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Stochastic Interest Rates and Price Discovery in Selected Commodity Markets

by

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STOCHASTIC INTEREST RATES AND PRICE DISCOVERY IN SELECTED COMMODITY MARKETS

SUMMARY

The temporal relationship between Chicago corn and soybean cash prices, nearby futures prices, and interest rates is examined using daily 1980-1989 data. Johansen cointegration tests suggest joint movement of the three series over the data period considered. In addition, analyses of individual crop years, which is consistent with previous work, shows co-movement between cash, futures, and interest rates in years when bivariate cointegration between cash and futures prices was not found. The results provide initial empirical evidence that a potential limitation of previous research in the study of cash-futures simple efficiency has been the exclusion of the interest rate as a common stochastic factor explaining equilibrium in models of cash and futures prices.

1. INTRODUCTION

One important role of a futures market is to serve as a risk management vehicle for businesses facing price risk in a cash market. The success of a specific futures contract in providing price risk protection, however, is dependent on the ability of a potential hedger to accurately anticipate the future relationship between cash and futures prices. Attempts to quantify and forecast futures/cash price relationships have received considerable attention in the futures market literature.

Recent developments in cointegration theory have provided a new basis from which to examine the explicit relationships between cash and futures commodity markets. Bessler and Covey studied U.S. cattle markets and found marginal support for the cointegration hypothesis between cash prices and futures contracts closest to delivery. Schroeder and Goodwin failed to find cointegration for cash and futures markets for U.S. live hogs. Fortenbery and Zapata examined markets for storable commodities (corn and soybeans) and found support for the cointegration hypothesis in some crop years but not others. Although it is well known from cointegration theory that non-cointegration does not imply a lack of causation between cash and futures prices (Granger), it is not clear what has contributed to the inconsistency of previous results. Further, it is not clear what the previous cointegration tests imply about market performance. Is it reasonable, for example, to believe that the live cattle markets operate efficiently, but that the live hog markets do not, as has been suggested by previous research? If cointegration tests do hold implications for market efficiency, what would cause the grain markets to operate efficiently in some crop years but not in others?[1]

This article reviews alternative specifications of futures and cash price relationships advanced in the theoretical literature and applies cointegration theory to test whether the seemingly inconsistent results of previous work are a function of asymmetric performance across markets, or whether model specification may influence cointegration results, and thus interpretations of specific market efficiencies. It examines cash and nearby futures prices (that is, futures prices for the contract closest to maturity) for U.S. corn and soybean markets to empirically test whether the observed nonstationarity in the cash/futures relationship can be explained by the omission of a common stochastic element in the empirical model specification used in previous research.

In general, theory suggests that the current cash price and the current futures price for a deferred delivery date are linked by a market carrying charge (Blank, Carter, and Schmiesing). The carrying charge represents the potential compensation available to a market participant who forgoes making a cash market transaction at the current cash price in favor of making the same transaction at a later date. If the carrying charge is itself nonstationary, then we would expect bivariate cointegration tests between a cash and futures price to be biased against a finding of cointegration.

The carrying charge observed in the market is made up of several components. These include a possible risk premium, a convenience yield, the prevailing interest rate, physical storage costs, and insurance costs. The existence and measurement of risk premiums and convenience yields has received considerable attention in the literature (Dusak; Carter, Rausser, and Schmitz; Fortenbery and Hauser; and Wright and Williams). Neither risk premiums nor convenience yields are directly observable, however, and there is no clear consensus from the literature as to whether either exists.

Interest rates are directly observable. They represent the opportunity costs associated with holding inventory between the current period and the period in which a specific futures contract matures. It has been shown that identifying the correlation between changes in interest rates and changes in cash and futures prices is an important component in measuring intertemporal hedging effectiveness (Chang and Fang), and in describing the relative efficiencies of cash and futures markets (Baillie and Myers). If interest rates are nonstationary, then it can be assumed that carrying charges are nonstationary and critical in describing the dynamic relationship between cash and futures prices. If inclusion of interest rates in a cointegration type model affects the identified cointegration relation between cash and futures, then it can be concluded that failure to explicitly account for at least this component of the market carrying charge does in fact bias cointegration test results, and previous work which has not accounted for this should be viewed as suspect.

