# PRICE DISCOVERY IN THE FUTURES AND CASH MARKETS FOR LIVE BEEF CATTLE

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The authors gratefully acknowledge the comments of Jon Brandt and B. Wade Brorsen on an earlier draft.

AAEA paper presented 1984

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Whether the cash or the futures market is the center of price discovery for slaughter cattle has been debated since the inception of the live cattle futures contract in 1964. Using a theoretical model, Stein (1961) showed that futures and cash prices for a given commodity are determined simultaneously. However, the prices actually discovered in one market might lead those discovered in the other (Brorsen, Bailey, and Richardson, 1984). Buyers and sellers in the futures markets may have greater access to new information than participants in the cash market. In addition, transaction costs may differ in the two markets. Thus, prices might respond more quickly to changes in underlying supply and demand conditions in one market than in the other.

If prices discovered in futures markets are used to price cash market transactions, futures markets may contribute to increased efficiency in commodity markets (Working, 1948). The relationship between futures prices and corresponding cash commodity prices can reflect the impact of futures markets on cash market transactions (Garbade and Silber, 1983).

In this paper, dynamic relations between changes in cash and futures prices are examined for live beef cattle. In particular, the analysis seeks to delineate which market leads the other in discovering price, and whether this lead-lag relationship has changed as use of the live cattle futures contract has expanded and supply-demand conditions in the cattle market have evolved.

## METHODS

Bivariate time-series models have been employed extensively to determine leads and lags between pairs of economic variables. Macroeconomists have studied the relationships between money and income (Sims, 1972), interest rates and money (Pierce, 1977), and wages and prices (Geweke, 1975). Examples of applications of such techniques to agricultural markets include the determination of leads and lags between wheat acreage allotments and acreage supply response (Weaver, 1980), the money supply and nominal agricultural prices (Barnett, Bessler, and Thompson, 1983), and livestock prices and quantities and income (Bessler and Brandt, 1982).

One group of statistical tests commonly used in examining lead-lag relationships between economic variables is referred to as "causality tests". While no single definition of economic causality is universally agreed upon, the definition proposed by Granger is helpful in describing lead-lag relationships. Explicitly stated, Granger's definition of causality is as follows: X causes Y, with respect to a given information set which includes X and Y, if current Y can be better predicted by using past values of X than if these past X's were not used. Pairs of economic variables may exhibit unidirectional causality, bidirectional causality (feedback), or instantaneous causality relationships (Bessler and Brandt, 1982).

Three causality testing procedures, those developed by Granger, Sims, and Haugh, have been used most extensively. Several recent Monte Carlo studies have shown that the Granger causality testing procedure is more powerful than those recommended by Haugh and Sims (Nelson and Schwert, 1982; Guilkey and Salemi, 1982; Geweke, Meese, and Dent, 1983). The Granger testing scheme applies ordinary least squares regression to the time series under consideration. Gamber and Hudson (1984) discovered that this testing procedure performs best when the data are filtered to remove such systematic components as trend and seasonality. To test whether causality runs from X to Y (i.e., causality is "one-way"), the following pair of models is specified:

$$(1)\quad Y_t = a_{10} + \sum_{j=1}^{p} a_{1j} Y_{t-j} + e_{1t}$$

$$(2)\quad Y_t = a_{20} + \sum_{j=1}^{p} a_{2j} Y_{t-j} + \sum_{k=1}^{q} b_{2k} X_{t-k} + e_{2t}$$

where the $a_{1j}$ and $a_{2j}$ are parameters which relate $Y_t$ to past values of $Y_t$, the $b_{2j}$ are parameters relating $Y_t$ to lagged values of $X_t$, and $e_{1t}$ and $e_{2t}$ are white-noise residuals. The null hypothesis to be tested is:

$$b_{21} = b_{22} = \ldots = b_{2q} = 0.$$

The test statistic is:

$$F^* = \frac{SSE(1) - SSE(2) \,/\, q}{SSE\ (2) \,/\, N-p-q-1} \quad \sim \quad F(q, N-p-q-1)$$

where SSE(1) and SSE(2) are the sum of squared residuals obtained from OLS regressions on equations (1) and (2), respectively, and N is the number of observations of $Y_t$ in the time series. When F* is significantly large, the null hypothesis that X does not cause Y is rejected.

