Spatial Market Integration in Regional Cattle Markets

Dustin L. Pendell,
Graduate Research Assistant
Department of Agricultural Economics
Kansas State University
Manhattan, Kansas 66506-4011
Phone: (785) 532-4438
Fax: (785) 532-6925
Email: dpendell@agecon.ksu.edu

Ted C. Schroeder,
Professor
Department of Agricultural Economics
Kansas State University
Manhattan, Kansas 66506-4011
Phone: (785) 532-4488
Fax: (785) 532-6925
Email: tcs@ksu.edu

Selected Paper for Presentation at the Western Agricultural Economics Association Annual Meeting, Honolulu, Hawaii, June 30-July 2, 2004

Abstract

Geographic markets are extremely important to agriculture because agricultural products are bulky and/or perishable and production and consumption areas are separated. This study investigates how mandatory price reporting has influenced the degree of spatial market integration between U.S. regional fed cattle markets. Results indicate the market prices across the regional cattle markets are cointegrated. In addition, the amount of time it took for one market to react to the other market's change in price varied across the three time periods used in this study. This suggests mandatory price reporting has not substantially increased market integration.

Key words: cattle markets, cointegration, mandatory price reporting, spatial prices.

Introduction

Geographic markets are extremely relevant to agriculture because agricultural products are bulky and/or perishable and production and consumption areas are separated; hence, transportation is costly (Sexton, King, and Carman). Market integration usually considers the time frame to which shocks are transmitted among spatially separate markets. Markets that are not integrated may express imprecise price information that may alter producer marketing decisions. In addition, with declining cattle volumes in some regions and increasing cattle volumes in other regions, regional cattle prices could diverge because of poor flow of information across regions. In the presence of these influences, price changes across the market regions may not fully reflect relevant economic conditions (Goodwin and Schroeder).

Congress passed the Livestock Market Reporting Act of 1999 with the intent of facilitating price discovery through increasing availability of price information to producers (Grunewald). Prior to mandatory price reporting (MPR), a voluntary reporting system was used by USDA Agricultural Marketing Service (AMS) to collect and report fed cattle prices. The voluntary system was criticized for not being representative of all trade and frequently not having a reliable price quote (Grunewald, Schroeder, and Ward). In April 2001, MPR went into effect and required slaughtering plants to report all price and transaction information on a daily basis. With complete price and transaction data available to the public, arbitrage opportunities should decrease, thus one would expect integration between spatial markets to increase.

The purpose of this study is to empirically test how mandatory price reporting has influenced the degree of spatial market integration between five U.S. regional fed cattle markets. More specifically, this research will compare market integration before and after implementation of the Livestock Mandatory Price Reporting Act in April 2001. After considerable controversy and problems surrounding MPR, comparing market integration Pre and Post MPR has important implications. These implications include price discovery, defining of geographic markets, and overall market performance since persistent deviations may imply arbitrage opportunities.

In this study, cointegration analysis provides a framework for investigating long-run price relationships among five U.S. regional fed cattle markets. If the long-run cattle prices diverge from each other, prices are not cointegrated over time, they are considered to be in separate geographic markets. However, if the fed cattle markets have cointegrated prices, then the markets are operating in stable long-run spatial price equilibrium.

The error correction model is a procedure used to determine how long it takes for the price to adjust to long-run spatial equilibrium. This model provides information regarding the amount of time it takes for a cattle market to change its price in response to a price change at other cattle markets. Cattle markets that react quickly to changes in prices at other cattle markets are more likely to be in the same geographic market than other cattle markets that respond slow.

Literature Review

A considerably body of research has investigated market integration issues both domestically and internationally (e.g., Padilla-Bernal, Thilmany, and Loureiro; Yin, Newman, and Siry; Goodwin and Piggott; Abdulai; Asche, Bremnes, and Wessels; González-Rivera and Helfand; Goodwin; Sexton, King, and Carman; Ravallion). In addition, several studies have explicitly examined cointegration and dynamics of spatial price behavior in fed cattle (e.g., Schroeder; Goodwin and Schroeder; Schroeder and Goodwin; Koontz, Garcia, and Hudson; Bailey and Brorsen).

