Dynamics of Regional Fed Cattle Prices

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The dynamic relationship between four regional cash prices for fed (slaughter) cattle is investigated using time series analysis and causality tests. The results indicate that price adjustments to new information take about one week. Texas Panhandle price also was determined to dominate the price discovery process.

Regional prices also were found to be interdependent. This suggests that increasing regional meat packer concentration may not grant meat packers increased regional market power in their pricing practices.

Equilibrium prices for different locations are determined by supply and demand conditions. The process of reaching an equilibrium is termed price discovery. Arbitrage activities are expected to force prices to an equilibrium across space. In the case of regional prices, arbitrage takes the form of transportation activities. If these arbitrage activities are performed efficiently then the price difference between two locations will be less than or equal to transportation costs.

However, arbitrage of regional prices may not be instantaneous, and thus commodity markets would be slow to adjust to supply/demand fluctuations across different locations. Such a situation reflects a lack of perfect efficiency in utilizing information. Sporleder and Chavas maintain the efficiency of a market may be judged by the timeliness and accuracy with which prices reflect new information. Market efficiency is related to production efficiency since producers base their production plans on price signals. If markets are slow to reflect information, then producers may allocate their resources nonoptimally, resulting in production inefficiency.

When price adjustments over space are not instantaneous, it becomes relevant to investigate the dynamics of regional price adjustments. Two factors expected to be important in the size of dynamic adjustments are the volume in each market and the distance between the markets. Since information and other transaction costs associated with transportation likely increase with distance, price arbitrage between remote locations is expected to become less effective. Also, a larger market would be expected to have a larger impact on the price discovery process.

The speed of price adjustments between regions may have important implications about the structure and behavior of the markets. For instance, concentration levels in the meat packing industry are high on a regional basis. The four firm concentration ratio (CR_4) for commercial fat cattle slaughter in the Utah and Southern Idaho region in 1982 was 89 percent. The CR_4's for some of the largest meat packing areas of the country for slaughter steers are also high; e.g., Texas North Plains 98.7 percent, Southwest Kansas 96.1 percent, Eastern Nebraska-Northwest Iowa 75.1 percent, and Central Iowa 100

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percent (Ward). These concentration ratios would be considered high in any industrial setting. If regional markets function in relative isolation, these regional concentration levels would give packers the potential to exert market power on producers. If regional prices respond quickly to prices in other locations, implying the relevant market may be the entire Western United States, these high regional concentration levels would have limited or no impact on producer prices, since packers must respond to what is happening in other regional markets. Thus, the speed of price adjustments has important industrial organization implications.

This paper analyzes the speed of fat cattle price adjustments over space, and thus indirectly the level of efficiency in spatial fat cattle markets. The speed of price adjustments will also provide some evidence about the relevant market area for fed cattle. The procedure utilizes a time series model of weekly fat cattle prices for four different regions in the United States. Two issues hypothesized to influence dynamic price adjustments are the volume of trading in each location and the distance between the markets.

Economic Efficiency

The concept of efficiency has many different meanings to economists. Panton defined an efficient market as one in which a speculator would be unable to obtain an "above normal" return. Along this same vein, Bailey and Brorsen found that price differences between some regional markets for fat cattle were greater than estimated shipment costs (transportation plus shrinkage costs) as much as 14 percent of the time, reflecting inefficient markets. Alternatively, Fama defined an efficient market as one that fully reflects all available information. Fama's efficiency tests interpret efficiency in strong, semistrong, and weak form contexts. His strong form test includes all information, including that available to insiders. The semistrong form test includes all publicly available information while the weak form test utilizes past prices only. The tests of inefficiency employed in this study use only past prices and, therefore, are weak form tests.

Unfortunately, Fama's tests are simultaneous tests of a number of assumptions (Danthine; Rausser and Carter). In cash markets these assumptions include risk neutrality, costless information, and zero transaction costs which cannot reasonably be expected to hold. Thus, price adjustments to new information in spot markets are not expected to be instantaneous. Spriggs *et al.*, for example, found less than instantaneous adjustment for spot prices. Perhaps a measure of relative efficiency is appropriate for spot markets rather than Fama's measure of absolute efficiency. Thus, in this paper the markets are considered to be efficient if markets reflect all information in a "short" period of time.

Data and Modeling Procedure

The data used consist of the weekly quoted prices for fat cattle graded choice (yield grade 2–4) for four separate markets between January 1, 1978, and June 4, 1983. The four markets considered are the Texas Panhandle (Texas), Omaha (Nebraska), Colorado-Kansas (Colorado), and Utah-Eastern Nevada-Southern Idaho (Utah). The data are published in Livestock, Meat, Wool Market News (USDA) with the exception of the Utah-Eastern Nevada-Southern Idaho prices which were obtained from the Utah State Department of Agriculture. These locations were chosen to represent the two largest markets, Texas and Nebraska, and two smaller markets.