One can test for no instantaneous causality by using equation (2) and adding current values of X (Geweke, 1980):

$$(3)\quad Y_t = a_{30} + \sum_{j=1}^{p} a_{3j} Y_{t-j} + \sum_{k=0}^{q} b_{3k} X_{t-k} + e_{3t}$$

where the parameters $a_{3j}$, $b_{3j}$, and $e_{3t}$ are defined similarly to those specified for equations (1) and (2). In this case, the null hypothesis to be tested is $b_{30} = 0$, and the test statistic is analogous to that used for one-way causality.

For these tests, the selected number of lags (i.e., the values of p and q) must be large enough so that significant autocorrelation is removed from the regression residuals; otherwise, generalized least squares must be applied. Two possible methods to select p and q are either to apply a priori knowledge on the possible length of leads and lags, or to rely on mechanical procedures such as those suggested by Akaike.

## EMPIRICAL ANALYSIS

The data used for this analysis were obtained from the Dunn and Hargitt Commodity Data Bank and the U.S.D.A. Market News Office in Omaha, Nebraska. The data series used are daily closing (settlement) prices of the live cattle contract on the Chicago Mercantile Exchange and average daily cash price of 1100 to 1300-lb. choice steers in Omaha (the major cash market for slaughter beef cattle). The size and quality specifications for these two markets differ slightly but the price series are expected to closely parallel each other.

The observation period for this study is 1966 through 1982. Since many changes occurred in the cattle market during this period, the lead-lag relationship between the two markets may have changed during this period. From 1964 to the early 1970s, the live cattle futures contract gradually gained public acceptance. During the mid-1970s, the cattle market experienced a period of increased price volatility. In more recent years, the market has returned partially to a more stable price pattern. The level of participation in cattle futures trading increased greatly throughout the period. Based on these historical factors, the period of analysis was separated into three time spans: 1966-72, 1973-77, and 1978-82.

To improve the performance of the lead-lag testing procedure, the data were filtered and further separated by time. The data were first-differenced to remove trend and ensure stationarity of the time series. Because of the seasonal nature of cattle production and marketing, the lead-lag relationship between futures and cash prices may differ during different times of the year. As a result, each of the three time spans was further divided into six time-of-year subperiods, one for each of the six contract months regularly traded in live beef cattle. The two months immediately prior to each delivery month were selected as the time period to be analyzed for each contract month subperiod within each year. Therefore, the analyses of different periods of the year did not overlap. (Throughout the remainder of the paper, the periods 1966-72, 1973-77, and 1978-82 are referred to as "time spans". The eighteen intervals corresponding to each delivery month within the three time spans are identified as "subperiods".)

Table 1 depicts some general characteristics of the live cattle futures market for the eighteen subperiods selected for this analysis. The table shows (1) the substantial growth in trading volume and open interest throughout the period and (2) the sharp increase in price variation during the 1970s and some decline in amplitude since.

As mentioned above, the general procedure of selecting the order of the bivariate autoregressive process is either to apply *a priori* knowledge or to utilize a mechanical procedure. Since the Omaha cash market is usually active only the first three days of each week, the order of the autoregressive model was essentially limited to one. Recalling that the data were first-differenced, the Monday-to-Tuesday price changes for cash cattle and the nearby futures contract were used as single-day lagged observations, and the Tuesday-to-Wednesday price changes were used as current-day observations in the Granger testing scheme. Therefore, only one set of observations was obtained for each week. The single-day order of the multivariate process may not capture the full extent of the lagged influences; however, this specification of the model is more appropriate than one which includes days of the week during which a testable cash market is not established. Also, previous studies of lead-lag relationships have used models with orders of one day (Garbade and Silber, 1983).

## EMPIRICAL RESULTS

The results of the Granger causality tests performed for the eighteen contract subperiods and the three combined time spans are summarized in Table 2. Though not reported, Ljung-Box diagnostic Q statistics were calculated to determine whether the residuals of the regressions were autocorrelated. The Q statistics were non-significant, with the exception of those for the October 1978-82 cash price equations. These results indicate that the residuals from nearly all the regression equations are white-noise. This allows greater confidence in the reliability of the causality tests results, and indicates that the one-day lag is sufficient.

