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Assessing the Relationship between Market Factors and Regional Price Dynamics in U.S. Cattle Markets

Allan M. Walburger and Kenneth A. Foster

Regional live cattle prices are decomposed into two components: (*a*) a trend common to all regional cattle price series and (*b*) regional deviations or price dynamics around that trend. Tests are developed to determine if market factors are related to the regional price deviations around a common trend. Slaughter volume, distance between a market and the next closest, and forward contract deliveries are significantly related to price deviations from the estimated common trend.

Key words: beef-packing, fed cattle, forward contracts, state space

Introduction

Vertical linkages have become increasingly important to beef-packers. Beef-packers purchase a growing percentage of their procurement needs through direct means (92.4% in 1988, see Ward 1990). The increased sales through direct markets may limit information to sellers. In addition, the lower volume public markets may provide less reliable information (Tomek and Robinson). While direct sales limit access to information and, thus, limit the "open" bidding process, they may not affect the resulting sale prices. The real issue is whether industry structure is such that slaughter firms can use their information to distort prices. That is, information asymmetries may result in opportunistic behavior by those with the improved information (Williamson), in this case, the beef-packers, and for this reason the efficiency of cattle markets is in question.

In addition, captive supplies have increased. These include cattle fed in the packers' own feedlots or custom fed; those purchased through forward contracts; and cattle acquired through marketing agreements with livestock producers and feeders. Captive supplies may result in more efficient timing of cattle arrival to the packing plant. Conversely, they further restrict market information to sellers, heightening the concern over the efficiency of fed cattle markets and the exercise of market power.

Bailey and Brorsen (1985), in one of the first attempts to address the issue of efficient price discovery in regional fed cattle markets, argued that arbitrage activities will tend to force prices to an equilibrium across space. When arbitraging is efficient then the price differences between locations will be less than or equal to the transportation costs (assuming negligible transaction costs). They expected two major factors to affect regional price dynamics: volume in each market and distance between markets. They discovered evidence of price differences which exceed transportation costs between locations, but

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Allan M. Walburger is assistant professor, Department of Economics, University of Lethbridge, and Kenneth A. Foster is associate professor, Department of Agricultural Economics, Purdue University.
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these existed for only short periods of time. Further, causality tests revealed that size of market and distance influenced dynamic price adjustments.

A number of studies have followed: Bailey and Brorsen (1989); Koontz, Garcia, and Hudson; Schroeder and Goodwin; Goodwin and Schroeder (1990, 1991); Faminow and Benson; and Hayenga and O'Brien are a few examples. The later studies have tried to relate time-series properties (cointegration) to market efficiency. Faminow and Benson caution that care must be taken when interpreting such results.

The research by Goodwin and Schroeder (1991) merits closer consideration in the context of this study. They empirically evaluated cointegration in regional cattle markets and then showed the impacts on cointegration of several market characteristics.[1] Goodwin and Schroeder (GS) performed pairwise tests of cointegration on various regional fed cattle price series.[2] They found only weak evidence of cointegration. GS suggested that this implies possible inefficiencies. The authors used a bootstrapping technique to regress the cointegration test statistics on market factors: market type, beef-packer concentration, relative slaughter volume, and distance between the pairs of markets. The results were interpreted as follows. Direct markets are less likely to exhibit "cointegration." Four-firm concentration is positively related to the test statistics and significant, implying (*a*) increasing concentration resulted in more efficient markets, or (*b*) basing-point pricing evolved with higher concentration and resulted in market "cointegration." Slaughter volume is negatively related to "cointegration" which the authors suggested is a result of smaller markets being more dependent. Finally, distance reduces the relatedness of markets.

The purpose of this study is to estimate a common underlying trend of the system of regional cattle prices and relate regional price deviations from that trend to various market factors such as those discussed above. The study uses the linear system state-space technique developed by Aoki (1987a) to develop an "equilibrium" model. This model is used to estimate the common dynamic factors (i.e., common long-run trend(s)) which characterize live cattle prices reported from different geographical regions. Since regional cattle prices may deviate from the estimated long-run trend, an additional regression model is developed to estimate the relationships between these deviations and market factors which might affect the efficiency of regional price discovery in the fed cattle industry.