The procedure utilizes "causality tests" between the four price series. The definition of causality used in this study is that given by Granger: X2 "causes" X1 if and only if X1(t) is better predicted by using the past history of X2 than by not doing

so with the past history of X1 being used in either case. If X2 causes X1 and X1 does not cause X2, then X2 causes X1 unidirectionally. If X2 does not cause X1 and X1 does not cause X2, then X1 and X2 are either statistically independent or related contemporaneously, but in no other way. If X2 causes X1 and X1 causes X2, then feedback exists between X1 and X2 (Guilkey and Salemi).

Most of the first causality tests used the methods of Haugh or Sims (1972). However, Geweke, Tjostheim, and Hsiao have all advocated using some form of the following test. This method was first suggested by Granger and has been shown to be more powerful than the causality tests of Sims or Haugh on the basis of Monte Carlo studies (Guilkey and Salemi; Geweke *et al.*; Nelson and Schwert). First, an autoregressive model of order p (AR(p)) is estimated. The AR(p) is

$$Y(t) = \sum_{j=1}^{p} \begin{bmatrix} a_{11}^{(j)} & \cdots & a_{1n}^{(j)} \\ \vdots & & \vdots \\ a_{n1}^{(j)} & \cdots & a_{nn}^{(j)} \end{bmatrix} Y(t-j) + E_t \qquad (1)$$

where Y(t) is an n × 1 vector of observations (n is 2 for bivariate time series), p is the order of the autoregressive model, $a_{ik}^{(j)}$ i, k = 1, . . . , n; j = 1, . . . , p are parameters (where p constitutes the number of restrictions which, in this case, is the order of the autoregressive model) and E_t is a vector of multivariate white noise error terms. The causality tests are conducted using equation (1). If $a_{12}^{(j)} = 0$ for all j, then variable 2 does not cause variable 1 (Tjostheim). This test is performed by examining the significance of the group as a whole. If an intercept term is included then the test statistic may be calculated as follows (Guilkey and Salemi):

$$F = \frac{(SSE_r - SSE_u)/p}{SSE_u/T - (np + 1)} \qquad (2)$$

where SSE_u is the sum of squared residuals without the restrictions, SSE_r is the sum of squared residuals with the restrictions and T is the number of observations.

The modified Q-statistic of Ljung and Box (Qm) is used to test the adequacy of the AR models to remove autocorrelation. The null hypothesis of no autocorrelation is rejected at the α significance level if

$$Q_m = T(T + 2) \sum_{k=1}^{m} r_k^2/(T - k) > \chi^2_{m-p}(\alpha) \qquad (3)$$

where T is the number of observations used to calculate the statistic, the r_k^2 are the squared estimated autocorrelations at lag k, $\chi^2_{m-p}(\alpha)$ is the chi-square table value for significance level α and m − p degrees of freedom, and m is a positive integer chosen large enough to include expected nonzero coefficients.

Transforming Data

There is no real agreement in the literature regarding the use or nonuse of a difference operator (prefilter) to obtain a stationary time series before the causality tests are performed. Nerlove *et al.* suggested that nonstationarity in one time series should be used to explain the nonstationarity in another time series.

Granger and Newbold state that a time series should be differenced to obtain stationarity prior to performing a regression. Bessler and Kling found that by examining the relationship between two time series, one stationary (sunspots) and one nonstationary (GNP), that the identified relationships may not hold in post sample forecasting tests. However, when the GNP data were differenced to make them stationary the same results held both in-sample and out-of-sample. Using a Monte Carlo simulation procedure, Hudson found that first differenced (stationary) data used in Geweke and modified Sims causality tests correctly predicted known causal flows between time series more often than when raw or unfiltered data were used. This suggests that causality tests should be

more reliable when conducted using stationary time series.

Thus, we conduct our causality tests using filtered data.[1] The justification for filtering is that the data can be decomposed as

$$Y_t = D_t + S_t + e_t \tag{4}$$

Equation (4) decomposes the price series into three parts: the deterministic part D_t; the short memory process S_t which is assumed to be covariance stationary; and the error term e_t which is a zero mean white noise process. The deterministic part D_t typically involves trend and seasonality factors that cause the time-series to be nonstationary. They reveal nothing about the market's response to new information. Therefore, the deterministic component D_t should be removed (filtered) before applying time series analysis if conclusions are to be drawn about efficiency of information use. The stochastic process $S_t + e_t$ is of interest here since it reflects how new information is processed by the markets. For example, if S_t is zero, then there are no dynamic adjustments in prices. In this case, prices reach their equilibrium immediately, suggesting the markets are efficient (at least in Fama's weak form sense). The process S_t is modeled here using equation (1).[2]