Several important features emerge from the results in Table 2. In all but two of the subperiods, October 1966-72 and February 1973-77, the lagged change in futures price was shown to be significantly associated at the 95 percent confidence level with the current-day change in cash price. This pattern occurred in all six contract subperiods during the 1978-82 period. These results indicate that changes in the futures market price tend to lead changes in the cash market price for live beef cattle. The one-way futures-to-cash F-statistic for the February 1973-77 subperiod, reported as non-significant in Table 2, is, however, significant at the 90 percent level. In the single remaining subperiod, October 1966-72, the relationship was not statistically significant. Table 1, however, indicates that the average coefficient of futures price variation was much lower for the October 1966-72 subperiod than for any other contract interval. This extremely low amount of price variation may have accounted for the lack of statistical significance in this subperiod.

The lagged change in cash price was significantly associated with change in current-day futures in two of the subperiods during 1978-82. Since futures price was also shown to lead cash price during these intervals, a form of feedback appears to have occurred between the futures and cash markets during these time periods.

The tests of instantaneous causality indicate that in seven of the eighteen subperiods, changes in cash and futures prices exhibited a significant same-day relationship. During these subperiods, it appears that prices tended to be discovered instantaneously in the two markets. The number of subperiods in which instantaneous causality occurred decreased from three during the 1966-72 and 1973-77 time spans to one during 1978-82. To determine whether the level of instantaneous causality changed over the three time spans, an extra sum-of-squares procedure was conducted to test for differences in the lagged and current futures price coefficients in the cash equation. The hypothesis that the lagged futures coefficient did not change was not rejected; however, the coefficient on current-day futures price differed among the three time spans (Table 3). Paired t-tests indicated that the current-day coefficient did not change between 1966-72 and

1973-77, but became significantly less positive during 1978-82. These results provide some evidence that during the most recent period, the degree of instantaneous causality has decreased in the two markets.

Table 4 presents the equations obtained when current-day change in cash price was regressed against changes in lagged cash and futures prices, plus current-day futures price. The level of price volatility among the subperiods was not shown to be systematically related to lead-lag price change patterns. All coefficients on lagged change in futures price are positive. All but one of the coefficients on current-day change in futures price are positive, and the exception is non-significant. These signs are consistent with the theoretical expectations that current-day cash price will move in the same direction as futures price moved yesterday, and that same-day cash and futures prices tend to move in parallel. These outcomes again increase the confidence one can place in the results obtained.

The results are most effectively interpreted in the context of the institutional setting surrounding the cash and futures markets for live cattle. One important consideration is the time of day at which the prices for each market are reported. The futures market for live cattle opens at 9:05 a.m. and closes at 12:45 p.m. Central time, and its settlement prices are reported shortly thereafter (Chicago Mercantile Exchange). The cash cattle market in Omaha, on the other hand, opens at 8:30 a.m. Central time. Most transactions are completed by 10:45 a.m., and a report regarding cash prices for the day is issued to the wire services at 11:00 a.m. (Phillips, 1984).

The disparity in the time of day at which the two prices are reported prompts a special interpretation of the results of this analysis. As reported above, the most notable causality relationship appears to run from the futures to the cash market. One is led to conclude that at least during many days, traders in the cash market are heavily influenced by the change in futures settlement price on the previous day. In those cases where current-day cash and futures prices are closely related, the relationship between the two markets could be conceived as a feedback situation; that is, previous-day futures price influences current-day cash price, which in turn has an impact on the current-day futures settlement price. In such cases, some information is likely to also be simultaneously incorporated by traders in both markets. However, since the same-day relationship of the two price series is weaker than the lagged futures-current cash relationship, the results of this study suggest that futures prices lead cash prices.

## CONCLUSIONS

This study investigated the lead-lag relationship between changes in futures and cash prices for live beef cattle between 1966 and 1982. The period was divided into three time spans and six time-of-year subperiods, one for each futures delivery contract. Subperiods aggregated across the six contract months were also analyzed. Results differed by time of year and among the three time spans analyzed.

In this study, the futures price led the cash price during nearly every subperiod analyzed. Most information incorporated into the futures market appears to be integrated into the cash market within one day after the time at which the futures price is affected. In about one-third of the individual contract periods, an instantaneous or feedback relationship was observed. Less instantaneous causality was observed for the most recent period analyzed (1978-82), which may imply that the futures market leads the cash market more strongly than it had previously. Further research is required to clarify whether this is the case.