Data

Eighteen and one-half years of weekly price data, beginning in 1973, on nineteen direct and public markets of 1100-to-1300-pound steers were obtained from the U.S. Department of Agriculture (USDA), Agricultural Marketing Service. The markets included in the analyses are California Direct, Colorado Auctions, West Fargo Terminal, Idaho Direct, Illinois Direct, Iowa–Southern Minnesota Direct, Western Kansas Direct, Lancaster Terminal, Louisville Auctions, National Stock Yard Terminal, Eastern Nebraska Direct, Omaha Terminal, South St. Paul Terminal, St. Joseph Terminal, Sioux City Terminal,

[1] Goodwin and Schroeder (1990) use a similar approach to assess how market factors affect the relatedness of markets.

[2] The restrictions imposed by the pairwise nature of the model, and thus the tests, imply much of the dynamics of the system may not be embodied in the results. This is perhaps a severe impairment and illustrates the need for a multivariate model such as the one in this research.

Sioux Falls Terminal, Texas Panhandle Direct, Washington-Oregon Direct, and Wyoming, Southwest South Dakota, Western Nebraska Direct.

The price data from all the above markets were used to estimate a common long-run trend. As the price discovery system is composed of multiple markets, the determination of common price dynamics requires including prices from as many markets as possible.

To determine the factors which are related to deviations from the estimated long-run trend (from the first stage) the following are used: weekly volumes from a reduced set of the public and direct markets listed above (USDA, *Livestock, Meat, Wool Market News*), Cattle-Fax (CF) weekly estimates of state forward contract deliveries (Cattle-Fax Update), percent of "large" (greater than 32,000 head) feedlot marketings (Cattle Industry Reference Guide), state weekly slaughter (USDA, *Livestock, Meat, Wool Market News*), four-firm regional concentration ratios (calculated from Cattle-Fax Resources statistics), national concentration ratios (USDA, *Packers and Stockyards Statistical Report*), and distance, in miles, between markets.[3]

Because the explanatory data required for the regression model are not available for all nineteen markets, a reduced set is used in the second part of the research. The markets in that part of the analysis are Colorado Auctions, Western Kansas Direct, Eastern Nebraska Direct, and Texas Panhandle Direct. Further, some of the data were only available for the years after 1988 and thus only two and one-half years of data are used in the second stage of the analysis.[4]

The State-Space Model

The state space technique due to Aoki (1987a) is used to model the multivariate time series (regional cattle prices) and to estimate a common trend, if it is present.[5] This technique is well suited to such applications vis-à-vis other time-series techniques, because it can identify the number and form of the dynamic factors representing the multivariate autoregressive moving average (ARMA) processes in a manner similar, but not identical, to the Kalman filter. Below we will write the mathematical representation of the Aoki (1987a) state-space model in a form recognizable by those familiar with the Kalman filter. Recall, that Kalman's filtering technique is simply a means of representing a linear dynamic system, which has greater than first-order lags, as a first-order system in the original series plus additional state variables. Most econometric applications of state-space models (including the Kalman filter) focus on estimation of unobservable time-varying parameters (Dorfman and Foster or Chavas, for example). In contrast, the state variables in our application are estimates of unobservable dynamic factors or higher-order dynamics in the time series themselves rather than the parameters of the model. For example, we can envision a set of agricultural time series that contain trends around which there are seasonal and even cyclical phenomenon. In fact, livestock prices are an excellent example of a case where there is an upward trend over time (possibly due to

[3] As noted by an anonymous reviewer, Cattle-Fax data are not a complete data set of all captive supplies. Further, there is no way to check the consistency of the data collected. The information is provided voluntarily by feedlots. Clearly, this limitation may result in a data set that is not representative of all captive supplies.

[4] The limiting factor which resulted in the use of only four of the nineteen market areas is the availability (or lack thereof) of forward contract data. Cattle-Fax only provides contract data for delivery to the four states which are covered by these markets. In addition, the first year the data were consistently collected was 1989.