Bailey and Brorsen examined weekly fat cattle prices using a multivariate autoregressive framework in the regions of the Texas Panhandle, Omaha, Nebraska, Colorado-Kansas, and Utah-Eastern Nevada-Southern Idaho from January 1978 through June 1983. Cattle prices in the Texas Panhandle market led cattle prices in the other three regions, but there was feedback from the Omaha market.

Koontz, Garcia, and Hudson used Granger causality to identify dominant-satellite relationships. Four direct and four terminal markets were examined using weekly fed cattle prices over the period January 1973 through December 1984. Direct markets were dominant with the Nebraska direct market being the most influential.

Schroeder and Goodwin examined 11 direct and terminal trade cattle markets from 1976 though 1987. A multivariate vector autoregressive (VAR) model was applied using weekly average slaughter steer price data. Cattle markets with larger volumes fully reacted to price changes at the other major cattle markets usually within one or two weeks. However, cattle markets with smaller volumes took two to three weeks to fully respond to price changes in larger volume cattle markets.

Goodwin and Schroeder explored cointegration and spatial price linkages for 11 U.S. regional slaughter cattle markets. They also examined how cointegration affected certain market characteristics. Weekly price series data for slaughter steers over the period of January 1980 to September 1987 was used in this study. Cointegration over time increased, but paralleled with increasing concentration in cattle slaughtering. Also, market pricing was influenced by distances between the cattle markets.

Schroeder investigated daily dressed fed cattle prices from March 23, 1992 through April 3, 1993 at 28 beef packing plants to determine spatial price relationships. In this study of long-run price relationships and speed of price adjustment to long-run spatial equilibrium across beef packing plants, Nebraska plants reacted the fastest to price changes. Implying Nebraska plants were price leaders and a significant source of price information. Distances between cattle markets, size and ownership of packing plants, and procurement methods of cattle all affected cointegration.

This research adds to the work of these earlier studies in an important manner. To date, no previous published research has incorporated MPR data collected by the USDA into a market integration framework. MPR data will be integrated into this research to assess the impact on spatial market integration in livestock markets. The results from this study can be used to draw implications for pricing efficiency within these regional cattle markets and to determine whether MPR has changed spatial markets.

Methodology

The procedure used to examine how two spatially distant fed cattle markets are linked together via prices (i.e., regional market prices should not diverge from one another in the long-run) utilizes a cointegration approach. Although, cointegration will test to see if spatial prices are liked together in the long-run, it is not possible to determine if the spatial prices are integrated in the short-run. The error correction model is a procedure that is used to test for both short-run and long-run integration of spatially separate markets.

In spatially integrated markets, arbitrageurs can move cattle from geographic regions in which sales prices are low to regions in which prices are high, as long as transport costs are not excessive. This implies that within a group of spatially integrated regional cattle markets, price differentials at any point in time for cattle sold in different geographic regions can increase with distance separating the regions even if the markets are cointegrated.

The Engle-Granger Methodology

To test for cointegration, a procedure suggested by Engle and Granger, also used and described in numerous studies and textbooks (e.g., Greene; Weliwita; Ghosh; Schroeder; Enders), is used. The first step of this procedure is to test each individual price series to determine if the series are nonstationarity. The Augmented Dickey-Fuller (ADF) unit root test can be used to test if the series contains a unit root. If the null hypothesis, the series contains a unit root, is not rejected, then the series is nonstationary.

If the price series are nonstationary in levels and their first differences are stationary, then the next step is to estimate the long-run equilibrium relationship using ordinary least squares (OLS) in the form:

$$Y_t = a_0 + a_1 Z_t + e_t, \quad (1)$$

where Y_t and Z_t are the individual price series, a_0 and a_1 are the intercept and slope coefficients, respectively, and e_t is the error term. Parameter estimates of the regression are used to calculate estimates of the residual errors given in the following equation:

$$\hat{e}_t = Y_t - \hat{a}_0 - \hat{a}_1 Z_t, \quad (2)$$

where $\hat{e}_t$ is the estimated residual error of the long-run relationship, $\hat{a}_0$ and $\hat{a}_1$ are the cointegrating parameters. Next, to determine if the price series are cointegrated, one needs to test for stationarity of the residual series. If the $\hat{e}_t$ in equation (2) exhibits serial correlation, an ADF test can be used given by:

$$\Delta\hat{e}_t = b_0\hat{e}_{t-1} + \sum_{i=1}^{n} b_{i+1}\Delta\hat{e}_{t-i} + e_t \, , \tag{3}$$

where Δ denotes the first-order time difference in the estimated residual term (i.e., $\Delta\hat{e}_t = \hat{e}_t - \hat{e}_{t-1}$) and n_i, i=1, 2,…,4 are the lag lengths, and $\hat{e}_{t-1}$ is the lagged error correction term. If there is a unit root, then the two series are considered to be nonstationarity. If b_0 is statistically different from zero the null hypothesis of no cointegration is rejected.

The error correction model is used to test for both short-run and long-run integration of spatially separate markets and provides information regarding how fast markets change prices in response to price changes at other markets. If the price series are cointegrated, the residual errors from equation (2) can be used to estimate the error-correction model as follows:

$$\Delta Y_t = d_1 + d_y\hat{e}_{t-1} + \sum_{i=1}^{n} d_{11}(i)\Delta Y_{t-i} + \sum_{i=1}^{n} d_{12}(i)\Delta Z_{t-i} + e_{yt} \, , \tag{4}$$

$$\Delta Z_t = d_2 + d_z\hat{e}_{t-1} + \sum_{i=1}^{n} d_{21}(i)\Delta Y_{t-i} + \sum_{i=1}^{n} d_{22}(i)\Delta Z_{t-i} + e_{zt} \, , \tag{5}$$

where e_{yt} and e_{zt} are assumed to be white noise. Equations (4) and (5) are VAR in first differencing, except for the lagged error correction term, $\hat{e}_{t-1}$. The parameters of interest are d_y and d_z which are the speed-of-adjustment coefficients. If these parameters are equal to zero, this indicates there is no adjustment to the deviation from the long-run equilibrium while an absolute value of one suggests rapid adjustment.

Data

The composite weighted average weekly price series for both dressed and live steers and heifers were assembled for five U.S. regional markets over the period covering January 1995 to June 2004. A composite combined dressed and live steer and heifer weighted average price was constructed for each regional market to represent the fed cattle price at that location. In order to compare how spatial market integration has changed over time as a result of the implementation of MPR, the individual price series were divided into approximately three equal time periods (Jan. 1995 to Dec. 1997 (Pre1-MPR), Jan. 1998 to March 2001 (Pre2-MPR), and April 2001 to June 2004 (Post-MPR)). The data were collected from the USDA's AMS. Price data were collected for the cattle markets of Nebraska Direct (NE), Colorado Direct (CO), Western Kansas Direct (KS), Texas-Oklahoma Panhandle Direct (TX-OK), and Iowa-Southern Minnesota Direct (IA-MN). These five markets were selected because they are the only markets for which fed cattle price data have been collected and reported since inception of mandatory price reporting. Summary statistics of the weekly price series are presented in table 1.

The five U.S. regional cattle markets had a small number of price series observations that were missing. The total number missing prices was 20, which is approximately 0.8% of the total data points across time and location. The missing prices were proxied by the predicted values from a regression of each series on the 5-area weighted weekly-weighted average price during the same time period.

Results

Stationarity and Cointegration Results

The first step was to test nonstationarity of the individual price series. The ADF unit root test was utilized to test the null hypothesis of a unit root in each of the five price series for all three time horizons, Pre1-MPR, Pre2-MPR, and Post-MPR. The results, reported in top portion of table 2, indicate the price series are all nonstationary in levels at the 95% level with one exception being Colorado during the first time period. However, the Colorado (CO) series is nonstationary in levels at the 99% level. Therefore, we treated this series as nonstationary. After first differencing the prices, all five data series were stationary or integrated to order one, I (1) (bottom portion of table 2). As a result, cointegration tests were applied to the price series in levels.

