Price Discovery and Convergence of Futures and Cash Prices

by

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Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 19-20, 2010

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Prices for corn, soybeans, and wheat futures contracts traded on the Chicago Mercantile Exchange and corresponding cash prices at delivery locations frequently failed to converge to the per bushel cost of delivering on futures contracts from 2000 to 2009. We found that convergence failure did not adversely effect the incorporation of market fundamentals from unanticipated information. Essentially identical mark fundamentals, from unanticipated information was incorporated into futures and cash prices when convergence failed. Futures and cash prices moved closer together as contract maturity approached even when they did not converge all the way to the per bushel contract delivery cost, indicating that arbitrage was occurring between the two prices but not completed. Without arbitrage the prices would most likely not incorporate identical market fundamentals from unanticipated information when convergence failed. Our results indicate that the failure to complete the arbitrage between futures and cash prices by driving the difference between them down to per bushel delivery cost at contact maturity affected the ability of the two prices to reflect identical market fundamentals.

Keywords: price discovery, futures-cash convergence, market failure

Introduction

Price discovery in a market is the process of incorporating market fundamentals into price and market fundamentals determine equilibrium prices. The price discovery role of a futures market includes passing market fundamentals to the corresponding cash market in addition to discovering market fundamentals. Market efficiency requires that a futures market and corresponding cash market incorporate the same market fundamentals into their prices. Regulators, elected officials, and participants in these futures and corresponding cash markets could use information about the influence of convergence failure on price discovery in deciding when to advocate for and make changes in a futures contract. In this paper we examine the effects on price discovery from the recent failures of futures and cash prices for corn, soybeans, and wheat to converge at futures contract maturity.

An Agricultural Roundtable held by the Commodity Futures Trading Commission in April 2008 focused attention on the question, of whether the recent convergence failures, adversely affected price discovery? A spokesperson for the National Corn Growers Association, at the roundtable stated that “This loss of convergence has many asking if the corn futures market still provides price discovery and are there still market fundamentals underpinning the current grain prices” (Niemeyer)? These concerns were repeated at the roundtable by those representing cash market participants (Commodity Futures Trading Commission Roundtable).

Irwin *et al.* provided a record of convergence failures for the corn, soybeans, and wheat futures contracts from January 2000 and through March 2009 and also proposed possible solutions. They examined daily futures closing prices from the Chicago Mercantile Exchange Group for corn, soybeans, and wheat during futures delivery periods, and corresponding Illinois River elevator cash bid prices for corn and soybeans and Toledo elevator cash bid prices for wheat. The elevator cash bid prices were provided by the Agricultural Marketing Service, USDA. Their research showed frequent convergence failures. Ten corn contracts, 23 soybean contracts, and 20 wheat contracts had convergence failures of 20 or more cents per bushel (Irwin *et al.*, Figure 1 p. 24).

We examine futures prices and corresponding cash bid prices from these sources for price discovery but prior to delivery periods. We select and examine futures contracts for corn, soybeans, and wheat that had price convergence and those that had convergence failure. The selections and examinations are used to examine the questions:

1. Does convergence failure influence the ability of futures and cash markets to incorporate the same market fundamentals into price?

2. Are there market fundamentals underpinning futures and cash prices when convergence fails?

Procedures and Explanation of Futures and Cash Price Discovery

We used the vector error correction (VEC) and autoregressive (AR) models and the moving average representations of these models to examine price discovery in futures and cash markets. The moving average representations decompose price into permanent and transitory parts. The permanent part estimates market fundamentals. The transitory part estimates the errors in determining market fundamentals.

The VEC model provides conceptual support for our analysis while the AR model provides empirical support. The VEC model is used to show the requirements for related markets to incorporate the same market fundamentals into price. Related markets trade the same asset. The AR model is used to examine if futures and corresponding cash markets are incorporating the same market fundamentals into price.[1]

The procedures used to decompose price into permanent and transitory parts require each price to have a unit root (stochastic trend) in levels but not in first differences. The permanent part of price contains the unit root. It may also contain a deterministic part or deterministic trend.

The VEC model is shown in Equation 1.[2]

$$(1)\quad \Delta Z_t = \Pi Z_{t-1} + \mu_t + \sum_{i=1}^{n-1} \Gamma_i \Delta Z_{t-i} + \varepsilon_t$$

where:

(a) $Z_{t-1} = \begin{bmatrix} f_{t-1} \\ c_{t-1} \end{bmatrix}$ are the futures price, f_{t-1}, and cash-bid price, c_{t-1}, in period t-1.