[5] See also Aoki and Havenner (1989, 1991).

inflation), a well-documented cycle, and correlations on a seasonal lag shorter than the so-called hog or cattle cycle. To model this vast spectrum of dynamic effects in a traditional vector autoregressive moving average (VARMA) context, we would require a model with a high order of lags. Multicollinearity would surely become a problem for any sizeable system, and the increased sampling error would diminish the forecasting potential of the model as well as the precision of parameter estimates. The state-space approach condenses these complex dynamic effects into the first-order states which must then be linear combinations of autoregressive and moving average terms of the more complex model. In the case of cointegrated time series, some of these dynamic factors (states) represent common stochastic trends (unit roots). The choice of specification based on singular value decomposition is another practical advantage of Aoki's model, because it provides an objective data-based method of determining the dynamic structure.

Below we develop the model in general terms and attempt to provide some additional intuition to support its use when the time series may be cointegrated or at a minimum share strong long-run trends. Consider a multivariate time series containing m elements. These observed series (in this case, the prices of fed cattle at various locations) are first converted to deviations from their means, scaled by their standard deviations, and then stacked to produce an $(m\times1)$ vector, y_t. The scaled deviations are used so that the model specification based on singular values of the Hankel matrix will be in the context of autocorrelations which can be consistently estimated by least squares even if the data are nonstationary due to the superconsistency of least squares when there is a stochastic trend in the data (Hamilton).

The vector, y_t, is linearly related to the $(n\times1)$ vector of state variables, z_t. This relationship, depicted mathematically below, is commonly called the observation equation because it contains y_t, the observable part of the model:

$$(1) \qquad y_t = Cz_{t|t-1} + e_t.$$

In the above equation, $z_{t|t-1}$ is a vector of conditional means of unobservable states in time, t, and e_t is an $(m\times1)$ vector of serially uncorrelated errors. Further, C is an $(m\times n)$ matrix of parameters to be estimated. Although the elements of the state vector are unobservable, they are specified to follow a first-order stochastic dynamic process:[6]

$$(2) \qquad z_{t+1|t} = Az_{t|t-1} + Be_t,$$

where A and B are $(n\times n)$ and $(n\times m)$ matrices of parameters to be estimated. Equation (2) is commonly referred to as the state equation. Taken together, equations (1) and (2) compose the standard state-space representation of the time series in y_t.[7]

Aoki's estimation method for this specification does not impose stationarity on the system dynamics in (2).[8] Nonstationarity may take either of two forms. The first, and most obvious, way is that it may manifest itself as unit roots in the matrix A. The second,

[6] Note, although z_t is first order, it does not imply that y_t is a first-order process. In fact, Aoki (1987a) shows that (1) and (2) are a minimal first-order augmentation of the true complex model for y_t.

[7] Any state-space representation has an equivalent ARMA representation and vice versa (Aoki and Havenner 1991). However, it is extremely unlikely that the modeler estimating in ARMA form will arrive at the same empirical model as the state-space modeler. Essentially, the state-space modeler will incorporate restrictions implied by the data that are not apparent to the ARMA modeler.

[8] At times, throughout the remainder of the article, we shall use the terms nonstationary and trend interchangeably. This is not an ad hoc notation that we have adopted. It represents the standard time-series pattern recognition step for modeling nonstationary series. That is, trending in plots of the underlying data represents nonstationary components. Prior to just a few years ago this would have invited first differencing as the appropriate modeling exercise.

and less understood, way is that the nonstationary components may be captured in the state variables themselves. Our experience is that this second form is the most common in practice. However, these states will also invariably be associated with large roots close to, but not equal to, one. Aoki (1987b) has shown rigorously how a bivariate system with component unit roots can be represented as a state-space form without unit roots in A. His analyses generalize to higher-order models. When nonstationary components of either ilk are present in fewer numbers than the number of series in the model, we contend that the state-space form is a cointegrating regression in the spirit of Engle and Granger.