Nonstationarity and seasonality are properties exhibited by most agricultural price time series. Fat cattle prices are no different. They have trends due to inflation and other economic factors. The data in this study were first differenced to remove any trend components. Since first differencing does not remove the seasonal component in a series, it was necessary to remove any significant seasonal variations in the data. This was accomplished by using the method in Bowerman and O'Connell (pp. 308–9):

$$FDP_{it} = a + \sum_L [b_L \operatorname{Sin}(2\pi t/L) + c_L \operatorname{Cos}(2\pi t/L)] + e_{it} \tag{5}$$

where FDP is the first differenced price for the ith series, "a" is an intercept, b and c are parameter estimates, t is time, L is the specified cycle length, and e is the residual error term.

The periods of the cycles tested in this study were 1, 3, 6, and 12 months. Significant 12 month cycles were found for all four price series. In addition to significant 12 month cycles, significant six month cycles were also found for the Colorado and Texas series.

The order of the AR process was identified using Akaike's Information Criteria (AIC) (Akaike). The regression parameters were estimated by ordinary least squares (OLS).[3] The relationship of the prices in the current period was investigated by calculating the correlations of the residuals from the multivariate autoregressive model.

Results

Nebraska and Texas represent the two largest areas in terms of slaughter. About twice as many fat cattle are slaughtered in the Nebraska area; however, packing plants are more dispersed in Nebraska and,

[1] The causality tests in this paper were also conducted using unfiltered data using the method in Guilkey and Salemi. The results using unfiltered data were similar but not precisely identical to those using filtered data. This confirmed the results obtained by conducting the causality tests using filtered data. However, since little additional information was obtained using unfiltered data, only the filtered data results are reported in this paper.

[2] Sims (1977) argued that prefiltering the data with separate prefilters may bias the results in favor of the null hypothesis. In this study, the same prefilter was used to remove trend, but different prefilters were used to remove seasonality.

[3] If the AIC selects the "true" order of the AR process, consistent and asymptotically efficient estimates of the parameters may be obtained using seemingly unrelated regression (SUR) (Theil). Since the right hand side variables were the same for all four equations to be estimated, OLS yielded the same results as SUR. Consequently, the OLS estimates are those reported in the paper.

TABLE 1. Multivariate Autoregressive Models for Utah, Colorado, Texas, and Nebraska Regions[a] for Fat Cattle.[b]

Independent Variable	Model			
	Utah	Colorado	Texas	Nebraska
Intercept	0.003	0.002	0.003	0.0005
	(0.038)	(0.023)	(0.026)	(0.006)
Utah	0.003	0.066	−0.035	0.073
	(0.038)	(0.600)	(−0.335)	(0.706)
Colorado	−0.101	−0.436	0.040	0.132
	(−0.800)	(−2.78)**	(0.277)	(0.913)
Texas	0.693	0.863	0.512	0.483
	(4.93)**	(5.10)**	(3.19)**	(3.03)**
Nebraska	−0.144	−0.236	−0.252	−0.460
	(−1.57)	(−2.14)*	(−2.41)**	(−4.19)**
R-Square	0.261	0.135	0.119	0.147
Q-Statistic[c]	9.676	10.606	11.357	6.942

[a] Utah = Utah-Eastern Nevada-Southern Idaho Region, Colorado = Colorado-Kansas Region, Texas = Texas Panhandle, Nebraska = Nebraska-Iowa Region.
[b] t-values are in parentheses.
[c] The Q-statistic was calculated using 10 lags (i.e., 9 degrees of freedom).
* Denotes significance at the 5 percent level.
** Denotes significance at the 1 percent level.

thus, they may not all compete directly with each other. Most of the slaughter in the Texas Panhandle takes place around Amarillo, and thus, most packers compete directly. Since we did not know the relevant market for Nebraska, we did not know which market represents the largest quantity, and we had no a priori expectation about which market is the most important for price discovery.

Utah and Colorado are closer to the Texas Panhandle than they are to Nebraska. Because of lower transportation costs, Utah and Colorado probably compete more directly with Texas and, thus, they are expected to follow the Texas price. An institutional factor which may be important is that the U.S. Department of Agriculture Market News Division is currently located in Amarillo, Texas. The close proximity of the Texas Panhandle market may eliminate much of the statistical error associated with reported fat cattle prices in that area (Uvacek). This could lead the cattle industry to look to the reported Texas price as a more accurate indicator of market conditions, and thus, the Texas price would lead the other prices.