[1] Figuerola-Ferretti and Gilbert chose the AR model over the VEC model to estimate the effect of introducing aluminum futures trading on price discovery in the corresponding cash market. They found that the VEC model was more sensitive to sample and lag length specification.
[2] This explanation draws on Hansen, on Huang, and on Mills.

(b) $\Delta Z_t = \begin{bmatrix} \Delta f_t \\ \Delta c_t \end{bmatrix}$ and $\Delta Z_{t-i} = \begin{bmatrix} \Delta f_{t-i} \\ \Delta c_{t-i} \end{bmatrix}$ are the changes in the futures and cash-bid prices from period t –1 to t and from period t-i-1 to period t-i.

(c) Π = adjustments toward the long run equilibrium (fundamental) price

(d) $\mu_t = \begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix}$ = constant and trend terms for futures and cash-bid prices

(e) Γ_i = short run adjustments to previous price changes unrelated to long run adjustments toward the equilibrium (fundamental) price

(f) $\varepsilon_t = \begin{bmatrix} \varepsilon_{t,f} \\ \varepsilon_{t,c} \end{bmatrix}$ is a vector of error terms where $\varepsilon_{t,f}$ and $\varepsilon_{t,c}$ are error terms for futures and cash-bid prices

If futures and cash-bid prices share a stochastic trend (are cointegrated) then Π can be factored into $\alpha\beta'$ where β is a 2 by 1 vector containing the coefficients on the long run equilibrium (cointegration) relationship between futures and cash-bid prices and α is a 2 by 1 vector containing the rates of adjustment to long run equilibrium for futures and for cash-bid prices.[3]

The cointegration relationship between futures and cash-bid prices in period t-1 is

$$\beta' Z_{t-1} = [\beta_1 \quad \beta_2] \begin{bmatrix} f_{t-1} \\ c_{t-1} \end{bmatrix} = [\beta_1 f_{t-1} + \beta_2 c_{t-1}].$$

The adjustments toward equilibrium for the futures and cash-bid prices where α_1 and α_2 are the adjustment coefficients is

$$\alpha [\beta_1 f_{t-1} + \beta_2 c_{t-1}] = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} [\beta_1 f_{t-1} + \beta_2 c_{t-1}] = \alpha_1 [\beta_1 f_{t-1} + \beta_2 c_{t-1}] \text{ and } \alpha_2 [\beta_1 f_{t-1} + \beta_2 c_{t-1}]$$

A statistically significant value of α_2 is evidence that the cash market adjusts to information passed from the futures market.[4] A statistically significant value of α_1 is evidence that the futures market similarly adjust to price information from the futures market.

Johansen considered five specifications for the constant and trend terms, $\mu_t = \begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix}$, in equation 1 (Johansen, 1988, 1991). It is important to choose the appropriate specification because the choice influences estimation of the permanent parts of futures and cash-bid prices. Symbols for

[3] Sharing a stochastic trend implies that futures and cash prices incorporate unanticipated information from the same source. Market efficiency in addition to sharing a stochastic trend implies that the two markets incorporate identical market fundamentals from the stochastic trend.

[4] As explained next the cointegrating relationship may contain a constant or trend.

each of the five cases are listed below followed by specifications of constant and trend terms in matrix shorthand and explicit matrix notation.[5]

1. H_2 $\mu_t = 0$ $\begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix} = 0$

2. H_1^* $\mu_t = \alpha\rho_0$ $\begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix} = \begin{bmatrix} \alpha_1\rho_0 \\ \alpha_2\rho_0 \end{bmatrix}$

3. H_1 $\mu_t = \mu_0$ $\begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix} = \begin{bmatrix} u_{of} \\ u_{oc} \end{bmatrix}$

4. H^* $\mu_t = \mu_0 + \alpha\rho_1 t$ $\begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix} = \begin{bmatrix} u_{of} \\ u_{oc} \end{bmatrix} + \begin{bmatrix} \alpha_1\rho_1 t \\ \alpha_2\rho_1 t \end{bmatrix}$

5. H $\mu_t = \mu_0 + \mu_1 t$ $\begin{bmatrix} u_{tf} \\ u_{tc} \end{bmatrix} = \begin{bmatrix} u_{of} \\ u_{oc} \end{bmatrix} + \begin{bmatrix} u_{1f} t \\ u_{1c} t \end{bmatrix}$

The cases are listed from the most to least restrictive specifications of the constant and trend terms. $\mu_0 = \begin{bmatrix} u_{of} \\ u_{oc} \end{bmatrix}$ are constants for the futures and cash price changes. $\mu_1 t = \begin{bmatrix} u_{1f} t \\ u_{1c} t \end{bmatrix}$ are linear trends for the futures and cash price changes. The constant in the cointegrating relationship is represented by ρ_0 while $\rho_1$indicates the influence of the time trend variable, t, in the cointegrating relationship. The absence of constant and trend terms implies they are equal to zero.