An ADF unit root test was applied to test for cointegration. This involves testing the residuals series (recovered from OLS regression) for stationarity. As seen in table 3, the ADF tests indicate all of the cointegration tests support cointegration at the 5% level across the five regional cattle markets for all three time periods. These results suggest that on a weekly basis there was a long-run spatial equilibrium price relationship among all five markets studied, and prices did not significantly diverge from each other.

Error Correction Model

After determining the price data were nonstationary in levels and the market prices were cointegrated, the error correction model was applied. Speed-of-adjustment coefficients are the parameters of interest in that they have important implications for the dynamics of the system. They indicate how long it takes for the market price in market A to adjust to the long-run spatial equilibrium when the price changes at market B. If these coefficients are equal to zero, this indicates there is no adjustment to deviations from long-run equilibrium while an absolute value of one suggests rapid adjustment. The overall averages of absolute values of speed-of-adjustment estimates were 0.20, 0.32, and 0.29 for Pre1-MPR, Pre2-MPR, and Post-MPR, respectively. These values indicate that one-fifth to one-third of all deviations away from the equilibrium were on average corrected in one week.

Table 4 illustrates the averages of absolute values of the speed-of-adjustment parameter estimates by markets. The Kansas and Texas-Oklahoma markets reacted the fastest to price changes in each of the three time periods studied with the average absolute value of speed-of-adjustment estimates at 0.40 (Pre1-MPR), 0.48 (Pre2-MPR), and 0.58 (Post-MPR). This suggests that 40-58% of the responses to price changes between the two markets were reflected within one week. All of the average absolute value of speed-of-adjustment parameter estimates were smaller for Pre1-MPR than Pre2-MPR while one-half of the parameter estimates were smaller for Pre2-MPR than Post-MPR. All of the parameter estimates were larger for Post-MPR compared to the early time period (Pre1-MPR) while only one-half of the parameter estimates were larger compared to Pre2-MPR. Based upon these results, it does not appear that introduction of mandatory pricing has substantially increased market integration or speed of adjustment of markets back to spatial equilibrium. Regional fed cattle markets were cointegrated before MPR and remained so after its introduction. In addition, these markets responded similarly after introduction of MPR by returning to equilibrium at similar rates over the pre and post MPR time periods. This does not necessarily suggest MPR has not been effective in facilitating price discovery through increasing the availability of price data information to producers, but simply that it has not appreciably affected regional fed cattle price relationships.

Conclusions

The importance of market integration has been documented by numerous studies. This study makes an important contribution to the market integration literature in the sense; this is the first study to explicitly incorporate MPR data. Spatial market integration in cattle markets has important implications in price discovery, geographic efficiencies, and overall market performance. Markets that are not integrated may express imprecise price information that may alter producer marketing decisions.

Based on the results from this study, all of the weekly price series were found to be cointegrated. All 20 bivariate cointegration tests indicated the cattle prices tend to move together and did not diverge from one another, suggesting the two cattle markets were competing for cattle. Error correction results indicate one-fifth to one-third of all deviations away from the equilibrium were on average corrected within one week. However, the amount of time it took for one market to react to the other market's change in price varied across the three time periods. While all of the parameter estimates were larger for Post-MPR compared to the earliest time period (Pre1-MPR), only one-half of the parameter estimates were larger compared to Pre2-MPR. These findings suggest, it does not appear that introduction of mandatory pricing has substantially increased market integration or speed of adjustment of markets back to spatial equilibrium.

References

Abdulai, A. "Using threshold cointegration to estimate asymmetric price transmission in the Swiss pork market." *Appl. Econ*. 34(2002):679-87.

Asche, F., H. Bremnes, and C.R. Wessels. "Product Aggregration, Market Integration, and Relationships Between Prices: An Application to World Salmon Markets." *Amer. J. Agr. Econ*. 81(1999):568-81.

Bailey, D., and B.W. Brorsen. "Dynamics of Regional Fed Cattle Prices." *West. J. Agr. Econ*. 10(1985):126-33.

Enders, W.E. *Applied Econometric Time Series*. New York: John Wiley and Sons, Inc., 1995.

Engle, R.F., and C.W.J. Granger. "Co-Integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55(1987):251-76.