In summary, futures prices for live cattle appear to have been used extensively to price cash market transactions from 1966 through 1982. In fact, the results of this study indicate that in most instances, the futures market is the center of price discovery for this commodity. A likely explanation of these results is that the futures market serves as a focal point of information assimilation, where large numbers of market participants meet to assess and evaluate supply and demand conditions and to act on the basis of their evaluations. Because futures price information is available at such a low cost, cattle producers and packers depend heavily on price changes in the futures market when making their own pricing decisions. As a result, the futures market appears to contribute significantly toward a more efficient price discovery process in the live cattle market.

Table 1. Average Volume, Average Open Interest, and Average Coefficient of Price Variation for the Two-Month Period Prior to Delivery in the Live Beef Cattle Futures Market, 1966-82.

| Subperiod and Contract Month | Average Volume | Average Open Interest | Avg. Coef. of Price Variation |
|---|---|---|---|
| 1966-72: | Number of Contracts | | Percent |
| February | 738.2 | 4,899.1 | 2.20 |
| April | 906.3 | 5,124.0 | 1.97 |
| June | 865.0 | 5,778.3 | 2.12 |
| August | 1,140.4 | 5,766.6 | 1.99 |
| October | 811.6 | 5,089.0 | 1.22 |
| December | 792.9 | 5,371.0 | 2.11 |
| 1973-77: | | | |
| February | 4,061.6 | 11,498.4 | 5.38 |
| April | 3,448.2 | 10,555.8 | 3.97 |
| June | 5,270.6 | 12,251.0 | 4.87 |
| August | 4,706.2 | 12,579.6 | 5.78 |
| October | 3,290.1 | 10,545.2 | 8.03 |
| December | 4,271.5 | 11,029.7 | 3.83 |
| 1978-82: | | | |
| February | 8,740.8 | 22,551.0 | 3.57 |
| April | 9,632.3 | 23,505.6 | 4.50 |
| June | 11,353.8 | 23,659.4 | 3.50 |
| August | 10,211.1 | 22,775.8 | 3.10 |
| October | 8,354.6 | 19,728.1 | 3.79 |
| December | 9,896.2 | 20,890.1 | 2.80 |

Table 2. Results of Granger Causality Tests Between Cash and Futures Prices of Live Cattle.

| Contract Month | Regression[b] | Causality F-Test Values[a] 1966-72 Instantaneous[c] | 1966-72 One-Way[d] | 1973-77 Instantaneous | 1973-77 One-Way | 1978-82 Instantaneous | 1978-82 One-Way |
|---|---|---|---|---|---|---|---|
| February | CP:FP | 9.604[f] | 11.575[f] | 1.181 | 3.820 | 0.414 | 24.166[f] |
| | FP:CP | | 0.605 | | 0.191 | | 0.036 |
| April | CP:FP | 30.303[f] | 11.812[f] | 6.559[e] | 9.312[f] | 9.670[f] | 14.278[f] |
| | FP:CP | | 0.006 | | 0.994 | | 0.310 |
| June | CP:FP | 2.279 | 5.979[e] | 10.364[f] | 13.464[f] | 2.156 | 10.920[f] |
| | FP:CP | | 1.381 | | 0.237 | | 6.099[e] |
| August | CP:FP | 3.629 | 17.346[f] | 12.689[f] | 7.376[e] | 0.717 | 8.415[f] |
| | FP:CP | | 3.201 | | 0.594 | | 6.069[e] |
| October | CP:FP | 1.747 | 2.727 | 2.340 | 9.443[f] | 0.118 | 5.685[e] |
| | FP:CP | | 1.209 | | 1.376 | | 3.220 |
| December | CP:FP | 12.446[f] | 8.559[f] | 0.227 | 21.808[f] | 2.770 | 21.667[f] |
| | FP:CP | | 1.229 | | 2.002 | | 0.437 |
| All Contract Months Combined | CP:FP | 40.882[f] | 57.577[f] | 28.221[f] | 48.919[f] | 12.096[f] | 86.510[f] |
| | FP:CP | | 3.452 | | 0.527 | | 2.758 |

[a]Significance of F-values for one-way tests indicates that the variable to the right of the colon leads or causes the one to the left. Significance of F-values for instantaneous tests indicates that the two variables are simultaneously determined.

[b]The variable to the left of the colon is dependent. CP refers to "Cash Price", and FP refers to "Futures Price".

[c]Test is based on equations (2) and (3).

[d]Test is based on equations (1) and (2).

[e]Significant at 95 percent confidence level.

[f]Significant at 99 percent confidence level.