H_2 and H, the first and last cases listed are not appropriate for our analysis. H_2 implies that the expected difference between futures and cash-bid prices is always zero and that the long run equilibrium adjustment between futures and cash prices is always toward zero. H implies that the prices have quadratic trends and would be appropriate during times of extreme inflation (Zivot and Wang, p. 461).

H_1^* does not allow deterministic trends in either price. The long run equilibrium adjustment between futures and cash prices is toward the constant, ρ_0. This specification is appropriate if the convergence failure can be characterized as a constant difference between futures and cash-bid prices with no deterministic trends for either price.

H_1 allows individual deterministic linear trends in the prices but not in the cointegrating relationship. The expected constant difference between futures and cash prices may be a nonzero constant. This specification is appropriate if the convergence failure can be characterized as a constant difference between futures and cash-bid prices with deterministic trends in the prices.

[5] The symbols were used by Johansen and are the standard notation in the literature.

H^* allows individual deterministic linear trends in the prices and a trend in the cointegrating relationship. The cointegrating equilibrium adjustment is toward $\rho_1 t$. This specification is appropriate when futures and cash prices converge. The specification also allows for divergence.

If cointegration is not rejected by Johansen's test, the moving average representation of equation 1 can be used to estimate the permanent and transitory parts of futures and cash-bid prices. Equation 2 shows this representation which is an algebraic transformation of equation 1 based on the multivariate Beveridge-Nelson Decomposition of a VEC model (Hansen, 2005).

(2) $Z_t = C(1)\sum_{j=1}^{t}\varepsilon_j + \tau(t) + C(L)\varepsilon_t + Z_0$

where:

(a) $C(1)\sum_{j=1}^{t}\varepsilon_j$ estimates changes in the permanent part of each price due to the unit root (stochastic trend)

(b) $\tau(t)$ estimates the permanent part of each price due to deterministic trend

(c) $C(L)\varepsilon_t$ estimates the transitory part of each price

(d) Z_0 are the initial values of futures and cash prices.

$\varepsilon_t = \begin{bmatrix} \varepsilon_{t,f} \\ \varepsilon_{t,c} \end{bmatrix}$ in the third term are the errors from equation 1.

$\sum_{j=1}^{t}\varepsilon_j = \begin{bmatrix} \sum_{j=1}^{t}\varepsilon_{j,f} \\ \sum_{j=1}^{t}\varepsilon_{j,c} \end{bmatrix}$ in the first term are the errors from equation 1 summed from time 1 through time t for each time period t.

C(1) in the first term is the long run impact matrix from unit shocks via the error term. It equals $\begin{bmatrix} C_{f,f} & C_{f,c} \\ C_{c,f} & C_{c,c} \end{bmatrix}$. The first column contains the permanent (long run) impacts of a unit change in $\varepsilon_{t,f}$ (the futures price error) on the futures price $C_{f,f}$ and on the cash-bid price $C_{c,f}$. The second column contains the permanent (long run) impacts of a unit change in $\varepsilon_{t,c}$ (the cash-bid price error) on the futures price $C_{f,c}$ and cash-bid price $C_{c,c}$.

Hansen derived a closed-form expression for the deterministic term, $\tau(t)$, in equation 2 for each of the five deterministic term expressions for μ_t in equation 1 (Hansen, 2005). The expressions for each τ(t) maintains the same deterministic relationship between the prices as for the corresponding μ_t in for equation 1.

As shown in the list for the deterministic terms, H_2 in equation 2 is zero. This restriction along with restricting the cointegrating coefficients for two prices to equal [1 -1] is often used in the finance literature, for a stock (equity asset) trading in two or more markets. Hasbrouck (1995) began this specification for examining price discovery in equity markets. Yan and Zivot (2010) recently used it in examining price discovery in equity markets. This special case provides a convenient reference point for our examination. In addition to making the deterministic term in equation 2 equal to zero, this specification makes the two rows of the long-run impact matrix, C(1), identical (Yan and Zivot, p. 3). In this special case the permanent parts of both prices are equal and the deterministic trend makes no contribution to the permanent parts of either price. As a result, the permanent parts of the two prices are always identical. In this special case the two stock equity prices would interpret market fundamentals identically.[6]

Estimates of changes in market fundamentals due to stochastic trend for futures and cash prices will differ when cointegrated if the estimates of the cointegrating coefficients β_1 and β_2 for futures and cash prices in $[\beta_1 f_{t-1} + \beta_2 c_{t-1}]$ from equation 1differ from 1 and -1. In addition, estimates of market fundamentals at contract maturity due to deterministic trend will differ if the deterministic term H_1^* is chosen. Market fundamentals may differ at contract maturity if either H_1 or H^* is chosen.

