Price Discovery Role of Futures Prices: A Linear Feedback Approach

by

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This paper measures the degree of dependence between cash and futures prices for corn and soybeans using a linear feedback approach. The degree of dependence between these two series is decomposed into two directional and one contemporaneous feedback. These feedbacks are used to provide evidnce of price discovery role of futures price and also market efficiency. The feedback results suggest that soybean futures market is more efficient than that of corn. Regarding price discovery role of futures prices, one might argue for the price discovery role of corn futures, even though the directional feedback from futures to cash price was estimated to be only 5 percent. In case of soybeans, the price discovery role of futures prices can only be argued if one can justify the causal ordering of contemporaneous feedback from futures to cash prices.

Introduction

Futures markets have been extensively studied for their contributions to the price discovery process (Yun et al. 1995, Quan 1992, Garbade and Silber 1983, Brorsen et al. 1984). The price discovery process is analyzed by using futures prices as a basis for pricing cash market transactions (Working 1984, Wiese 1978, p.87, Garbade and Silber 1983). Whether futures prices contribute to the discovery of market price is tested by examining the relationships between the prices of futures contracts and cash commodities. Researchers have differed widely in their findings regarding the role of futures prices in price discovery. For instance, Martin and Garcia (1981); Leuthold and Hartman (1979) concluded that prices are not discovered in the futures markets. However, Just and Rausser (1981) found that the futures price is a good estimator of the cash price. Similarly, Brorsen et al.(1984) found results similar to those of Just and Rausser, concluding that futures prices cause cash prices but not vice-versa.

In this paper, we employ a method developed by Geweke (1982, 1984) and extended in papers by McGarvey (1985) and by Cushing and McGarvey (1990) to analyze the bivariate time series relationships between futures and cash prices. This approach seems to be useful in estimating relationships between two time series in the sense that it measures the degree of dependence and also decomposes this measure into two directional measures and one contemporaneous measure of feedback rather than testing only the hypothesis of unidirectional

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causality. In addition to price discovery, these directional and contemporaneous feedback measures should also yield further evidence regarding price efficiency, which may exist in the market.

Measures of Linear Feedback and Dependence

Borrowing from Cushing and McGarvey's notation and approach, we define Geweke's measures of linear feedback and dependence according to the following autoregressive projections:

$$y_t=\sum_{s=1}^{\infty} a_1(s)y_{t-s}+\sum_{s=1}^{\infty} a_2(s)x_{t-s}+\sum_{s=0}^{\infty} a_3(s)z_{t-s}+\varepsilon_{1t} \qquad \textbf{(1)}$$

$$y_t=\sum_{s=1}^{\infty} b_1(s)y_{t-s}+\sum_{s=0}^{\infty} b_2(s)x_{t-s}+\sum_{s=0}^{\infty} b_3(s)z_{t-s}+\varepsilon_{2t} \qquad \textbf{(2)}$$

$$y_t=\sum_{s=1}^{\infty} c_1(s)y_{t-s}+\sum_{s=0}^{\infty} c_2(s)z_{t-s}+\varepsilon_{3t} \qquad \textbf{(3)}$$

where y is a scalar process and x, y, and z are linearly indeterministic stationary processes. For complete development of these measures, see Geweke (1982, 1984).

The unconditional measures of feedback are defined for the bivariate case where z is identically zero. The measure of linear feedback from x to y is defined by

$$F_{x\to y}=\log[Var(\varepsilon_3)/\,Var(\varepsilon_1)]. \qquad \textbf{(4)}$$

This measure is generally nonnegative and is zero if and only if x fails to Granger cause y, i.e., $a_2(s)=0$ for all s. If x and y are normally distributed, $F_{x\to y}$ is the likelihood ratio statistic (scaled by sample size) used to test the hypothesis that x fails to Granger cause y. $F_{y\to x}$, the measure of linear feedback from y to x, is determined by switching x and y in equations (1), (2), and (3).
The measure of contemporaneous (or instantaneous) linear feedback between x and y is defined by

$$F_{xy}=\log[Var(\varepsilon_1)/Var(\varepsilon_2)]. \qquad \textbf{(5)}$$

This measure of contemporaneous feedback is identical to $F_{y\cdot x}$, determined by switching x and y in equations (1) and (2). $F_{y\cdot x}$ and $F_{x\cdot y}$ are indistinguishable because "x causes y

instantaneously" and "y causes x instantaneously" are equivalent statements.