Table 3. Results of Tests for Changes in Selected Coefficients of Cash Price Equation Among Time Spans.

| Difference Hypothesis Being Tested | Coefficients | |
|---|---|---|
| | Lagged Futures | Current Futures |
| | F-values | |
| All 3 Time Spans | 0.033 | 3.920[a] |
| | t-values | |
| 1966-72 vs. 1973-77 | 0.279 | -0.102 |
| 1966-72 vs. 1978-82 | 0.292 | -1.664[b] |
| 1973-77 vs. 1978-82 | -0.039 | -2.119[b] |

[a] Significant at 95 percent confidence level.

[b] Significant at 95 percent confidence level, one-tailed test.

Table 4. Equations Resulting from Regression of Current Cash Price Against Past Cash, Past Futures, and Current Futures Prices.

| Subperiod and Contract Month | Coefficient On:[a,b] Constant | $Cash_{t-1}$ | $Futures_{t-1}$ | $Futures_t$ | N | $R^2$ |
|---|---|---|---|---|---|---|
| 1966-72: | | | | | | |
| February | 0.022 (0.977) | 0.300 (2.027) | 0.370 (4.207) | 0.321 (3.099) | 55 | 0.4468 |
| April | 0.046 (1.905) | 0.273 (2.210) | 0.586 (4.899) | 0.567 (5.505) | 52 | 0.5457 |
| June | -0.010 (-0.404) | 0.275 (2.289) | 0.287 (2.199) | 0.205 (1.510) | 57 | 0.2452 |
| August | 0.036 (1.213) | 0.400 (1.998) | 0.589 (4.138) | 0.208 (1.905) | 53 | 0.3967 |
| October | -0.041 (-1.290) | 0.425 (2.587) | 0.294 (1.756) | 0.212 (1.322) | 53 | 0.1762 |
| December | 0.025 (1.339) | 0.283 (2.079) | 0.362 (3.227) | 0.315 (3.528) | 56 | 0.3492 |
| Contract Months Combined | 0.106 (1.032) | 0.342 (5.721) | 0.411 (8.217) | 0.299 (6.394) | 324 | 0.3349 |
| 1973-77: | | | | | | |
| February | 0.253 (2.558) | 0.181 (1.080) | 0.316 (2.069) | 0.139 (1.087) | 39 | 0.1556 |
| April | -0.006 (-0.072) | -0.100 (-0.747) | 0.407 (3.210) | 0.364 (2.561) | 37 | 0.3575 |
| June | 0.083 (0.897) | -0.226 (-1.883) | 0.656 (4.309) | 0.399 (3.219) | 40 | 0.4595 |
| August | -0.023 (-0.226) | -0.331 (-2.222) | 0.423 (2.722) | 0.485 (3.562) | 39 | 0.4280 |
| October | -0.067 (-0.586) | -0.540 (-2.947) | 0.440 (2.257) | 0.269 (1.530) | 37 | 0.3697 |
| December | 0.131 (2.180) | 0.227 (1.530) | 0.373 (4.634) | -0.050 (-0.477) | 42 | 0.4019 |
| Contract Months Combined | 0.031 (0.838) | -0.221 (-3.641) | 0.405 (7.059) | 0.293 (5.312) | 234 | 0.2855 |
| 1978-82: | | | | | | |
| February | 0.098 (1.320) | -0.008 (-0.063) | 0.463 (4.908) | 0.071 (0.643) | 38 | 0.4211 |
| April | 0.024 (0.335) | 0.186 (1.362) | 0.563 (4.917) | 0.264 (3.110) | 37 | 0.4817 |
| June | 0.097 (0.998) | 0.298 (1.696) | 0.455 (3.645) | 0.198 (1.468) | 40 | 0.4222 |
| August | 0.003 (0.040) | 0.049 (0.405) | 0.282 (2.646) | 0.089 (0.847) | 38 | 0.2161 |
| October | -0.046 (-0.530) | 0.159 (0.932) | 0.332 (2.380) | 0.040 (0.343) | 39 | 0.2298 |
| December | -0.010 (-0.099) | 0.159 (1.398) | 0.526 (4.566) | 0.188 (1.664) | 35 | 0.4810 |
| Contract Months Combined | 0.041 (1.206) | 0.145 (2.767) | 0.434 (9.810) | 0.147 (3.478) | 227 | 0.3571 |

[a]Coefficients are shown opposite the appropriate contract month, with t-values directly beneath in parentheses.

[b]The subscript "t-1" refers to single-day lag, "t" to current-day price changes.

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