The unfamiliarity of most economists with state-space models suggests that some explanation of the last claim is appropriate. The results of Engle and Granger suggest that the wisdom of first differencing all data prior to analysis may actually be an inefficient estimation method if indeed there are common nonstationarities (trends). That is, treating all series as though they followed individual trends by first differencing throws away any information about the commonality of those trends. In fact, first differencing assumes that the series revert in the long run to separate nonstationarities and thus could infinitely diverge. On the other hand, cointegrated models allow for common trends and the series modeled as such would be expected to revert to a common nonstationarity. What does this mean in practice? Engle and Granger propose a two-step method for estimating cointegrated systems. The first step is to estimate what they term the cointegrating regression which is simply a regression of one series (in levels not differences) on the level of the other series. That is, if the elements of the vector x_t are cointegrated then the cointegrating regression is

$$ax_t = u_t, \tag{3}$$

where u_t is a stationary but not necessarily serially uncorrelated linear combination of the nonstationary series in x_t, and a is called a cointegrating matrix. If we truncate the dynamics in the state-space model to only include those associated with nonstationary components (trends), then (1) looks much the same as (3) with a normalization placed on y_t. We can rewrite this truncated state and observation pair containing only the nonstationary components as follows [Aoki and Havenner (1991) refer to this submodel as the "trend model"]:

$$y_t = C_\tau \tau_{t|t-1} + y_t^*, \tag{4}$$

and

$$\tau_{t+1|t} = A\tau_{t|t-1} + By_t^*, \tag{5}$$

where $\tau_{t|t-1}$ is a $(k \times 1)$ matrix that represents those states (k) associated with nonstationary components and y_t^* is a detrended transform of y_t. Thus, if the components of y_t in (1) are cointegrated (have common trends) then (4) is a cointegrating regression, and C_τ is a cointegrating matrix.

The use of the data to determine the model order and specification through the singular values of the Hankel matrix of autocorrelations guarantees that cointegration will be found if it is embedded in the data. It is important to note that cointegration is not essential to the second-stage model that we propose in the next section of this article. We discuss cointegration only to demonstrate that if the series are cointegrated then the state-space model does not differ substantially from the Engle and Granger approach.

Regardless of whether the time series of interest in this study are stationary or not, we believe that there are strong long-run common dynamic components. These dominant components would dominate the other factors that we examine in the next section should they be modeled jointly. This is why differencing of data is commonly practiced. Consequently, the state-space model in (4) and (5) will be used obtain an estimate of the dominant long-run components (trended or otherwise). A second-stage analysis will be conducted using the residuals of this trend model ($y_t^* = y_t - C_\tau \tau_{t|t-1}$) as dependent variables. This model aims at estimating the role of various market factors in explaining these individual market price deviations from the long-run path.

Dickey-Fuller (DF) tests are performed to evaluate the stationarity of the individual series and the individual trend model residuals. If we cannot reject the unit root hypothesis for each of the individual series and we subsequently reject it for each of the trend model residuals, then we conclude that the series are indeed cointegrated. That is, the state-space trend model is a cointegrating regression that annihilates the nonstationary components in y_t without differencing the individual series.

The mechanics for estimating the state-space model are described in Aoki and Havenner (1991). In this research, the model was estimated using procedures programmed in GAUSS.

Regression Model Assessing the Importance of Market Factors

Regional fed cattle prices do not follow the common trend(s) precisely. That is, the price series of the regional markets experience short-run movements around, and potentially permanent shifts from, the common trend. These deviations are not generally random. Foster, Havenner, and Walburger demonstrated that the short-run deviations are, in fact, likely to be serially correlated. The hypothesis of this article is that these deviations are likely to be related to measurable market factors in the beef cattle industry.

The purpose at hand is to present a model which develops greater understanding about the relationships of the regional prices (and markets) and factors which affect their relatedness. The independent variable is the deviation of the price in market i from the estimated common trend, that is, y_t^* as defined above. Thus, the deviation is a measure of the unrelatedness of market i to the estimated trend(s). All of the observations are used to estimate the common trend(s). Thus, the deviations incorporated in this procedure are residual deviations and not forecast deviations.