The ideal outcome for our futures and corresponding cash prices is for the cointegrating vector to equal [1 -1] and for the constant term τH^*(t) to converge to zero at contract maturity. In this case, market fundamentals due to stochastic trend are the same each day for both prices. In addition, the deterministic trend eliminates the difference in market fundamentals due to storage costs. We concentrate on examining departures from this case.

The increments in the stochastic trend from one time period to the next are driven by the outcomes of the random variable ε_t while the increments in the deterministic trend from one time period to the next are specified as a constant. In price discovery examination the random increments represent the arrival of new unpredictable information that changes the equilibrium or fundamental price. Ideally, in our study the deterministic trend represents the predictable decrease in futures minus cash prices (the basis) as the contract maturity approaches.

Price discovery studies have concentrated on the ability of markets to capture market fundamentals from stochastic trends –the source of unpredictable (new unanticipated) information.[7] In our examination we also need to consider deterministic trends.

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[6] The price discovery literature is primarily concerned with determining each market's relative contribution to market fundamentals. We are interested in determining if futures and cash prices contain identical market fundamentals.

[7] For example, the studies by Figuerola-Ferrtti and Gilbert, by Haung, and by Yan and Zivot consider stochastic but not deterministic trends.

Deterministic trends in futures and cash prices represent arbitrage between futures and cash prices involving the decreasing cost of storage as contract maturity approaches. Arbitrage should prevent the futures price from being larger than the cash price by more than the cost of storage. However, the recent convergence failures with futures being above cash price at contract delivery by more than the per bushel delivery cost indicates that the arbitrage is failing.

Brenner and Kroner argue that examining futures and cash prices with the VEC model is difficult. They argue that futures and cash prices will not be cointegrated by themselves if the two prices share a unit root with storage costs and convenience yield p. 30. [8] If this is the case they argue that storage costs and convenience yield should be included in the cointegration vector (p. 30).

We use the AR model as an alternative to the VEC model. The AR model does not attempt to model the difference between futures and cash prices. Futures and cash market fundamentals are estimated separately with the AR model. The procedure we use involves estimating an AR model separately for a futures price and corresponding cash-bid price, converting the AR model into its moving average representation for each price and using the moving average representations to estimate market fundamentals of each price from new unanticipated information. The estimated market fundamentals of each price are compared to determine how closely they reflect the same underlying market fundamentals.

The AR model is given by

(3) $\Delta p_t = \sum_{i=1}^{n-1} \phi_i \Delta p_{t-i} + \mu + \varepsilon_t$ where p can represent either a futures price or a cash-bid price.[9]

where:

(a) Δp_t and Δp_{t-i} are the price changes from period t-1 to t and from t-i-1 to t-i

(b) ϕ_i estimates the effect of lagged price changes on the current price change

(c) μ is the constant term

(d) ε_t is an error term

All of the variables in equation 3 are scalars.

The moving average representation of equation 3 shown in equation 4 is the algebraic transformation based on the univariate Beveridge-Nelson Decomposition (Beveridge-Nelson, 1981).

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[8] Convenience yield is the value of having immediate access to a commodity by owning it. With convenience yield the relationship between futures and cash price is: futures price = cash price + cost of storage – convenience yield. Convenience yield is greater or equal to zero.

[9] This section draws on Figuerola-Ferretti and Gilbert and on Mills

(4) $p_t = C(1) \sum_{j=1}^{t} \varepsilon_j + \mu t + C^*(L)\varepsilon_t + Z_0$

where:

(a) $C(1) \sum_{j=1}^{t} \varepsilon_j$ is the permanent portion of price due to the unit root (stochastic trend)

(b) μt is the permanent part of price due to deterministic trend

(c) $C^*(L)\varepsilon_t$ is the transitory part of price

(d) Z_0 = initial condition

The errors in the third term, ε_t, and in the first term $\sum_{j=1}^{t} \varepsilon_j$ are taken from equation 3. For the first term, the errors are summed from period 1 through period t for each period t.