The measure of linear dependence between x and y is the sum of the measures of linear feedback:

$$F_{x,y}=F_{x\to y}+F_{y\to x}+F_{x\cdot y} \qquad \textbf{(6)}$$

For each of the feedback measures, the transformation *1-exp(-F)* provides the reduction in the one-step-ahead univariate prediction error variance of y. For example, $1\text{-}exp(-F_{x\to y})$ is the proportion of the variance in y, given past y, that is explained by past x. The transformation of the measure of linear dependence, $1\text{-}exp(-F_{x,y})$, is the reduction in the variance of $y(x)$ from including current, future, and past $x(y)$ in the projection of $y(x)$ on past $y(x)$.

These feedback measures provide useful information on degree of price discovery role of futures prices. In addition, these feedback estimates can be interpreted as a measure of efficiency. For example, directional feedback ($F_{x\to y}$), a measure of reduction in prediction error variance of y by including past x, can be used to determine role of y in the discovery of x. Contemporaneous feedback can also be used along with directional feedback to strength the price discovery results but a problem arises in determining its direction of causation. As suggested by Cushing and McGarvey (1990), economic or structural reasoning can be used to determine its direction and also, the magnitude of directional feedbacks may be used to determine its direction. For example, if $F_{x\to y}$ was found to be much higher than $F_{y\to x}$, then one may argue that contemporaneous feedback is from x to y.

These feedback measures can also be used to provide evidence for price efficiency. For example, presence of high contemporaneous feedback along with low directional feedbacks may suggest that movements in both x and y are adjusted within the same day and may be regarded as efficient.

Data and Estimation

In this study, we examined the Chicago relationship of cash and futures prices for corn and soybeans. The data used for the analysis include cash and futures prices for corn and soybeans for January 2, 1994 to December 24, 1995. Both cash and futures prices were collected from the Chicago Board of Trade. The cash price data are the closing quoted daily prices for no.2 yellow corn and no.2 yellow soybean in Chicago. The futures prices are the daily settlement prices for the nearby futures contract. Similar to Bessler and Covey (1991), several dummy variables are considered to account for possible systematic relationships in the data associated with the construction of the nearby futures price. A dummy variable for the last week of the contract and another dummy for the transition from one futures contract to another were considered. All test statistics and estimated relationships show little sensitivity to these different specifications. In the final autoregression specifications including Dickey-Fuller and Cointegration tests, dummy variables were not included.

Before we estimate the feedback measure, it is important to examine the time series properties of the price series to be used for analysis. If both futures and spot prices are nonstationary and cointegrated, then vector autoregression(VAR)in levels or first differences may be misspecified (Engle and Granger, 1987; Granger, 1986).

In this study, the order of integration of each price series is examined using augmented Dickey-Fuller test (ADF). The ADF test is based on the following regression.

$$\Delta X_t = \alpha + \beta X_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta X_{t-i} + \epsilon_t \qquad (7)$$

where Δ is the first difference operator and ϵ_t is a stationary error term. The number of lags to include in the equation was determined using the Aikaike information criterion and was found to be eight for all price series. The importance of including a constant term without a time trend has been addressed by Dickey, Bell, and Miller (1986) and Miller and Russek (1986). Based on their suggestion, the ADF equation was estimated with an intercept and no time trend. All price series are expressed in logarithmic form.

The ADF test statistics are reported in Table 1. The null hypothesis of nonstationarity was tested using a t-test on the β coefficient. The null hypothesis is rejected if β is significantly negative. Based on the critical values reported by Fuller (1976), nonstationarity cannot be rejected for the level of all price series at the 5 percent significance level but nonstationarity was rejected for all the price series expressed in first difference for all the price series at the same significance level. Because determination of lag order using statistical tests alone has been criticized, the ADF test was conducted using different lag orders. These alternative representations did not alter the results of the test. This implies that spot and futures prices of both corn and soybeans show similar temporal properties, i.e. they are integrated of order one.

