheat	Oats	0.0059	0.0182	0.0173	0.0103			
		(2.213)[c]	(1.153)	(1.095)	(0.649)	4.909[b]	1.037	3.231[b]
Soybean	Wheat	0.0063	0.0169	0.0010	0.0343			
		(2.733)[c]	(0.893)	(0.053)	(1.810)	7.487[a]	1.315	2.750[b]
Wheat	Soybean	0.0054	−0.0236	−0.0222	0.0049			
		(2.124)[c]	(−1.038)	(−0.980)	(0.214)	4.521[b]	0.702	3.266[b]
Soybean meal	Wheat	0.0062	0.0228	−0.0090	0.0300			
		(3.073)[c]	(1.122)	(−0.443)	(1.474)	9.468[a]	1.185	3.239[b]
Wheat	Soybean meal	0.0033	−0.0152	−0.0255	0.0081			
		(1.400)	(−0.754)	(−1.260)	(0.402)	1.967	0.782	1.158
Soybean oil	Wheat	0.0025	−0.0199	−0.0128	0.0373			
		(1.516)	(−0.943)	(−0.608)	(1.766)	2.302	1.511	1.709
Wheat	Soybean oil	0.0051	−0.0102	−0.0374	0.0068			
		(2.453)[c]	(−0.531)	(−1.948)	(0.357)	6.027[b]	1.443	2.608[b]
Soybean	Oats	0.0053	0.0207	0.0099	0.0222			
		(2.183)[c]	(1.350)	(0.645)	(1.451)	4.777[b]	1.525	2.683[b]
Oats	Soybean	0.0047	−0.1110	−0.0305	0.0459			
		(2.032)[c]	(−3.720)[c]	(−1.020)	(1.534)	4.136[b]	5.929[a]	5.647[a]
Soybean meal	Oats	0.0054	0.0181	0.0084	0.00040			
		(2.584)[c]	(1.105)	(0.511)	(0.245)	6.692[a]	0.548	2.634[b]
Oats	Soybean meal	0.0031	−0.0898	−0.0216	0.0465			
		(1.464)	(−3.400)[c]	(−0.818)	(1.756)	2.150	5.283[a]	4.612[a]
Soybean oil	Oats	0.0022	−0.0052	0.01200	0.0281			
		(1.391)	(−0.308)	(0.705)	(1.663)	1.937	1.173	1.314

TABLE IV (Continued)

Error Correction Model (ECM) for Testing for Long-Term (LT) and Short-Term (ST) Relationship for Prices of Agricultural Futures Contracts

Dependent Variable	Independent Variable	a_1, β_1	c_1, ϕ_1	c_2, ϕ_2	c_3, ϕ_3	H_0: No Relationship: No LT Impact	No ST Impact	No LT or ST Impact
Oats	Soybean oil	0.0042 (2.322)[c]	−0.0398 (−1.589)	−0.0644 (−2.860)[c]	0.0188 (0.750)	5.401[b]	3.142[b]	3.904[a]
Soybean meal	Soybean	0.0071 (2.369)[c]	0.0203 (0.560)	−0.0376 (−1.034)	−0.0411 (−1.134)	5.624[b]	0.879	2.716[b]
Soybean	Soybean meal	0.0018 (0.581)	0.0710 (2.364)[c]	0.0240 (0.798)	0.0452 (1.502)	0.337	2.658[b]	2.623[b]
Soybean oil	Soybean	0.0012 (0.574)	−0.0185 (−0.602)	−0.0020 (−0.065)	0.0572 (1.858)	0.330	1.301	1.048
Soybean	Soybean oil	0.0058 (2.402)[c]	0.0459 (1.969)[c]	−0.0097 (−0.415)	0.0030 (0.128)	5.781[b]	1.330	2.422[b]
Soybean oil	Soybean meal	0.0022 (1.404)	−0.0398 (−1.756)	−0.0014 (0.059)	0.0409 (1.808)	1.977	2.184	2.136
Soybean meal	Soybean oil	0.0039 (2.286)[c]	−0.0524 (−2.528)[c]	0.0173 (−0.830)	0.0008 (0.040)	5.240[b]	2.561	3.177[b]

Notes: The data are natural logarithms of daily closing prices for six nearby agricultural futures contracts: corn, wheat, oats, soybean, soybean meal, and soybean oil. The data cover the time period from January 2, 1981, to October 24, 1991. The variable Z_t, which tests for long-term relationship, is estimated using a procedure suggested by Engle and Granger (1987). When X_t is the dependent variable in the ECM, the regression used is $X_t = a_0 + \hat{a}_1 Y_t + \varepsilon_t$. $\hat{Z}_t$ is computed from $\hat{Z}_t = X_t - \hat{a}_1 Y_t$. The roles of X_t and Y_t are reversed when Y_t is the dependent variable in the ECM.
The following ECMs used are

$$\ln X_t - \ln X_{t-1} = a_0 + a_1\hat{Z}_{t-1} + \sum_{i=1}^{m} c_i(\ln Y_{t-i} - \ln Y_{t-i-1}) + \sum_{j=1}^{m} d_j(\ln X_{t-j} - \ln X_{t-j-1}) + \varepsilon_t$$

and

$$\ln Y_t - \ln Y_{t-1} = \beta_0 + \beta_1\hat{Z}_{t-1} + \sum_{i=1}^{m} \Phi_i(\ln X_{t-i} - \ln X_{t-i-1}) + \sum_{j=1}^{m} \Theta_j(\ln Y_{t-j} + \ln Y_{t-j-1}) + \varepsilon_t$$

These two models test if the independent variable, $Y(X)$, has long-term (LT), short-term (ST), and long-term or short-term (LT or ST) impact on the dependent variable, $X(Y)$. The null hypotheses of no-impact are tested with F-statistics.
[a,b]Indicates rejection of the null hypothesis of no-LT, no-ST or no LT or no ST impact at the 1%, or 5% level, respectively.
[c]Indicates the individual regression coefficient is statistically significantly different from zero at the 5% level or better.

one, $I(1)$. The time series of prices are also cointegrated. The empirical results of the ECM show strong, statistically significant, long-term relationships between the six commodity futures contracts but no short-term causality. These results reject the working hypothesis that the prices of the six agricultural products move independently. Such rejection is consistent with economic thought on substitutability and complementarity between agricultural commodities. It is believed, also, that rejection of the working hypothesis is due to the effects of specific factors, such as climate and geography, global demand shocks due to government farm policies at home and abroad, and the excess comovement hypothesis of Pindyck and Rotemberg (1990).

The very essence of futures markets is the opportunity they offer for price discovery. The results of this study suggest that the price discovery function of a commodity futures contract signals valuable information that is relevant to other related commodity futures contracts. For example, the results indicate that corn prices have a long-run impact on wheat, soybeans, and soybean meal. This means that the price discovery process generated in corn futures markets offers valuable information not only to corn cash markets but also to the spot markets of wheat, soybean, and soybean meal. This information incorporates several possible factors such as substitutability, complementarity, weather and climatological factors, world agricultural demand and supply shocks, even herd trends. No analyst could evaluate the impact of all these factors in the absence of a futures market. The price discovery mechanism of a well-functioning futures market allows the quantification of such information and its use across economically linked markets.

The findings have further implications in terms of cross hedging and cross speculation and offer justification for the introduction of the new crop yield futures and option contracts. In other words, if significant linkages are known to exist between two agricultural products, cross hedging opportunities become possible. For example, if corn and soybeans are economically linked for the various reasons explained above, a soybean position could be hedged in the much more liquid corn futures market. Similarly, linkages between agricultural markets could offer cross speculation opportunities.

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