C(1) here is a scalar and represents the long run (permanent) impact on price from a one unit change in ε_t. C(1) also equals $1/(1 + \phi_1 + \phi_2 \ldots + \phi_{n-1})$ where the $\phi\, i$'s are taken from equation 3.

Analysis and Findings

We examined closing futures prices and corresponding cash-bid prices for March corn and soybean contracts for 2001 through 2009. The corn and soybean prices were from the first trading day in November through the last trading day in February. Similarly, we examined December wheat futures contracts for 2000 through 2009. The wheat prices were from the first trading in July through the last trading day in November. The last day examined for each of the data sets was the last trading day before the delivery month. Per bushel delivery cost on a futures contract is estimated to be in the range of 6 to 8 cents per bushel (Irwin et al. pp. 3-4). Consequently, arbitrage at delivery should keep the futures price from being more than 6 to 8 cents per bushel above the cash price. Our use of 20 cents per bushel is conservative because it should be easier to detect the effect of convergence failure on price discovery for large convergence failures.

Table 1 shows the basis on the last trading day before the delivery month (the ending basis) and the basis at the beginning of each data set (the harvest basis) for the contracts examined. We defined convergence failure to be an ending basis greater than 20 cents per bushel. Basis equals futures price minus cash price. Seven of the 28 contracts examined had an ending basis greater than 20 cents per bushel. Two of them were between 20 and 30 cents per bushel. The other five were 40 or more cents per bushel.

There was only one convergence failure for corn --the March 2008 contract was 23.5 cents per bushel. There were two convergence failures for Soybeans --the March 2007 and 2008 contracts were 26.75 and 41.5 cents per bushel. There were 4 convergence failures for wheat --the December 2000, 2006, 2008, and 2009 contracts. The December 2008 contract had an ending basis of $1.26 per bushel.

Table 1 reflects the well documented increase in price variability beginning in the last half of 2007. Price variability is measured as the average standard deviation of the change in price from one trading day to the next. Corn price variability increased by more than 10 times from the March 2001 contract to the March 2008 contract. Soybean price variability increased by almost 4 times from the March 2001 to the March 2008 contract. Wheat price variability increased by more than 7 times from the December 2000 contract to the December 2008 contract.

The frequency of convergence failure for the March corn and soybean contracts and the December wheat contracts increased significantly after the price variability increase. The one corn convergence failure and both soybean convergence failures occurred after the price variability increased. Two of the 4 wheat convergence failures occurred after the price variability increase. Altogether 5 of the 7 convergence failures occurred after price variability increased. There were 2 convergence failures for the 21 contracts in table 1 before the price variability increase.

The harvest basis for corn more than tripled for the March 2009 contract after the large increase in price variability for the March 2008 contract. Similarly, the harvest basis for soybeans almost doubled for the March 2009 contract after the large increase in price variability for the March 2008 contact. Also, the harvest basis for the December 2008 wheat contract more than doubled after the increase in price variability for the December 2007 contact. The increases in the harvest bases may have been the short hedgers' response to the large margin calls from short hedging and the convergence failures in the previous year. Short hedgers may have bid less aggressively for commodity relative to the futures price at harvest to offset interest cost from potentially large margin calls due to the increased price variability and to provide storage returns if convergence again failed. Interestingly, the basis converged for the March 2009 corn and soybean contracts implying large returns to short hedging stored commodity.

The two lowest correlations between futures and cash price changes occurred for the March 2009 corn and soybean contracts. The correlations were 0.50 and 0.41, respectively. For corn immediately following harvest the cash price increased while the futures price decreased lowering the overall positive correlation between the two prices from harvest to contract maturity. For soybeans immediately following harvest the cash price increased much faster than did the futures price also lowering the overall correlation. The basis returned to normal levels after short hedgers established their hedges.

The bases, shown in table 1, narrowed except for March 2005 soybeans. They narrowed for all of the convergence failures. The narrowing indicates that arbitrage involving the decreasing remaining storage cost as contract maturity approaches forced the prices toward convergence even when convergence failed.

Standard deviations of price changes for futures-cash price pairs that are close and with large correlations imply that the price pairs were responding similarly to new information and that the two prices are tied together by arbitrage. Wheat had correlations of 0.89 and higher. Corn had 6 correlations of 0.80 correlations and lower. Soybeans had 1 correlation less than 0.80 –the 0.41 correlation discussed earlier. Seventeen of the 28 standard deviation price differences between futures and cash were less than ½ cent per bushel.

