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CAUSAL RELATIONSHIPS IN THE FED CATTLE MARKET

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INTRODUCTION

The production process of transforming a 600–700 pound feeder steer into a slaughter animal typically requires four to six months. Conceptually, there should exist some relationship between the prices of feeder calves and slaughter cattle prices. In one view, since the feeder calf constitutes the costliest input in the production of the slaughter animal, the prices of fed cattle should be temporally connected to the cost of the feeder animals. This view suggests that feeder calf prices should lead slaughter prices by the length of the production process (Trierweiler and Hassler). In another view, the price of feeder calves is determined by the interaction of the supply of and derived demand for feeder cattle by feedlot operators. It is presumed that the derived demand for feeder cattle is related to feedlot operators' expectations of future fed cattle prices. If their expectations are strongly influenced by current fed cattle prices, then a relationship is suggested whereby slaughter and feeder prices vary concomitantly.

Studies by Franzman and Walker, and Barksdale et al. suggest that feeder and slaughter cattle prices move together with little or no lag. Their findings support the second view outlined above. However, neither of these studies utilized Granger's notion of causality, which allows explicit statistical testing of lead-lag relationships. Further, feed costs play an important role in the cattle feeding industry and lead-lag relationships between feed costs and feeder and slaughter prices have not been previously investigated.

This study will consider the extent to which feeder prices and feed costs affect fed cattle prices. The approaches taken are somewhat non-traditional in terms of defining causality (recently used by Miller; Bessler and Schrader [1980a, b]). The discussion next defines the concept of causality used and presents several competing methods to test causal hypotheses. These approaches are then used to analyze monthly time series on cattle feed costs, feeder cattle prices, and fed slaughter cattle prices. The results are presented and interpreted. Tentative conclusions drawn from the analysis then follow.

DEFINING AND TESTING CAUSAL RELATIONS

The definition of causality proposed by Granger is "Y_t is causing X_t if we are better able to predict X_t using all available information than if the information apart from Y_t had been used" (p. 428).

This prediction-oriented definition appears quite powerful in its simplicity, but is subject to a major deficiency in that it is impossible to include all relevant available information in forecasting X_t. As a means for sidestepping this indeterminacy, the investigator typically assumes that Y_t causes X_t if knowledge of Y_t can improve the prediction of X_t compared to the prediction of X_t, taking account of the past history of X_t alone.

Causality may be unidirectional or have feedback, and be instantaneous or delayed. To indicate unidirectional causality, we write Y_t → X_t. Feedback between two series is denoted by Y_t ↔ X_t and occurs when current, lagged, or future Y causes and is caused by current, lagged, or future X. The exact nature of causality may be determined using tests that can discriminate among various causal hypotheses.

Granger suggests the following test of causality between two stationary time series X_t and Y_t. The models

$$(1) \quad X_t = \sum_{j=1}^m a_j X_{t-j} + \sum_{i=1}^n b_i Y_{t-i} + \epsilon_t$$

$$(2) \quad Y_t = \sum_{j=1}^m c_j Y_{t-j} + \sum_{i=1}^n d_i X_{t-i} + \eta_t$$

are estimated using ordinary least squares. We accept the hypothesis that Y_t ↛ X_t (i.e., the Y series does not cause the X series), if the b_i are all not significantly different than zero. A similar test of the d_i parameters will determine whether or not X causes Y. To assure the statistical validity of these tests, the error terms are assumed to be uncorrelated white noise series, that is, E(ε_tε_s) = E(η_tη_s) = 0 for s ≠ t, and E(ε_tη_s) = 0 for all t, s. To check for instantaneous causality, the index i is initialized at zero in expressions (1) and (2).

An alternative test of Granger causality has been set forth by Sims (1972). His test presumes that X and Y series are stationary with an autoregressive representation. Sims (1972) states that "Y can be expressed as a distributed lag function of current and past (but not future) X . . . if, and only if, Y does not cause X in Granger's sense" (pp. 544, 545). Thus, Sims's causal test requires regressing Y_t on lagged, current, and future values of X and testing whether the coefficients on future X variables are significantly different than zero. Specifically, the model to be estimated is

$$(3) \quad Y_t = \sum_{i=-n}^n b_i X_{t+i} + \eta_t$$

and if all b_i for the index $i > 0$ are not significantly different than zero, it is said that Y does not cause X. Again, the residual in (3) is assumed to follow a white noise process, independent of past, current, or future values of X.