González-Rivera, G., and S.M. Helfand. "The Extent, Pattern, and Degree of Market Integration: A Multivariate Approach for the Brazilian Rice Market." *Amer. J. Agr. Econ*. 83(2001):576-92.

Goodwin, B.K. "Multivariate Cointegration Tests and the Law of One Price in International Wheat Markets." *Rev. Agr. Econ*. 14(1993):117-24.

Goodwin, B.K., and N.E. Piggott. "Spatial Market Integration in the Presence of Threshold Effects." *Amer. J. Agr. Econ*. 83(2001):302-17.

Goodwin, B.K., and T.C. Schroeder. "Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets." *Amer. J. Agr. Econ*. 73(1991):452-64.

Ghosh, S. "The Casual Relationship between International Trade and Employment in the Manufacturing Sector of the United States." *International Trade J*. 14(2002):399-420.

Greene, W. *Econometric Analysis*. New Jersey: Person Education, Inc., 2003.

Grunewald, S. "Livestock Mandatory Price Reporting: Cattle Feeder Perception." MS thesis, Kansas State University, 2002.

Grunewald, S., T.C. Schroeder, and C.E. Ward. "Cattle Feeder Perceptions of Mandatory Price Reporting." *Review of Agricultural Economics* forthcoming 2004.

Koontz, S.R., P. Garcia, and M.A. Hudson. "Dominant-Satellite Relationships between Live Cattle Cash and Futures Markets." *J. Futures Mkts*. 10(1990):123-36.

Livestock Marketing Information Center (LMIC). Englewood, Colorado. Available at: http://www.lmic.info/. Accessed on June 22, 2004.

Padilla-Bernal, L., D.D. Thilmany, and M.L. Loureiro. "Market Integration and Efficiency of U.S. Tomato Markets." *J. Ag. Res. Econ.* 28(2003):435-450.

Schroeder, T.C. "Fed Cattle Spatial Transactions Price Relationships." *J. Agr. Appl. Econ*. 29(1997):347-62.

Schroeder, T.C., and B.K. Goodwin. "Regional Fed Cattle Price Dynamics." *West. J. Agr. Econ*. 15(1990):111-22.

Sexton, R.J., C.L. King, and H.F. Carman. "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." *Amer. J. Agr. Econ*. 73(1991):568-80.

Ravallion, M. "Testing Market Integration." *Amer. J. Agr. Econ.* 68(1986):102-9.

Weliwita, A. "Cointegration Tests and the Long-Run Purchasing Power Parity: Examination of Six Currencies in Asia." *J. Econ. Develop*. 23(1998):103-16.

Table 1. Summary Statistics of Average Weekly Regional Fed Cattle Prices, January 1995 through June 2004

Variable	Number of Observations	Mean ($/cwt)	Std. Dev. ($/cwt)	Min. ($/cwt)	Max. ($/cwt)
Pre1-MPR (01/95-12/97)					
Colorado	157	65.07	3.63	55.20	73.53
Iowa-Minnesota	157	65.82	3.56	55.49	74.45
Kansas	157	65.89	3.62	55.92	74.87
Nebraska	157	66.09	3.62	55.66	74.80
Texas-Oklahoma	157	65.88	3.64	55.50	74.98
Pre2-MPR (01/98-03/01)					
Colorado	169	65.94	5.68	55.94	81.09
Iowa-Minnesota	169	66.37	5.40	57.06	82.16
Kansas	169	66.55	5.41	56.82	81.62
Nebraska	169	66.42	5.34	57.23	81.70
Texas-Oklahoma	169	66.79	5.49	56.13	81.79
Post-MPR (04/01-06/04)					
Colorado	171	76.40	9.94	61.51	111.67
Iowa-Minnesota	171	76.08	10.22	61.79	112.78
Kansas	171	75.39	9.88	60.66	107.21
Nebraska	171	75.72	10.16	61.51	112.80
Texas-Oklahoma	171	75.61	9.81	60.79	107.31

Table 2. Augmented Dickey-Fuller Unit Root Tests for Weekly Regional Fed Cattle Prices