The regression model chosen for trend deviations takes the following form:

$$(6)\quad y_{it}^* = \beta_0 + \beta_1 Dis_i + \beta_2 Vol_{it} + \beta_3 Vol_{it-1} + \beta_4 FC_{it} + \beta_5 FC_{it-1} + \beta_6 S_{it} + \beta_7 S_{it-1} + \beta_8 LgFdlt_{it} + \varepsilon_{it},$$

where y^*_{it} is the deviation of price in market i from the estimated common trend at time t (obtained from the state-space trend model); Dis_i is the distance, in miles, from market i to the next nearest market; Vol_{it} and Vol_{it-1} are the total volume of sales at market location i at time t and $t-1$ respectively; FC_{it} and FC_{it-1} are estimates of forward contract *deliveries* at time t and $t-1$ in the state where market i is located; S_{it} and S_{it-1} are slaughter volume in market i at time t and $t-1$; $LgFdlt_{it}$ is the percentage of marketings by feedlots with yearly capacity exceeding 32,000 head in market i in time t, ϵ_{it} is the error term; and the β_is are parameters to be estimated.

Slaughter volume and the percentage of marketings by large feedlots are regional measures where the region is considered to be the state in which the market is located and all geographically contiguous states. This formulation will allow regional market areas to overlap. This is somewhat appealing, since it conforms to what is observed. However, it also deviates from the more accepted, yet overly simplistic, notion that market boundaries can be established between markets such that those markets are geographically distinct (Quail et al.).

Because of the data limitations (discussed in the data section above), only four markets are included in this part of the analysis: Colorado Auctions, Western Kansas Direct, Eastern Nebraska Direct, and Texas Panhandle Direct. Weekly data covering 235 time periods are used in the second stage of the analysis.

The various market factors which are expected to explain regional price deviations from the long-run trend are discussed below. Goodwin and Schroeder (1991) suggest that linkages between markets weaken as distance increases. Thus, the distance factor in the regression measures the conditional mean portion of the deviation that is due to either transitory or permanent differences between markets due to transaction costs. The expected relationship with deviations is unclear. As distance from other markets increase, independence also increases. This increase in independence could result in either consistently lower or consistently higher prices depending on local supply and demand conditions.

Another factor which may influence the relatedness of a regional market to the trend is the volume of sales in the market. Tomek and Robinson suggest that low-volume markets have a greater potential for experiencing pricing anomalies. In addition, Goodwin and Schroeder (1991) suggest that high-volume markets may be able to operate somewhat independently. Thus, the relationship with deviations is unclear.

A factor which has become increasingly important in recent years is captive supplies. Forward contract deliveries remain an important portion of captive supplies. Forward contracts are cattle purchases made by beef-packers potentially months in advance which must arrive in a given month (*Cattle-Fax Update*). Generally, the contracts are related to the futures price or are formula priced to a cash market. We have no way of knowing when the contracts were made, that is, when the contracting occurs, but we have estimates of the number of contracts delivered in a given week and month. Since there is a lot of flexibility regarding the time of delivery, forward contracts could easily be used to arbitrage and/or speculate. As a result, it is expected that packers can use these to capture possible arbitrage profits. This would tend to increase the relatedness of markets and thus reduce deviations of any kind implying no relationship. However, they could also be used to achieve market power and thus create downward price spreads. This would occur if packers increased the volume of deliveries at times when the local market was high relative to the trend. As a result, the expected relationship would be negative. The outcome will, thus, imply something about market efficiency and packer behavior.

Weekly fed cattle slaughter would also be expected to affect market relatedness. Slaughter and sale volumes are different measures. Sale volumes are purchases made where delivery is required within five to seven days and transportation to slaughter facilities in other market areas is possible. Slaughter, on the other hand, refers to cattle which are killed in a specific state in the given week. The expected effect is positive since as slaughter increases, so does the demand for slaughter cattle in that region or market, and thus the price would be expected to rise relative to the trend.

Finally, the percentage of marketings by "large" feedlots is expected to affect relatedness. This follows from the countervailing market power theory. If feedlots of a given firm span multiple markets, then that firm can also capture potential arbitrage profits which are available, just as packers exercise market power over regional prices. Also, the feedlot owner may face the same packers in different markets and have some leverage on price setting such that the same price is received for fed cattle in all of the common market areas. Thus, the expected relationship is positive.