A particular difficulty with these distributed lag methodologies for assessing causality is the requirement that the residuals evidence no serial correlation. Feige and Pearce, among others, have noted that such finite lag formulations may omit lagged variables with non-zero population coefficients. Such an omission may produce serially correlated errors and, consequently, invalidate the causality tests. In addition, Pierce notes that autocorrelation in the X and Y series should be taken into account prior to regression or correlation analysis. While Sims (1972) has suggested a particular filtering method to at least approximately accomplish this, Haugh's time series techniques seem more ideally suited for mitigating this complication.

The Haugh method of residual cross correlation analysis is a time series technique capable of assessing Granger causality between two stationary series X and Y. Assume that the series may be represented by

$$(4) \quad F(B)Y_t = v_t$$

$$(5) \quad G(B)X_t = u_t$$

where $F(B)$ and $G(B)$ are invertible polynomials in the lag operator B (the filters), and v_t , u_t are white noise processes having variances σ_v^2 , σ_u^2 . By construction, these noise processes are not autocorrelated, thus Haugh proposes that their cross correlation will provide information about causality between X and Y. This cross correlation between the residuals is denoted at lag k as

$$\rho_{uv}(k) = \frac{E(u_{t-k}, v_t)}{[E(u_t)^2 E(v_t)^2]^{1/2}}.$$

Actually, u and v are not observed, but are replaced by their estimated values from (4) and (5), which yield $\hat{r}_{\hat{u}\hat{v}}(k)$, the sample counterpart to the left-hand side of (6). Under the null hypothesis

that X and Y are independent series, Haugh has shown that the $\hat{r}(k)$ are asymptotically normally and independently distributed with mean zero and standard deviation $T^{-1/2}$.

Once the residual cross correlation estimates have been calculated, statistical tests of significance for individual estimates are obtained by the criterion that the absolute values of the sample cross correlations exceed their asymptotic standard deviations by a factor of two. That is

$$(6) \quad |\hat{r}_{\hat{u}\hat{v}}(k)| \geq 2T^{-1/2}$$

indicates a significant cross correlation, where T is the total number of observations available. Individual significant cross correlations may then be used to detect causal direction at specific lags.

An overall test of significance for eliciting whether joint dependence exists between the two series takes the form of a chi-square statistic. Given Haugh's results on the distribution of the $\hat{r}(k)$, the hypothesis that the two series are independent may be rejected at significance level α if

$$(7) \quad T \sum_{k=-m}^m [\hat{r}_{\hat{u}\hat{v}}(k)]^2 > \chi_{2m+1}^2(\alpha)$$

where $\chi_{2m+1}^2(\alpha)$ is the percentage point at α of a chi-square distribution with $2m+1$ degrees of freedom.

Similarly, tests of unidirectional causality have been suggested (Pierce). The hypothesis that X does not cause Y may be rejected at the α level of significance if

$$(8) \quad T \sum_{k=1}^m [\hat{r}_{\hat{u}\hat{v}}(k)]^2 > \chi_m^2(\alpha),$$

and the hypothesis that Y does not cause X may be rejected at the α level of significance if

$$(9) \quad T \sum_{k=-1}^{-m} [\hat{r}_{\hat{u}\hat{v}}(k)]^2 > \chi_m^2(\alpha).$$

Just as there were shortcomings associated with the distributed lag tests for Granger causality, several difficulties with the Haugh approach have been noted. It has been shown by Sims (1977) that the chi-square tests for unidirectional causality are biased toward acceptance of the null hypothesis. Feige and Pearce have pointed out that the causality tests may be conditioned by the filters used to obtain the whitened noise processes u and v. Therefore, we follow their recommendation and apply all three tests to determine the extent of Granger causality among feed costs, feeder prices, and slaughter cattle prices.

EMPIRICAL RESULTS

The data consist of monthly observations of Choice Omaha 900-1100 pound steer prices,

Kansas City 600–700 pound feeder steer prices, both measured in dollars per hundred weight, and a feed cost index that is a weighted average of Chicago corn price and Decatur soybean meal prices.¹ These variables are first differenced to transform them into approximately stationary series, which will be denoted by SP, FP, and FC representing steer and feeder prices and feed costs respectively. Data span the period from January, 1966, through December, 1979, yielding 168 observations (thus T=168).

The decision on the length of period over which to examine causal relationships was influenced by consideration of the production process. An eight-month period [m=8 in equations (7)–(9)] was chosen because it represents the time in which almost all cattle on feed are marketed (Gustafson and Van Arsdale). While longer, more complex interactions may likely exist in the cattle market, the shorter causal period examined is suggested more by the cattle feeding process than the possible longer-run dynamics resulting from the cattle cycle. In the Granger tests, distributed lags on the dependent variable were specified to extend 12 periods [m=n=12 in equations (1) and (2)] into the past in order to take into account possible seasonality of the series.