This paper proceeds as follows. Section 2 introduces a compact summary of the previous economic modeling efforts focused on commodity price discovery. Section 3 introduces the econometric methodology of cointegration analysis, followed by a discussion of the data used in the current empirical investigation. Next, results and implications of the work are discussed. The paper concludes with a discussion of the role of interest rates in identifying cash/futures relationships for storable commodities, with implications for the importance of explicitly considering carrying charges.

2. PRICE DISCOVERY AND COINTEGRATION

The hypothesis (associated with market efficiency) that futures prices are unbiased predictors of future cash (spot) prices implies a hypothesis of joint equilibrium between the two price series (and rationality of expectations) (Gardner). Initial efforts to test this hypothesis consisted of estimating a static regression between cash and futures prices given by

(1) $$S_t = \alpha + \beta F_t + e_t$$

where the S is the spot price, F is a futures price, and e_t measures the stochastic difference between cash and futures. This relationship assumes that new information will affect both cash and futures markets instantaneously (i.e., one market does not lead the other one) and that new information will affect both markets in the same way. However, it can be shown under some plausible assumptions that particular changes in information, such as a decline in interest rates, can cause changes in cash prices that move in the opposite direction of those for futures prices (Dewbre). Further, movement to long run equilibrium may not occur instantaneously. The realization that prices may take some time to adjust to a new long run equilibrium after the introduction of new market information has led to the application of cointegration theory to market relationships.

The cointegration model most often used in the study of agricultural commodity markets has been a bivariate regression between cash and futures prices (Bessler and Covey, Fortenbery and Zapata). The model specifies a relationship between cash price (S_t) and futures (F_t) that, when solved for the price difference results, in:

(2) $$F_t - S_t = \alpha + \delta(F_{t-1} - S_{t-1}) + \varepsilon_t.$$

The larger δ in the above equation the greater the range of allowed disparity between futures and cash price changes before the two series are brought back to equilibrium. If δ is close to one, then cash and futures prices do not converge rapidly, and their difference is assumed to be stable. If δ is small, prices will converge quickly because only a small fraction of the price difference on day t-1 will persist to day t.

Equation (2) is based on the theoretical market relationship outlined by Garbade and Silber. Garbade and Silber, however, specified the cash/futures relationship as being between a cash price and the cash equivalent futures price. The cash equivalent futures price is measured as:

(3) $$F_t' = F_t - r\tau_k$$

where r is the prevailing interest rate and τ_k represents the interval between the current time period and the maturity date of the futures contract. In their work on price discovery, Garbade and Silber assume that r is flat and stationary. Cointegration applications based on equation (2) have implicitly made the same assumption. If interest rates are flat and stationary, then failure to discount the observed futures price to its cash equivalent would have no effect on the finding of a cointegrating vector between cash and futures, although it might be argued that some information has been lost. However, the validity of the interest rate stationarity assumption has not been tested in previous work. If interest rates are not stationary, then failure to explicitly account for their influence on commodity prices will bias cointegration results against a finding of cointegration. This may lead to a conclusion of cash and/or futures market inefficiency when in fact the real problem is one of model mis-specification.

The potential importance of interest rates on commodity prices has been addressed by other research (Schuh and Frankel (1984,1986); Racer; and Kitchen and Denalby). Unfortunately, however, cointegration applications in commodity price analysis have not directly accounted for interest rate behavior.

3. COINTEGRATION AND ERROR-CORRECTION REPRESENTATION

If an equilibrium relationship between cash, futures, and interest rates exists then $y_t = (\ln S_t \; \ln F_{t-k} \; \ln r_{t-k})'$ is cointegrated with $Cy_t = z_t$, where z_t is a stationary error term about a mean of zero, suggesting that in equilibrium $Cy_t = 0$. Using Granger's representation theorem, an error-correction model (ECM) can be specified. By the recent asymptotic results in cointegration theory (Johansen (1988), and Phillips), the vector autoregressive model with Gaussian errors is given by

(4) $$y_t = \mu + \Pi_1 y_{t-1} + \ldots + \Pi_{p-1} y_{t-p+1} - \Pi_p y_{t-p} + e_t,$$

where t=1,2, ...,T, and $e_1,\ldots,e_T$ are independent Gaussian variables in k dimensions with mean zero and variance Ω . This model can be re-parameterized in ECM form as