It is quite likely that the impacts of these variables on price dynamics around the trend may not be seen instantaneously. That is, there may be some time lags before the effects show up in the price dynamics. In order to capture these lagged effects, the lagged observations for these variables are included in the model.

Since the "market regions" are permitted to overlap, it is very unlikely that the error terms are independent across cross sections. In addition, the time-series nature of the data suggests the strong probability of autocorrelation. The POOL routine in Shazam was used in estimation. This routine assumes cross sectionally correlated and timewise autoregressive errors. (See, also, Kmenta).

Two factors which are commonly used in market power and spatial price discovery studies have been omitted from this model, namely, national and regional packer concentration ratios. This is an unfortunate omission which resulted due to the short time period involved in the second stage of the analysis. The small size of the sample data being used and the fact that concentration ratios are an annual measure resulted in very little variation in these variables, and as a result, it was necessary to drop them from the analysis to prevent collinearity with the intercept.

Results

The state-space trend model is formulated using the entire data set (965 weekly observations per regional price series) in order to obtain an estimate of the long-run trend(s). There was one very large estimated root in *A*, 0.9912. This sole root, along with its single associated state, characterizes the long-run trend.[9] Clearly, actual prices deviate from the trend suggested; these deviations are used as the dependent variable in the following regression analysis developed in equation (4).

Four models are presented in table 1. In all of the models, lagged forward contract deliveries, lagged weekly slaughter volume, and the distance to the next closest regional market have significant coefficients.[10] Each of these merit some discussion.

First, note that forward contracts are cattle purchases made by beef-packers potentially

[9] This result was verified using DF tests. For all series, nonstationarity could not be rejected. However, nonstationarity of the residuals of the state-space trend model was rejected at the 95% level in all cases. For the four markets involved in the remainder of the study, the DF test statistics were Colorado Auctions, −20.64; Western Kansas Direct, −20.77; Eastern Nebraska Direct, −23.31; and Texas Panhandle Direct, −17.91.

[10] Clearly there is a possibility, as with any regression analysis, that there are omitted variables which are correlated with the regressors. In order to address this concern, we conducted the second-stage analysis separately for two time periods of market factors data (suggested by an anonymous reviewer). The data were split and regressions performed on the two subsets for each of the four models discussed. Chow tests were performed and the estimated statistics ranged from 0.86 to 1.27, which are clearly below the critical values. Thus, we conclude that the coefficients do not change over the subsets.

Table 1. Coefficient Estimates from Regression of Price Deviations from the Trend

Independent Variables	Model 1	Model 2	Model 3	Model 4
Constant term	−0.627 (−1.46)[a]	−0.612 (−1.43)	−0.491 (−1.46)	−0.589** (−1.96)
Forward contract deliveries	−0.228E−05 (−0.55)	−0.303E−05 (−0.83)	−0.258E−05 (−0.72)	—
Forward contracts from previous week	−0.768E−05** (−1.96)	−0.827E−05** (−2.30)	−0.819E−05** (−2.27)	−0.802E−05** (−2.22)
Forward contracts delivered in the month	−0.688E−05 (−0.39)	—	—	—
Slaughter volume	0.136E−02 (0.56)	0.142E−02 (0.59)	—	—
Slaughter volume in the previous week	0.482E−02* (1.95)	0.472E−02* (1.92)	0.552E−02** (3.12)	0.584E−02** (3.42)
Sales volume	−0.982E−03 (−1.08)	−0.105E−02 (−1.18)	−0.111E−02 (−1.28)	−0.111E−02 (−1.30)
Sale volume of previous week	0.330E−03 (0.36)	0.289E−03 (0.31)	—	—
Proportion of cattle marketings by feedlots with >32,000 capacity	−0.181 (−0.46)	−0.217 (−0.57)	−0.284 (−0.77)	—
Distance to nearest regional market	−0.227E−02** (−2.51)	−0.226E−02** (−2.50)	−0.203E−02** (−2.66)	−0.211E−02** (−2.85)
Squared correlations of combined model, by time series:[b]				
Colorado	0.95	0.95	0.94	0.92
Kansas	0.93	0.93	0.93	0.93
Nebraska	0.92	0.92	0.92	0.91
Texas	0.91	0.91	0.90	0.90