In the next step, cointegration was tested using the bivariate cointegration technique developed by Engel and Granger (1987) based on the stationarity of the residuals of the cointegration equation. X and Y are cointegrated if the residuals from regressing X on Y and Y on X are both stationary. Cointegration for P_{sco} and P_{fco} was tested by regressing P_{sco} on P_{fco} and testing the residuals from this regression for unit roots (so=soybeans, co=corn, s=spot, and f=futures). Similarly cointegration for P_{sso} and P_{fso} was tested by regressing P_{sso} on P_{fso} and testing its residual for unit roots. Table 2 presents the ADF test statistics on residuals. The results indicate that the nonstationarity of residuals can not be rejected even at the 10 percent significance level. This implies that futures and cash prices in the corn and soybeans market are not cointegrated and no long-run relationships exist between these prices. Cointegration was tested by reversing the price series (i.e. regressing P_{fco} on P_{sco} and P_{fso} on P_{cso}) and testing their residuals for unit roots. The unit root tests did not change.

Having confirmed that cash and futures prices are not cointegrated but first difference stationary, it is logical to use first differenced cash and futures price series for the linear feedback estimation. This ensures stationarity. Measures of unconditional linear feedback between cash and futures prices were estimated for corn and soybeans. The unconditional feedback measures were estimated using a model equivalent to the bivariate form of equations (1) through (3), in which Z is identically zero. As indicated earlier, autoregressions were performed using first difference logarithms of the futures and cash prices. Tweleve lags were included, as determined by Aikaike's Final Prediction Error method. Because this method has been criticized for underestimating lag length, autoregressions were also performed using 18 and 24 lags.

Results

Estimates of unconditional feedback between spot and futures prices for corn and soybeans, adjusted for small sample bias and the corresponding proportional reduction in the prediction error variance are presented in Table 3 and 4 respectively. These feedback measures were estimated using the 12 lag autoregression. Approximate 90% confidence intervals for the reduction in prediction error variance are shown in parentheses. The procedure to adjust for sample bias and determine the confidence interval is similar to that used by Cushing and McGarvey (1990) and is described in the appendix.

The results in Table 3 suggest that corn cash and futures prices are linearly dependent and that the linear feedback from futures to cash price is slightly higher than the feedback from cash to futures prices. The estimates indicate that the inclusion of past futures prices reduces the prediction error variance for cash price by approximately 5 percent, whereas the inclusion of past cash prices reduces the prediction error variance for futures price by about 4 percent. It is also interesting to note that the contemporaneous feedback (that occurring within the same day) between cash and futures prices was estimated to be zero.

Some interesting conclusions from these feedback measures can be derived regarding corn futures. Low directional feedbacks along with no contemporaneous feedback between corn cash and futures prices may be interpreted to mean that these prices are relatively independent. But the degree of independence may vary depending on one's loss functions. For example, given the negligible cost of acquiring cash and futures price data, a forecaster may find it worthwhile to use past futures price changes to predict cash price movements even though the forecast error reduction is quantitatively small. This decision will, of course depend on the forecaster's loss function.

Similarly, feedback measures between soybean cash and futures prices are presented in Table 4. The results suggest that directional feedback either cash to futures or futures to cash are estimated to be near zero. This implies that the inclusion of past futures does not contribute to better predictions of cash prices and vice-versa. The contemporaneous feedback was estimated to be about 18 percent.

Overall, the feedback results suggest that for the time period evaluated the degree of dependence between Chicago corn futures and cash prices is quantitatively low. Presence of low directional feedbacks along with zero contemporaneous feedbacks also indicate inefficiency in either cash or futures prices. But the low directional feedbacks makes the efficiency hypothesis somewhat weaker. On the other side, for soybean futures, near zero directional feedbacks along with high contemporaneous feedback suggest that both soybean futures and cash prices are dependent on each other and each series responds to the movements in the other series within the same day. Zero directional feedbacks in either direction also suggest that both cash and futures prices are efficient in the Chicago market in this period.

Concluding Remarks

This paper measures the degree of dependence between cash and futures prices for corn and soybeans using a linear feedback approach. The degree of dependence between these two series is decomposed into two directional and one contemporaneous feedbacks. Directional and contemporaneous feedbacks provide a measure of efficiency. In addition, directional feedbacks provide evidence of the price discovery role of each series. For the time period analyzed the results suggest that for the Chicago market the degree of dependence between corn cash and futures prices is lower than that of soybeans. This implies that in a relative sense, the Chicago soybean market is more efficient that the corn market.