TABLE 2. Correlation Matrix for Residuals of Multivariate AR Model.[a]

	Residuals for:			
	Utah	Colorado	Texas	Nebraska
Utah	1.000	0.780	0.800	0.673
Colorado	0.780	1.000	0.928	0.830
Texas	0.800	0.928	1.000	0.805
Nebraska	0.673	0.830	0.805	1.000

[a] All correlations are significant at the one percent level.

The causality tests were conducted using filtered data with the order of the autoregressive portion of the model being selected by Akaike's Information Criteria. The AIC selected a multivariate AR(1) for all four regional models. Since an AR(0) was not selected the markets are not efficient in utilizing information according to Fama's weak form definition. However, current prices were only significantly related to lagged prices of one week, a relatively short period of time, and thus, the markets were considered relatively efficient. The model was estimated using OLS

and the causality test calculated (Table 1). Since an AR(1) was selected for all four models, the causality tests were conducted using a standard t-test. The Q-statistics showed the null hypothesis of no autocorrelation in the residuals could not be rejected for any of the four models. All contemporaneous correlations were significant at the one percent level, indicating that prices reflect a large portion of information in less than a week (Table 2). Thus, producers are receiving information from the market quickly, allowing them to make near optimal decisions. Distance appears to be important for instantaneous price adjustments since the most distant markets had the weakest relationships.

The causality tests showed lagged Texas prices had a significant impact on each market. This impact was large and positive, indicating the other prices follow the Texas price. The Nebraska price had a small negative impact on prices in all markets except Utah which was the most distant. These results indicate the two largest markets, Texas and Nebraska, are the most important in terms of price discovery. However, the Texas market appears to dominate the price discovery process.

Colorado and Utah prices had no lagged impact on any other markets, which is further evidence that size of market influences dynamic price adjustments. Distance also appeared to be important since the two most distant markets, Utah and Nebraska, had no significant lagged relationship. The R-square values ranged from 0.261 for Utah to 0.119 for Texas. Texas had the smallest percentage of price movements explained by past price movements; therefore, the Texas price is the most efficient, but it is still inefficient according to Fama's restrictive definition.

The results show regional fat cattle markets do not act independently of each other. Thus, increasing concentration on a regional basis may not be of particular concern to producers. A significant portion of price adjustments take no longer than a week. Prices tend to be discovered in the Texas market although the Nebraska market has some impact.

Most packing companies do not operate on a multi-regional (large market area) basis. Some very large packing companies do operate plants in several regions. These results indicate studies which analyze increasing concentration in meat packing on a small regional basis may not be relevant since the relevant market area for large meat packers is at least multi-regional.

Summary and Conclusions

The dynamic price relationships between four regional markets for fat cattle were analyzed. Causality tests were performed, using filtered data, to determine the lead-lag relationships between the four markets. None of the markets was totally efficient in the sense that price adjustments were not instantaneous. However, all significant price adjustments were found to occur in a week or less. This was considered to be a short period of time and thus the degree of inefficiency is concluded to be low, if indeed it exists. The results suggest packers in these regional markets must compete with other markets. This indicates that even with increased concentration, packers may not influence price for any extended period of time. Thus, increasing regional concentration should not depress prices in any extraordinary way. However, increasing multi-regional concentration may be taking place. Further research should focus on the concentration of meat packers over large market areas.

The two larger markets were expected to reflect changing market conditions in prices at the fastest rate. All cross correlations were significant at the one percent level, indicating a large amount of the price adjustments between regions takes place in the current time period. Beyond a week, the two largest markets (Texas and Ne-

braska) dominate the adjustment process. However, Texas, the smaller of the two largest markets, had a much stronger impact than Nebraska.

Texas prices may dominate as a result of several factors. Although larger numbers of cattle are fed in the Nebraska-Iowa area than in the Texas Panhandle, production and processing in Texas takes place in a smaller geographic area. Also, feedlots and packing plants are larger in the Texas Panhandle, which may give them some economies of size in information. Feedlots in Texas may have more marketing alternatives, and, as a result, Texas prices may be determined in a market where feedlots and packers have more equal market power. This could result in a price that more truly reflects market conditions.

Another factor is that the U.S. Department of Agriculture Market News Division has relocated in Amarillo, Texas. The close proximity of the Texas Panhandle may allow the Market News to eliminate much of the statistical error in the reported Texas prices. This is especially important since smaller numbers of fat cattle are being sold through terminal markets and more by direct sales from feedlots (Shepherd and Futrell). Thus, it may only be that reported Texas prices are faster in reflecting new information. In this case any inefficiency would be in price reporting rather than price discovery.

These results suggest Texas prices are generating the clearest signals of market conditions. If this is the case, Texas prices are the best source of price information in research and should provide buyers and sellers with the best reported information for production and marketing decisions.

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