The convergence failures for December 2000, 2006, 2008 and 2009 wheat contracts had price change correlations of 0.89, 0.97, 0.99, and 0 .98, respectively. The convergence failure for the March 2008 corn contract had a price change correlation of 0.99. The convergence failures for March soybeans in 2007 and 2008 had price change correlations of 0.89 and 0.81. Standard deviation differences for the futures and cash prices were equal to or less than 3/10 cents per bushel for 6 of the seven convergence failures. These results indicate that futures and cash prices are responding similarly to new unanticipated information. Next we examine whether or not futures and cash prices are similarly incorporating market fundamentals from new unanticipated information.

We used the Phillips-Perron test to examine each individual futures and cash price series for the presence of a unit root. The Bayesian information criterion (BIC) was used to select the lag lengths for the test. The Phillips-Perron test statistic was calculated wit hout a mean, with a mean, and with both a mean and trend for price level and for price first difference. The BIC test results are shown in table 2.

The null hypothesis for the Phillips-Perron test is that the variable being examined contains a unit root. The null hypothesis for the futures price levels was rejected at the 10 percent significance level for 5 of the 28 contracts. It was rejected for cash price levels at the 10 significance percent level for 7 out of the 28 contracts examined. There were 9 price pairs with unit root rejection for either or both prices. The null hypothesis of a unit root was rejected at the 1 percent significance level for all 28 futures price first differences and for all 28 cash price first differences.

Unit root test results differed between convergence and convergence failures. Of the seven convergence failures only the December 2000 wheat contract had a unit root rejection for price levels.

Since the BN decomposition requires a unit root in levels but not in first differences we only continued examining the 19 futures-cash price pairs without a unit root rejection in price levels for futures, for cash, and or for both futures and cash. Of the 19 price pairs, there were 6 convergence failures.

The VEC model provided conceptual support by providing a set of requirements for incorporating identical market fundamentals into price. It did not, however, provide empirical support. It did not adequately model the basis as a linear relationship with an embedded trend. Consequently, we did not proceed with the multivariate BN decomposition. The simpler AR model provided the empirical support for examining the possible effects of convergence failure on price discovery. The AR model avoids the complications of estimating the cointegration relationship. We used the estimated parameters from AR model in the univariate BN decomposition

The VEC model and its moving average representation shows how identical market fundamentals from new unanticipated information are incorporated into the prices of related markets. The AR model approach we use detects identical market incorporation of market fundamentals from new information into futures and cash markets if the first term in equation 4 is identical for both markets. The first term will be equal if errors for futures and cash are equal and if the coefficient C(1) is equal for futures and cash. Equal error standard deviations for futures and cash prices and a plus one error correlation are good indicators that the errors will be close to each other.

We estimated the parameters of the AR model, equation 3, separately for each of the 19 futures-cash price pairs that were judged to contain a unit root in price levels. The long-run impact coefficient, C(1), was then calculated for futures and cash prices as previously shown. Each estimate of C(1) and the corresponding errors from equation 3 are used in the first term in equation 4 to estimate the change in permanent price each day from new unanticipated information using. The errors from equation 3 represent new unanticipated information.

The lag lengths in equation 3 for futures and cash prices were selected using the BIC test results for the price first differences. The BIC test results for the price first differences are shown in the last two columns in table 2. The test results mostly suggest a zero lag length, that is, no lag price changes in equation 3. Exceptions for the 19 contracts examined with the BN decomposition are the March 2005 and 2006 corn contracts and the December 2008 wheat contracts. The BIC test results for all three exceptions suggest a lag length of 1 for the cash price. The BIC test result for the December 2008 wheat contract also suggest a lag length of 1 for the futures price. A zero lag length indicates market efficiency because no information influencing current day's price is detected in previous day price changes. A zero lag length also means that the long-run impact coefficient, C(1), equals one.

The change in permanent price each day will be the same for futures and cash prices if the sum of errors prior through day t are the same and the if the long run impact coefficient ,C(1), matrix is the same for both prices. The BIC test results in table 2 suggest a zero lag length for most of the price changes. This means that the C(1) coefficients for futures and cash prices will generally equal 1. High correlations between the futures and cash price changes and similar standard deviations for the futures and cash price changes indicate that the errors from equation 3 will be essentially the same. Equal long run coefficients C(1) and essentially the same errors imply that the futures and cash markets are incorporating essentially the same market fundamentals from unanticipated information into their prices.