(5) $$\Delta y_t = \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} - B[C, \eta][y'_{t-p} \; 1]' + e_t,$$

where

(6) $$\Gamma_i = -(I_K - \Pi_1 - \ldots - \Pi_p), \quad i=1,2, \ldots, p-1,$$

and

(7) $$\Pi = -I + \Pi_1 + \ldots + \Pi_p.$$

These specifications are convenient since the hypothesis of cointegration implies restrictions on the Π matrix leaving the other parameters free. The hypothesis of at most r cointegrating relations is formulated as the restriction

(8) $$H_r^* = \Pi = BC \text{ and } \mu = BC_0$$

which we test using the trace test:

$$\text{Trace Test} = -T\Sigma_i \ln(1 - \lambda_i), \quad i=r+1,..., K$$

and the λmax statistic:

$$\lambda\text{max Test} = -T\ln(1 - \lambda_{r+1}),$$

Critical values for testing the number of cointegrating relations are tabulated in Johansen and Juselius (see Appendix tables A2 and A3).

The Data and Estimation Procedure

The data used in this analysis consists of daily closing futures prices for corn and soybean futures contracts from 1980-89, daily Chicago corn and soybean cash prices for the period 1980-89, and the 90-day U.S. T-bill rates for the same period. Consistent with previous cointegration work, the futures contract observed is the one closest to maturity. Corn futures contracts are traded for delivery in March, May, July, September and December. Soybean futures contracts are for January, March, May, July, August, September and November delivery. On first notice day (i.e. the first day on which physical delivery can be made against a given futures contract) the expiring contract is dropped and the next contract closest to maturity is observed. By always observing the futures contract closest to maturity, the temporal span between the cash price (which is for immediate delivery) and the futures price for later delivery is minimized. This has the effect of minimizing the impact of interest rates on the relationship between cash and futures prices. If interest rates are significant in explaining co-movement between nearby futures and cash prices, they must be important in explaining the relationship between cash and futures prices for more distant delivery.

The Cash and futures commodity prices were collected from Knight Ridder's CRB Infotech data bases. The daily 90-day T-bill rates were collected from various issues of The Wall Street Journal.

The cointegration tests have been conducted two ways. The first approach tests for cointegration between the three series (cash prices, futures prices, and interest rates) over the entire data period. This is consistent with the traditional notion of attempting to approximate the long run by employing a relatively long time series. In general, it is assumed that the longer the time span considered, the closer one comes to approximating long run dynamics.

As suggested by Hakkio and Rush, however, measuring the long run for economic time series may not be as trivial as collecting the longest time series available. For some economic variables, the long run may be defined very specifically. Fortenbery and Zapata have suggested that agricultural futures contracts for seasonally produced commodities may be an important example. The role of futures contracts for grains and soybeans are to essentially allocate the current year's production through to the next production period. As such, the relationship between a specific futures contract and cash prices may be crop year unique, reflecting specific supply and demand conditions expected to persist only through the given crop year. This implies that the appropriate definition of the long run for commodity futures contracts may simply be the period over which they allocate supply. For corn and soybeans, this would be the relevant crop year. To account for this, we also examine cointegrating relations on a crop year basis. Corn and soybean crop years begin on September 1. This corresponds generally with the new crop harvest. The data are divided into 10 individual crop years, and the importance of interest rates is examined on a crop year basis. While the appropriate definition of the long run is debatable, the crop year results are generally consistent with those from the entire sample period, and allow for a specific comparison of the results generated here with those of previous work.

4. RESULTS

Nonstationarity

Chicago terminal cash and nearby futures prices, and the 90 day T-bill rate behave as nonstationary series. Phillips-Perron tests for unit roots suggest[2] that cash and futures prices are nonstationary of order one; the T-bill rate is nonstationary of order one at the 5 % level for the aggregate data period and in all individual crop years except 82-83, 83-84, and 86-87 when it is nonstationary at the 10 % level. This suggests that Chicago cash prices and nearby futures prices behave as stochastic trend variables during all ten years, and that the 90-day T-bill rate has a stochastic trend during most years. To accommodate stochastic behavior, equation (5) is specified as a three variable system for both the corn and soybean markets. Results from the trivariate model specification are reported for both the aggregate period, and on a crop year basis. The crop year results are compared to those generated with the standard bivariate model specified in previous work.