Another interesting aspect of the result is that the small proportion of variations in corn cash and futures prices are explained by past but not current futures and cash prices respectively whereas a high proportion of movements in soybean cash and futures prices are explained by current but not past futures and cash prices respectively. In other words, this implies that the Chicago soybean market is more efficient than that of corn. Regarding the price discovery role of futures prices, one might argue for the price discovery role of corn futures prices, even though the feedback from corn futures to cash price was estimated to be only about 5 percent but in the case of soybeans the price discovery role of futures prices can only be argued if one can justify the causal ordering of contemporaneous feedback from futures to cash prices (this cuould be the case if market adjustments occur virtually instantaneously).

Appendix

Procedure for Bias Correction and Confidence Interval Estimation

For this paper, we estimated the sampling distributions for each of Geweke's unconditional and conditional feedback measures. In the following, we describe the procedure we used to correct for small sample bias and construct confidence intervals for the three unconditional (two directional and one contemporaneous) measures.

First, we estimated the 6-lag autoregressions using the 96 observations of actual data. Next, we generated 200 sets of simulated data 96 observations in length. Each of the simulated data sets contained the actual values of the initial 6 observations, corresponding to the 6 lags. The remaining 90 observations were generated from the two equations in the bivariate autoregression. The estimation of the three feedback measures from the 200 sets of simulated data provided a sampling distribution for each of the measures f_i, where i is the type of feedback. Given the value of the population feedback F, each sampling distribution's mean, first, and ninth decile were calculated and defined as $E(f)$, L, and U respectively, where L and U are the lower and upper limits of the 80% confidence interval (i.e., $P(f < L) = P(U < f) = .8$ or $P(L < f < U) = .8$).

Defining $\ell = L/E(f)$, $u = U/E(f)$, and $a = F/E(f)$, the above statement becomes

$$P(\ell E(f) < f < uE(f)) = .8$$

or

$$P(a\ell E(f) < af < auE(f)) = .8$$

where af is an unbiased estimator of F. Substituting $aE(f)$ into the previous equation yields

$$P(\ell F < af < uF) = .8$$

or

$$P(af/\ell > af > af/u) = .8.$$

Assuming that ℓ^i, u^i and a^i are parameters of the sampling distribution of f_i, the 80% confidence interval for F is

$$f_a a^i/u^i < a^i f_o < f_o a^i/\ell^i.$$

ℓ^i, u^i, and a^i were estimated by averaging the values of ℓ, u, and a obtained from similar feedback measures. f_o is the feedback point estimate obtained from the autoregression using the original data and a^i is the correction factor. This procedure ensures us that the adjusted point estimates fall within the confidence interval.

Table 1. **Non-stationarity results using Augmented Dickey-Fuller Tests**

Variable	ADF Test Statistics	
	Levels	1st Difference
P_{sco}	-1.856	-11.829*
P_{fco}	-0.751	-7.394*
P_{sso}	-0.347	-7.969*
P_{fso}	-0.109	-8.549*

*Indicates rejection of null hypothesis of non-stationarity or unit root at 5 percent significance level; critical values at 5 percent significance level is -2.88 for n=250 (Fuller).

P_{sco}= daily quoted closing cash price for no.2 yellow corn in Chicago; P_{fco}= corn daily settlement price for nearby futures contract; P_{sso}= daily quoted closing cash price for No.2 yellow soybean in Chicago; and P_{fso}= soybean daily settlement price of nearby futures contract.

Table 2. **Cointegration Tests for Spot and Future Prices for Corn and Soybean**

Variables	ADF Test Statistics
P_{sco} & P_{fco}	-0.8404
P_{sso} & P_{fso}	-1.8673

Table 3. **Estimates of Unconditional Feedback between Futures and Cash Prices for Corn**

Measure	Adjusted Estimate	Proportion of Prediction Error Variance Explained*
$F_{Psco \to Pfco}$	.0434	.0424 (.0422, .0428)
$F_{Pfco \to Psco}$	.0515	.0502 (.0501, .0504)
$F_{pfco, Psco}$	.00016	.00016 (.00015, .00017)

Table 4. **Estimates of Unconditional Feedback between Futures and Cash Prices for Soybeans**

Measure	Adjusted Estimate	Proportion of Prediction Error Variance Explained*
$F_{Psso \to Pfso}$	.0014	.0014 (.0005, .0467)
$F_{Pfso \to Psso}$	.0021	.0021 (.0008, .0599)
$F_{psso, Pfso}$	.1970	.1788 (.1121, .6006)

*Variables represent 1-exp(-F).

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