Before applying the Haugh test for causality, the three series must be filtered. The specified models used along with the standard errors of coefficients and relevant fit statistics are:

$$\begin{aligned}
 (10) \quad & (1 - .26B - .174B^3 - .207B^4) \\
 & \quad (.08) \quad (.08) \quad (.08) \\
 & (1 - .167B^{15})^{-1}FC_t = a_t \quad \hat{\sigma}_a = 1.69 \\
 & \quad (.08) \quad \chi^2_{20} = 17.7 \\
 (11) \quad & (1 - .181B - .186B^2) \\
 & \quad (.08) \quad (.08) \\
 & - .268B^{15}FP_t = b_t \quad \hat{\sigma}_b = 2.14 \\
 & \quad (.09) \quad \chi^2_{21} = 18.7 \\
 (12) \quad & (1 - .173B - .162B^3) \\
 & \quad (.08) \quad (.08) \\
 & - .222B^{12}SP_t = c_t \quad \hat{\sigma}_c = 2.25 \\
 & \quad (.09) \quad \chi^2_{21} = 16.9
 \end{aligned}$$

The chi-square statistics presented support the hypothesis that the calculated residuals are white noise. These residuals then are cross correlated so that tests of causality may be obtained.

Results of the tests for causal relationships using the methodologies of Granger, Sims, and Haugh are presented in Table 1. Under the Granger and Sims tests of no causality, only two hypotheses may be rejected at reasonable levels of significance. Both of these methods demonstrate that feed costs lead both slaughter steer and feeder prices.

The Haugh approach highlights the depen-

TABLE I. Causality Tests.

Hypothesis	Tests		
	Granger F-statistics (with 8, 128 df)	Sims	Haugh-Pierce χ^2 - statistics
SP \nleftrightarrow FP	1.44	1.18	113.4 ^b (17) ^a
SP \nleftrightarrow FP	1.17	1.48	5.15 (8)
FP \nleftrightarrow SP			10.04 (8)
SP \nleftrightarrow FC			39.97 ^b (17)
SP \nleftrightarrow FC	.88	.75	4.21 (8)
FC \nleftrightarrow SP	3.57 ^b	2.79 ^b	31.91 ^b (8)
FP \nleftrightarrow FC			40.25 ^b (17)
FP \nleftrightarrow FC	1.11	.67	6.85 (8)
FC \nleftrightarrow FP	4.23 ^b	2.62 ^c	30.05 ^b (8)

^a The numbers in parentheses denote the degrees of freedom associated with χ^2 statistics.

^b Rejection of the null hypothesis at the .01 level.

^c Rejection of the null hypothesis at the .025 level.

dence of all three series (X \nleftrightarrow Y). Recall that this test does not imply causality and is statistically valid. The other tests are all conservatively biased, but do indicate that feed costs lead steer and feeder prices. Thus, the results of the disparate methods are in mutual agreement.

In addition, the Haugh test shows joint dependency between feeder and slaughter prices (rejection of FP \nleftrightarrow SP), but it simultaneously reveals that feeder prices do not lead slaughter prices (acceptance of FP \nleftrightarrow SP), and slaughter prices do not lead feeder prices (acceptance of SP \nleftrightarrow FP). Thus, the relationship between the two series is instantaneous. This finding is confirmed by the estimated zero-lag cross correlation coefficient of .796 between the two price series.

Table 2 shows the estimated residual cross correlations between feeder prices and feed costs, and between steer prices and feed costs. Significant cross correlations are found at the fourth and eighth lag, suggesting a distributed lag relationship between the residuals. That is

TABLE II. Cross Correlations.

Lagged feed costs residual (a_t)	Feeder price residual (b_t)	Steer price residual (c_t)
a_t	.184	.174
a_{t-1}	-.076	-.017
a_{t-2}	.186 ^a	.157
a_{t-3}	.013	-.153
a_{t-4}	-.340 ^a	-.364 ^a
a_{t-5}	.076	.061
a_{t-6}	-.090	-.036
a_{t-7}	-.127	.017
a_{t-8}	.225 ^a	.265 ^a

^a Exceeds calculated standard error by a factor of two or more.