Cointegration

The results of the cointegration tests between corn and soybean cash prices, nearby futures prices, and T-bill rates for the period 1980-1989 are reported in table 1. Following a suggestion in Johansen, the residuals for each series were tested for serial correlation using the Box-Ljung Q statistic. The trace and λmax tests of Johansen are reported for the hypotheses of no-cointegration (r=0), at most one cointegrating relation (r <= 1), and at most two cointegrating relations (r=2). The tests find cointegration between cash, futures, and T-bill rates suggesting that interest rates are indeed critical in describing basis behavior in both corn and soybean markets. This result suggests that at least some of the inconsistent and weak results of previous work may reflect less on individual market performance than an inappropriate specification of cash and futures price relationships in empirical model formulations.

Table 2 reports cointegration tests for individual crop years for both the bivariate model used in previous work, and the trivariate model proposed here.[3] The test statistics are as defined in table 1, and P is the lag in the error correction model for which the residuals act as white noise. The bivariate tests detect cointegration between cash and futures prices in 1983-84, 1984-85, 1986-87, and 1988-89, but not other crop years. In the years when there is bivariate cointegration it takes about two days for cash and futures to return back to equilibrium. Except in the 1988-89 crop year, the cointegrating relation between cash and futures is close to the expected (1,-1) cointegrating vector when cointegration is found (table 3). The speed of adjustment towards equilibrium in the years when there is cointegration is faster for the cash market than for the futures markets, except for the 1983-84 crop year.

The results of the cointegration tests for cash prices, nearby futures prices and interest rates, by crop year, are reported in table 4. The trace and λmax tests of Johansen are reported for the hypotheses of no-cointegration (r=0), at most one cointegrating relation (r <= 1) and at most two cointegrating relations (r <= 2) corresponding to the trivariate system. The results suggest that Chicago cash prices for soybeans, the nearby futures price, and the interest rate followed each other in most crop years, except during 1985-86, 1986-87 and 1987-88. The lag in the error correction term (p) suggests that the cash market for soybeans is not necessarily just a satellite market responding to changes in futures prices since it takes about 2 days (except for 1982-83 when it takes about a week) for the futures market to completely adjust back to equilibrium.

The estimated cointegrating vectors and speed of adjustment towards equilibrium are reported in Table 5. An important observation concerns the sign and magnitude of the estimated coefficients. Except for 1984-85 and 1985-86, the estimated cointegrating vectors have the expected signs (+,-,-). At first glance, the magnitudes of the cointegrating vectors are not as predicted by the equilibrium relation of cash-futures-interest rates, that is (1,-1,-1). However, since futures and cash prices are measured as levels, and interest rates are measured as rates of return the expectation of (1,-1,-1) is not appropriate. A second observation of note is for the years when the three variables do not appear to be cointegrated. In these years the estimated cointegrating coefficient between cash and futures is basically (1,-1). The speed of adjustment towards equilibrium in cash prices is consistently negative (except for 1987-88), however, its magnitude varies across years, from very low speed of adjustment in 1985-86 (-0.035) to relatively fast adjustment in 1984-85 (-0.508). Observe that B in table 5 measures the speed with which the cointegration relation (the residuals from the estimated equilibrium relation) enters the equation for each of the three series. The speed of adjustment in the futures price equation is negative during 1981-82, 1982-83 and 1988-89, but positive for the other crop years.

Also note that during the early 1980s the results from the bivariate system suggest no cointegration between soybean cash and nearby futures markets whereas the trivariate results indicate a strong long-term co-movement for cash-futures-interest rates. The early 1980s were years of high and volatile interest rates. The U.S. federal reserve system was beginning to experience the effects of variable interest rates, the U.S. economy in general was experiencing a historical high level of inflation, and it appears that commodity prices were responsive to changes in interest rates. Cointegration in the trivariate model is also found during the years when there was bivariate cointegration, except during 1986-87.

5. IMPLICATIONS

The empirical evidence presented here lends support to the proposition that interest rates tend to affect, and move together with, cash and futures prices for storable commodities. Interest rates appear to have had a significant effect on cash and futures prices for both corn and soybeans in the early 1980s. These results support the findings of Fortenbery and Zapata, and suggest that bivariate cointegration tests for storables may be fragile.