Notes: Significance at the 95 and 90% level are denoted by two and one asterisks, respectively.
[a] *t*-Statistics are in parentheses.
[b] The combined model refers to the combination of the trend formulation from the state-space model and the regression of deviations on market factors.

months in advance which must arrive in a given month (*Cattle-Fax Update*). Generally, the contracts are related to the futures price or are formula priced to a cash market. Thus, given that packers have great flexibility on delivery, forward contracts could easily be used to arbitrage and/or speculate. We do not know when these contracts were signed, but we have estimates of when they were delivered. Thus, our measure is contract *deliveries.*

The sign on lagged forward contract deliveries is negative. This may be interpreted in a number of ways. One possible explanation is that beef-packers may be using forward contracts as a tool to influence prices and perhaps exercise market power. That is, packers may be using them to drive prices down or weaken positive shocks that have occurred. This would require that the packers request delivery of forward contracts to place downward pressure on local markets.

Alternatively, they may be using forward contracts to improve market efficiency when positive price shocks occur, but using them less when negative price swings occur (i.e., postpone delivery of the contracts until market prices increase, which implies using more open market purchases. Such behavior would be consistent with dynamic arbitraging). On the other hand, efficiency gains in processing due to improved timing of cattle arrival may exceed those which accrue due to dynamic arbitrage. The need for timely arrival may be under pressure at specific times related to price swings.

One last explanation for such behavior is that profits captured by exercising market power may be larger than those captured through dynamic arbitrage. That is, in the long-run profits from dynamic arbitrage will be bid away, but gains from market power may persist.

Regardless of the reasons, it appears that forward contracts (deliveries) are placing downward pressure on prices and resulting in prices potentially below the perfectly competitive level.

Although the coefficient on forward contract deliveries is small, care must be used in interpreting the meaning behind it. It would be inappropriate to suggest that, even using the largest estimated coefficient from the four models, Model 2, and average delivery per week of 5,915.1 head of cattle, the negative effect is only five cents per cwt or approximately 0.065% of fed cattle prices over the period (assuming the average price was $75.00 per cwt). This interpretation would imply that there is virtually no economic significance. The trend undoubtedly captures some of the relevance of forward contracts on price setting as well. More will be said on this below.

The coefficient on lagged slaughter is positive. This appears to suggest that demand effects, measured by slaughter volume, require one week to influence prices. The positive result conforms to the economics of demand. Note that the sales volume variable is insignificant in all models. It appears the sales volume information is captured well by the price movements in the trend and is not significant in explaining deviations.

The distance to the next nearest market has an interesting relationship to deviations from the trend. The negative sign implies that as distance to the next nearest market increases the prices tend to fall in relation to the trend. This suggests that more isolated markets have lower prices.

All other factors are insignificant in explaining price deviations. Cattle marketings by the largest feedlots did not have the expected sign but were not significant at any important levels.

One important implication must be noted about these results. The model is conditional on the trend. That is, no iterative procedure is used in order to maximize the power of the combined model (i.e., trend plus regression). Thus, the trend is taken as given when doing the second-stage analysis. That is, the results merely suggest that when deviations from trend occur, certain factors may explain some of these deviations. Some of the effects from these factors on overall prices are likely to have already been imbedded in the trend and thus may be more relevant in the price discovery process than the coefficients in this model suggest.

Conclusions

A state-space model was fit to eighteen and one-half years of weekly data on nineteen price series from regional U.S. live cattle markets. The discovery of a common trend where regional prices exhibited short-run deviations and permanent shifts suggested a method of determining if any market factors were related to the regional price deviations. The results of this pursuit suggested that slaughter volume, distance between a market and the next closest, and forward contract deliveries are significantly related to price deviations from the estimated common trend.

Perhaps the factor of most concern is forward contract deliveries. This is a conduct tool which could be used by beef-packers to capture dynamic arbitraging profits and to improve market efficiency. It appears that the use of this tool may place downward pressure on prices, resulting in prices potentially below the perfectly competitive level.

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