¹ The feed cost index (FCI) is given by $FCI = 10 \cdot CP + .055 \cdot SM$, where CP is the price of No. 2 yellow corn at Chicago, measured in dollars per bushel, and SM is the price of 44-percent protein soybean meal at Decatur, measured in dollars per ton. The weights used correspond to an approximate ratio of 85 percent corn and 15 percent soybean meal.

$$(13) \quad b_t = (\omega_0 - \sum_{i=1}^8 \omega_i B^i) a_t$$

and

$$(14) \quad c_t = (\gamma_0 - \sum_{i=1}^8 \gamma_i B^i) a_t$$

where

$$(15) \quad \omega_i = \frac{\sigma_b}{\sigma_a} \rho_{ba}(i)$$

and

$$(16) \quad \gamma_i = \frac{\sigma_c}{\sigma_a} \rho_{ca}(i).$$

Following Haugh and Box, the estimated counterparts of (15) and (16) are substituted into (13) and (14), respectively. Then (13) replaces b_t in the univariate model given by (11), and (10) replaces a_t in that same expression. After making these substitutions and simplifying, the implied lag relationship between feeder prices and feed costs is

$$(17) \quad FP = (\alpha_0 - \alpha_2 B^2 - \alpha_4 B^4 - \alpha_7 B^7 - \alpha_8 B^8) FC_t + \phi(B) \mu_{1t}$$

where the α_i are parameters to be estimated, $\phi(B)$ is a polynomial in the lag operator B , and μ_{1t} is the white noise disturbance associated with the feeder price equation.²

After performing similar calculations for steer prices, the implied lag relationship between steer prices and food costs is

$$(18) \quad SP_t = (\beta_0 - \beta_2 B^2 - \beta_3 B^3 - \beta_4 B^4 - \beta_8 B^8) FC_t + \theta(B) \mu_{2t}$$

where the β_i , $\theta(B)$, and μ_{2t} are defined analogously to α_i , $\phi(B)$, and μ_{1t} in (17).³

Maximum likelihood estimation of (17) and (18) yield

$$(19) \quad \begin{aligned} FP_t = & (.199 + .225B^2 - .284B^4 - \\ & .158B^7 + .118B^8) FC_t + \\ & (1 + .264B) \mu_{1t} \end{aligned} \quad \begin{aligned} \hat{\sigma}_{\mu_{1t}} &= 1.71 \\ \chi^2(19) &= 25.09 \end{aligned}$$

and

$$(20) \quad \begin{aligned} SP_t = & (.250 + .106B^2 - .086B^4 - \\ & .286B^4 + .133B^8) FC_t + (1 + .209B - \\ & .195B^8) \mu_{2t} \end{aligned} \quad \begin{aligned} \hat{\sigma}_{\mu_{2t}} &= 1.84 \\ \chi^2(18) &= 21.86 \end{aligned}$$

The chi-square statistic indicates that the residuals from both estimated equations are white

noise. The residual standard error of both series has been reduced, compared to the univariate models (11) and (12), respectively.

The implications of the estimated lag relationship between steer prices and feed costs is that the immediate effect of increased feed costs is an increase in steer prices. Cattle feeders usually have some feed in inventory. When grain bins must be replenished with higher-priced feed, however, cattle feeders react through accelerated marketings. Thus, at three to four months, steer prices and, concomitantly, feeder prices fall. As the full impact of the feed price change is felt, fewer cattle are placed on feed, hence at eight months, prices rise.

The sum of the coefficients on the lagged variables in (19) is .100 and in (20) is .117 (ignoring the noise component). Thus the long-run effect of a sustained increase in feed costs is an increase both in steer and feeder prices. Given the magnitude of the sum of the estimated coefficients, however, the impact of a sustained increase in feed costs both on steer and feeder prices is relatively small.⁴

The positive relationship between feed costs and feeder prices is contrary to the widely held belief that an inverse relationship between the two series should exist. For example, Ehrich estimated a price-dependent derived-demand relationship for feeder cattle using annual data and observed a negative sign on the coefficient of the feed variable. However, Arzac and Wilkinson, using a quarterly simultaneous equation model, observe that an increase in corn prices results in a long-run increase both in choice steer and feeder cattle prices. Our results conflict with those of Ehrich, but are consistent with those of Arzac and Wilkinson.

CONCLUSIONS

With the use of three different tests to assess the presence of Granger causality in the beef cattle market, it was determined that slaughter steer and feeder animal prices are determined simultaneously, which is consistent with the findings of Barksdale et al. Feed costs were found to lead prices of both animal categories. This result implies that, when forecasting steer or feeder prices, not only should the past history of those prices be examined, but also the past history of feed costs. Further, increased feed costs appear to increase steer and feeder prices in the first two months, then depress them at four months, followed by an increase eight months later. The long-run effect of increased feed costs is a slight increase both in steer and feeder prices.

^{2,3} After performing the indicated polynomial divisions, the infinite remainders were truncated by dropping those lags with relatively small coefficients (all were less than .1 in absolute value). The estimated standard errors of these coefficients have not been derived, thus our approach follows that of Haugh and Box (pp. 128, 29). Since the three series were all first differenced, their means are all close to zero. The magnitudes of the variables are comparable, thus justifying the symmetrical truncation rule.

⁴ The magnitudes of the variables are comparable, see footnote 2.

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