An important implication of the results presented here is that market efficiency conclusions for commodity markets based on bivariate cointegration analysis may in many cases be inappropriate. A lack of bivariate cointegration does not constitute a finding of market inefficiency if the relationship between the two examined series is being impacted by a third stochastic component. This suggests that the inconsistency of cointegration results from previous studies of commodity markets may result from model mis-specification rather than be indicative of actual market performance. This is an important point. In most cases where researchers have examined the pricing relationship of futures and cash markets, the markets studied have been separated by both a spatial and temporal component not explicitly accounted for in the cointegration analysis. If there are pricing components in either the temporal or spatial market links which are themselves nonstationary, then a bivariate cointegration model is biased in favor of finding no cointegration between the cash and futures markets, even though they both may be efficient markets for like assets. A more complete model specification would then be necessary before drawing meaningful conclusions related to overall market efficiency. The results here suggest that in at least some crop years temporal relationships between futures and cash prices are non-stationary, and must therefore be explicitly considered in a cointegration framework.

Results presented above support the hypothesis that futures markets provide a price discovery function, and suggest that cash markets are not merely a derivative market of the futures. The finding of cointegration over the aggregate data period, as well as in 7 of the 9 years studied (either through the bivariate or the trivariate model) suggests that there is long-run causation either from the futures to the cash market or vice versa; this results directly from the fact that if there is cointegration between two or more series then there is also causation in at least one direction (Granger, 1986). As can be seen from the results, failure to explicitly account for the role of interest rates in the cointegration model would bias a researcher away from the above observations since bivariate cointegration is found in less than half of the crop years studied. It appears that independent of the direction of causation, interest rates do play a role in the way cash and futures prices relate to each other. Or, in the rational expectations framework, the effect of economic information contained in interest rates is important in explaining the co-movement of futures and cash prices, and therefore their interrelationship. We note that the question of whether the relationship between cash and futures is better explained by incorporating the response in cash and futures prices to interest rate changes can be challenged during the years (1985-86, 1986-87 and 1987-88) when cointegration tests fail to find expected co-movement between the three series. However, a lack of long-term co-movement does not preclude a response in cash and futures to interest rates in the sense that interest rates can Granger cause cash and/or futures prices (in a forecasting sense), and yet not have a long-term co-movement with either series.

6. CONCLUSIONS

This paper presents credible evidence of potential errors which can be made in drawing market performance conclusions from bivariate cointegration estimates which do not adequately recognize the theoretical relationships between the two data series being examined. However, the results here are still not definitive from a market efficiency perspective. There are several assumptions that should be more closely examined before making any definite conclusions about the efficiency of soybean and corn markets in the U.S. The first relates to the omission of storage costs in the above analysis, and the second, and perhaps more importantly, the role of convenience yields. If returns to storage are non-stationary in a given crop year, then under an assumption of efficient markets we would expect no cointegration to exist given the models used here.[4] As noted by Hakkio and Rush, efficient markets for different commodities should not be cointegrated. For the data sets used in this study (crop year data), it is not possible to study storage cost data. We have implicitly assumed that any stochastic behavior in the cost of storage data is incorporated in the interest rates if in fact storage cost data follows a stochastic process.

The effects of convenience yields is perhaps the most problematic factor to explain because it cannot be directly measured in a cointegration context. The cointegration results, however, appear to suggest that nonstationary behavior in convenience yields is unlikely because when there is no cointegration for the three series, cash and futures are cointegrated (except in the 1985-86 crop year) suggesting that in equilibrium, the residuals from the cointegrating equation are I(0), eliminating, in this context, the possibility for a fourth stochastic trend.