The permanent part of price due to the stochastic trend in equations 3 is influenced by the sum of the errors from the estimated AR model equaling zero. This constraint means that the permanent part of price due to the changes in the stochastic trends over the entire sample also sum to zero on the last day in the time series which is each contract's maturity. One way around this constraint is to bootstrap or simulate the errors for a large number of error paths over the sample. Then calculate the permanent part of price due stochastic trend on the last day of the sample for each error path and lastly average across all the paths simulated. We chose instead to evaluate incorporating stochastic trend into permanent price by estimating the differences between permanent price due to stochastic trends for futures and corresponding cash prices each day over the entire sample using the errors from the AR model equation 3. The maximum difference in the change in daily permanent price between futures and cash prices is our price discovery performance measure.

The cumulative changes in permanent price each day for futures and cash are estimated for each contract. The lowest and highest changes for futures relative to cash are reported in table 3. In addition, the error correlations between futures and cash for each contract are reported in table 3.

The correlations between the errors for futures and cash prices in table 3 are close to the correlations between the price changes reported in table 2. This is to be expected because most of the AR models had a zero lag in prices, that is, no lagged prices in the AR model.[10]

The correlations for the March 2009 corn and soybean contracts are the smallest, 0.59 and 0.51. As explained earlier, this was due to the large cash price increases following harvest. The corn futures permanent price for the March 2009 contract was at most 8 percent higher and at most 8 percent lower than the cash permanent price. The soybean futures permanent price for the March 2009 contract was at most 5 percent higher and at most 3 percent lower than the cash permanent price. The error correlations for the other soybean contracts were higher and the permanent price differences were smaller. Error correlations of 0.64 and 0.72 for March corn for 2005 and 2006 correspond with futures permanent price change from unanticipated information correspond up 5 percent more and 5 less than the permanent cash price.

The error correlations for the December wheat convergence failures for the 2006, 2008, and 2009 contracts were 0.96, 0.98, and 0.98. The permanent price changes from new unanticipated information for the wheat futures price were within plus and minus 3 percent of the permanent price changes for the wheat cash price.

The error correlation for the March corn contract convergence failure in 2008 was 0.87. The permanent price changes from new unanticipated information for the March 2008 corn futures price were within plus and minus 1 percent of the permanent price changes for cash price.

The error correlations for the March soybean contracts in 2007 and 2008 that had convergence failures were 0.90 and 0.80. The permanent price changes from new unanticipated information for the March 2007 and 2008 corn soybean futures prices were within plus and minus 1 percent of the permanent price changes for cash price.

The findings indicate that the convergence failures did not prevent cash and futures markets from incorporating essentially identical market fundamentals into price from unanticipated information.

Conclusions

We used the auto regressive model and its moving average representation to examine whether or not futures and cash markets incorporated identical market fundamentals into their prices from

[10] Natural logs of the prices were used in estimating equation 3.

new unanticipated information. We found that corn, soybean, and wheat convergence failures for the contracts examined did not adversely affect the incorporation market fundamentals into price from new unanticipated information. The two prices incorporated essentially identical market fundamentals from unanticipated information when convergence failed.

Futures and cash prices moved closer to one another as contract maturity approached even when convergence failed. This outcome indicates that two markets were arbitraging the decreasing cost of storage as contract maturity approached but was not completed. Without arbitrage the prices would most likely not incorporate identical market fundamentals from unanticipated information when convergence failed.

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Table 1. Basis, price variability, and futures-cash correlation.1/

Commodity	Contract	Harvest Basis ¢/bu.	Ending Basis ¢/bu.	Standard Deviation Futures Price Change ¢/bu.	Standard Deviation Cash Price Change ¢/bu.	Correlation Futures-Cash Price Changes
corn	March 2001	27.5	10	2.2	2.6	0.79
corn	March 2002	36.5	0.5	2	2.4	0.8
corn	March 2003	11.75	3.25	2.2	2.7	0.82
corn	March 2004	19	1.75	3.60	3.7	0.87
corn	March 2005	31.5	15.5	2.40	3.1	0.66
corn	March 2006	32.25	11	2.50	3.2	0.74
corn	March 2007	32	9.25	2.00	2.4	0.8
corn	March 2008	32	23.5	22.40	22.4	0.99
corn	March 2009	103.25	-3.25	11.50	11.5	0.50
soybeans	March 2001	23.75	5.5	4.30	4.8	0.89
soybeans	March 2002	29	0.25	4.30	4.4	0.92
soybeans	March 2003	4.5	-1.5	6.10	6.4	0.96
soybeans	March 2004	18.75	5.5	12.90	13.8	0.98
soybeans	March 2005	14	19	8.30	9.3	0.82
soybeans	March 2006	50.75	16.25	8.20	8.8	0.91
soybeans	March 2007	48	26.75	8.90	8.6	0.89
soybeans	March 2008	56.75	41.5	16.80	15.1	0.81
soybeans	March 2009	103.25	4	22.30	22.5	0.41
wheat	December 2000	67.5	48.5	3.10	3.4	0.89
wheat	December 2001	53.5	6	3.90	4.4	0.96
wheat	December 2002	27	2	7.70	7.7	0.98
wheat	December 2003	19.5	8	6.70	7	0.92
wheat	December 2004	21.5	3.75	5.10	5.2	0.97
wheat	December 2005	32.75	15	4.30	4.4	0.98
wheat	December 2006	99	40	9.10	10	0.97
wheat	December 2007	82	15	16.50	17.5	0.98
wheat	December 2008	172	126	22.40	22.4	0.99
wheat	December 2009	146	70	11.50	11.5	0.98