Perhaps the main challenge emerging from this discussion is the development of a cointegration theory formally explaining the dynamics of the expected interrelationships similar to that developed in Chang and Fang whereby stochastic interest rates are included in measuring intertemporal hedging effectiveness. A somewhat similar interpretation is developed in Brenner and Kroner who explain the evolution of cash (spot) prices by a Brownian motion process which, under given assumptions, explains the stochastic trend behavior of cash, and, as a result of the identity in equation (2) , of futures prices. They also assume that the interest rate follows a mean reverting process that seems consistent with the empirical properties of interest rate data. Whether these stochastic models provide valuable insight to understanding the dynamics of cash-futures interrelationships for storable commodities remains an open question. The original work of Garbade and Silber recognized the role of interest rates but assumed that the term structure of interest rates is flat and stationary and that the cash market value of a commodity follows a Gaussian diffusion process. It remains an open question whether their partial equilibrium analysis can be expanded to allow for a less restrictive process in interest rate behavior. Other researchers (Baillie and Myers) have suggested that cash and futures prices for various commodities can be well described as martingales with near-integrated GARCH innovations and find some empirical support for this hypothesis. It is not clear to what degree the inclusion of interest rates may affect the results from GARCH specifications. Perhaps the results presented here will motivate a closer evaluation of the role of interest rates in determining dynamic relationships between and cash and futures prices for storable commodities.

Table 1. Testing the Number of Cointegrating Relations between Chicago Soybean Cash Prices, Nearby Futures Prices, and 90-Day T-bill Rates, Aggregate Data, United States.

H_2^*	Trace	λ_{max}	Series	BETA	ALPHA
			CORN		
r<=2	2.8944	2.8944	Futures	1.00	0.005
r<=1	19.4497	16.5552	Cash	-0.367	0.076
r =0	53.3902	33.9405	Interest R.	-0.079	-0.044
			SOYBEANS		
r<=2	4.7455	4.7455	Futures	1.00	0.028
r<=1	21.9581	17.2127	Cash	-0.154	0.665
r =0	98.2822	76.3240	Interest R.	-0.032	0.002

NOTES:

1) There are three series (p=3); therefore, 3-r is the number of common stochastic trends between futures prices, cash prices, and interest rates, with r being the number of cointegrating relations (r=2,1 or 0). Critical 95% Quantiles (Johansen and Juselius) for 1, 2, and 3 common stochastic trends are Trace(9.904, 20.168, 35.068), and λ_{max}(9.094, 15.752, 21.894).

2) H_2^* represents the hypothesis testing the number of cointegrating relations or alternatively the dimension of the system in terms of the number of common stochastic trends. The * is used to represent the model with constant added to the EC term of equation (7). p is the number of lags in the EC term.

Table 2. Testing the Number of Cointegrating Relations between Chicago Soybean Cash Prices and Nearby Futures Prices, Selected Crop Years, United States.

H_2^*	Trace	λ_{max}	p		Trace	λ_{max}	p
	1980-81		2	1981-82			2
r<=1	2.242	2.242			1.996	1.996	
r=0	19.467	17.225			17.068	15.072	
	1982-83		4	1983-84			2
r<=1	6.663	6.663			3.154	3.154	
r =0	16.792	10.129			38.631	35.477	
	1984-85		2	1985-86			2
r<=1	2.569	2.569			2.269	2.269	
r =0	56.514	53.945			7.747	5.477	
	1986-87		2	1987-88			2
r<=1	3.871	3.871			2.899	2.899	
r =0	21.922	18.051			17.663	14.764	
	1988-89		2				
r<=1	3.397	3.397					
r =0	35.892	32.496					

NOTES:

1) There are two series (k=2); therefore, 2-r is the number of common stochastic trends. Critical 95% Quantiles (Johansen and Juselius) for 1 common stochastic trend are Trace(9.904), and λ_{max}(9.094).

2) H_2^* represents the hypothesis testing the number of cointegrating relations or alternatively the dimension of the system in terms of the number of common stochastic trends. The * is used to represent the model with constant added to the EC term of equation (7). p is the number of lags in the EC term.

3) The underlined numbers denote 95% quantile significance.

Table 3. Estimated Cointegrating Vectors (C) and Speed of Adjustment (B) among Chicago Soybean Cash Prices and Nearby Futures Prices, Selected Crop Years, United States.

	C	B	p		C	B	p
1980-81			2	1981-82			2
Cash	1.000	-0.226			1.000	-0.160	
Futures	-0.784	-0.087			-0.837	-0.027	
1982-83			4	<u>1983-84</u>			2
Cash	1.000	-0.110			1.000	-0.129	
Futures	-1.053	-0.018			-0.892	0.151	
<u>1984-85</u>			2	1985-86			2
Cash	1.000	-0.507			1.000	-0.067	
Futures	-0.963	0.068			-0.631	-0.040	
<u>1986-87</u>			2	1987-88			2
Cash	1.000	-0.074			1.000	0.180	
Futures	-1.079	0.003			-0.998	0.269	
<u>1988-89</u>			2				
Cash	1.000	-0.433					
Futures	-0.838	-0.228					

NOTES:

1. The normalization is on cash prices. For 1980-81, for instance, the C column represents the cointegrating equation given by $\ln S_t = 0.784 \ln F_t$, with the constant term omitted. The residuals from this equation, that is z_t, are given by $z_t = \ln S_t$ - constant - $0.78 \ln F_t$ and is often referred to as the cointegrating relation. The B column is the speed with which the cointegrating relation enters the equation for each series. For 1980-81 the B column suggests that the speed of adjustment towards equilibrium in cash prices is about 2.6 times faster (.226/.087) than that in futures.

2. The underlined years denote significant cointegration at the 95 % quantile.

Table 4. Testing the Number of Cointegrating Relations for Chicago Soybeans Cash Prices, Nearby Futures Prices, and 90-day Treasury bill, Selected Crop Years, United States.

H_2^*		Trace	λ_{max}	p		Trace	λ_{max}	p
	1980-81			2	1981-82			2
r<=2		9.699	9.699			3.048	3.048	
r<=1		20.182	10.483			15.702	12.654	
r =0		43.714	23.532			45.086	29.384	
	1982-83			5	1983-84			2
r<=2		1.960	1.960			2.461	2.461	
r<=1		9.860	7.899			9.883	7.422	
r =0		39.438	29.579			49.179	39.295	
	1984-85			2	1985-86			2
r<=2		3.575	3.575			3.058	3.051	
r<=1		14.227	10.651			7.836	4.778	
r =0		69.046	54.891			24.749	16.913	
	1986-87			2	1987-88			2
r<=2		3.938	3.938			3.562	3.562	
r<=1		8.788	4.849			9.519	5.958	
r =0		28.366	19.578			23.121	13.601	
	1988-89			2				
r<=2		1.169	1.169					
r<=1		8.528	7.359					
r =0		41.119	32.590					

NOTE: 1) There a three series (k=3); therefore, 3-r is the number of common stochastic trends. Critical 95% Quantiles (Johansen and Juselius) for 1, 2, and 3 common stochastic trends are, respectively, Trace(9.904, 20.168, 35.068), and λ_{max}(9.094, 15.752, 21.894).

2) See note 2 in table 2.

3) The underlined numbers denote 95% quantile significance.

Table 5. Estimated Cointegrating Vectors (C) and Speed of Adjustment (B) among Chicago Soybean Cash Prices, Nearby Futures Prices, and 90-day Treasury bill, Selected Crop Years, United States.

	C	B	p		C	B	p
1980-81			2	1981-82			2
Cash	1.000	-0.088			1.000	-0.131	
Futures	-0.853	0.070			-0.783	-0.022	
I. Rate	-0.094	0.218			-0.021	0.603	
1982-83			5	1983-84			2
Cash	1.000	-0.381			1.000	-0.114	
Futures	-0.955	-0.323			-0.906	0.198	
I. Rate	-0.366	0.091			-0.053	-0.080	
1984-85			2	1985-86			2
Cash	1.000	-0.508			1.000	-0.035	
Futures	-0.970	0.070			-1.006	0.014	
I.Rate	0.010	-0.023			0.099	-0.107	
1986-87			2	1987-88			2
Cash	1.000	-0.069			1.000	0.108	
Futures	-1.007	0.012			-0.967	0.160	
I. Rate	-0.171	0.047			-0.103	0.221	
1988-89			2				
Cash	1.000	-0.436					
Futures	-0.840	-0.233					
I. Rate	-0.017	0.037					

NOTE: See notes 1 and 2 in table 2.

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ENDNOTES

1. A potential answer, of course, is that cointegration measures long-run relationships and individual crop years may not be sufficient to approximate the long run. This is discussed in more detail later.

2. Tabulated results for Phillips-Perron test statistics are available from the authors.

3. In the interest of brevity, we only report soybean results for individual crop years. Results for corn are similar to soybeans, and are available from the authors.

4. This would also be true of transport costs if the two markets were for delivery in different locations. We have avoided that problem here by choosing a cash and futures market which both bid for delivery in Chicago.