1/ Basis equal futures price minus cash price.

Table 2. Basis, and unit-root tests for price levels and for first differences.

			Futures		Cash		Futures	Cash
Commodity	Contract	Ending Basis ¢/bu.	BIC Levels	Unit Root Rejected	BIC Levels	Unit Root Rejected	BIC First Diff.	BIC First Diff.
Corn	March 2001	10	1	no	1	Yes	0	0
corn	March 2002	0.5	1	yes	1	yes	0	4
corn	March 2003	3.25	2	yes	1	yes	0	0
corn	March 2004	1.75	1	no	1	no	0	0
corn	March 2005	15.5	1	no	1	no	0	1
corn	March 2006	11	1	no	1	no	0	1
corn	March 2007	9.25	1	yes	1	no	0	0
corn	March 2008	23.5	1	no	1	no	0	0
corn	March 2009	-3.25	1	no	1	no	0	0
soybeans	March 2001	5.5	1	no	3	no	0	0
soybeans	March 2002	0.25	1	no	1	yes	0	0
soybeans	March 2003	-1.5	1	yes	1	yes	0	0
soybeans	March 2004	5.5	1	no	1	no	0	0
soybeans	March 2005	19	4	no	1	no	0	0
soybeans	March 2006	16.25	3	no	3	yes	2	2
soybeans	March 2007	26.75	1	no	1	no	0	0
soybeans	March 2008	41.5	1	no	1	no	0	0
soybeans	March 2009	4	1	no	1	no	0	0
wheat	Dec. 2000	48.5	1	yes	1	no	0	0
wheat	Dec. 2001	6	1	no	2	yes	0	0
wheat	Dec. 2002	2	1	no	1	no	0	0
wheat	Dec. 2003	8	1	no	1	no	0	0
wheat	Dec. 2004	3.75	1	no	1	no	0	0
wheat	Dec..2005	15	1	no	1	no	0	0
wheat	Dec..2006	40	1	no	1	no	0	0
wheat	Dec. 2007	15	2	no	2	no	0	0
wheat	Dec. 2008	126	2	no	2	no	1	1
wheat	Dec. 2009	70	1	no	1	no	0	0

1/ Basis equal futures price minus cash price.

Table 3. Estimates of permanent price changes from unanticipated information.

Commodity	Contract	Ending Basis ¢/bu. 1/	Error Correlation	Futures perm anent price change relative to cash permanent price change from unanticipated information	
				Maximum percent less	Maximum percent more
corn	March 2004	1.75	0.85	-4	+2
corn	March 2005	15.5	0.64	-5	+2
corn	March 2006	11	0.72	-5	+5
corn	March 2008	23.5	0.87	-1	+1
corn	March 2009	-3.25	0.59	-8	+8
soybeans	March 2001	5.5	0.88	-1	+1
soybeans	March 2004	5.5	0.97	-1	+1
soybeans	March 2005	19	0.82	-1	+2
soybeans	March 2007	26.75	0.90	-1	+1
soybeans	March 2008	41.5	0.80	-1	+1
soybeans	March 2009	4	0.51	-3	+5
wheat	Dec. 2002	2	0.98	-2	+1
wheat	Dec. 2003	8	0.92	-5	+4
wheat	Dec. 2004	3.75	0.96	-2	+2
wheat	Dec..2005	15	0.97	-1	+2
wheat	Dec..2006	40	0.96	-3	-3
wheat	Dec. 2007	15	.97	-2	+3
wheat	Dec. 2008	126	0.98	-3	+3
wheat	Dec. 2009	70	0.98	-3	-2

1/ Basis equal futures price minus cash price.