Price Series	Test Statistic[1]	Critical Value
Price Levels		
Pre 1-MPR (01/95-12/97)		
Colorado	-2.91[2]	-2.89
Iowa-Minnesota	-2.50	-2.89
Kansas	-2.73	-2.89
Nebraska	-2.64	-2.89
Texas-Oklahoma	-2.77	-2.89
Pre 2-MPR (01/98-03/01)		
Colorado	-0.61	-2.89
Iowa-Minnesota	-0.33	-2.89
Kansas	-0.64	-2.89
Nebraska	-0.42	-2.89
Texas-Oklahoma	-0.56	-2.89
Post-MPR (04/01-06/04)		
Colorado	-1.98	-2.89
Iowa-Minnesota	-1.59	-2.89
Kansas	-1.62	-2.89
Nebraska	-1.74	-2.89
Texas-Oklahoma	-1.59	-2.89
First Differences		
Pre 1-MPR (01/95-12/97)		
Colorado	-12.96	-2.89
Iowa-Minnesota	-11.68	-2.89
Kansas	-11.60	-2.89
Nebraska	-12.13	-2.89
Texas-Oklahoma	-11.47	-2.89
Pre 2-MPR (01/98-03/01)		
Colorado	-12.54	-2.89
Iowa-Minnesota	-10.99	-2.89
Kansas	-11.29	-2.89
Nebraska	-11.64	-2.89
Texas-Oklahoma	-10.92	-2.89
Post-MPR (04/01-06/04)		
Colorado	-13.72	-2.89
Iowa-Minnesota	-11.41	-2.89
Kansas	-11.41	-2.89
Nebraska	-12.15	-2.89
Texas-Oklahoma	-12.40	-2.89

[1]If the test statistic is smaller than the critical value at 95% level, the unit root hypothesis can be rejected.
[2]Colorado is the only market that is not stationary in levels at the 95% level, but it is stationary in levels at the 99% level.

Table3. Augmented Dickey-Fuller Cointegration Tests of Weekly Regional Fed Cattle Prices

Price Series	Pre1-MPR Test Statistic[1]	Pre2-MPR Test Statistic	Post-MPR Test Statistic	Critical Value[2]
Nebraska (Regressand)				
Colorado	-8.69	-10.48	-12.49	-1.94
Kansas	-11.99	-10.69	-11.44	-1.94
Texas-Oklahoma	-12.61	-9.96	-11.15	-1.94
Iowa-Minnesota	-7.92	-8.44	-8.84	-1.94
Colorado (Regressand)				
Nebraska	-8.68	-10.50	-12.41	-1.94
Kansas	-8.56	-12.33	-14.54	-1.94
Texas-Oklahoma	-9.78	-11.64	-11.15	-1.94
Iowa-Minnesota	-13.23	-11.89	-11.00	-1.94
Kansas (Regressand)				
Nebraska	-11.86	-10.80	-11.31	-1.94
Colorado	-8.58	-12.36	-14.49	-1.94
Texas-Oklahoma	-10.19	-10.52	-9.66	-1.94
Iowa-Minnesota	-10.83	-14.75	-13.96	-1.94
Texas-Oklahoma (Regressand)				
Nebraska	-12.53	-10.08	-11.13	-1.94
Colorado	-9.72	-11.69	-11.18	-1.94
Kansas	-14.47	-9.29	-9.64	-1.94
Iowa-Minnesota	-11.32	-14.10	-9.89	-1.94
Iowa-Minnesota (Regressand)				
Nebraska	-7.91	-8.48	-8.72	-1.94
Colorado	-13.21	-11.92	-10.86	-1.94
Kansas	-10.72	-14.70	-14.06	-1.94
Texas-Oklahoma	-11.15	-14.04	-9.83	-1.94

[1]If the test statistic is smaller than the critical value, then there is evidence of conintegration.
[2]Critical values are at the 95% level.

Table 4. Average Absolute Error Correction Model Speed-of-Adjustment Parameter Estimates, by Markets

Markets	Pre1-MPR 01/95-12/97	Pre2-MPR 01/98-03/01	Post-MPR 04/01-06/04
Colorado and Iowa-Minnesota	0.18	0.30	0.30
Colorado and Kansas	0.25	0.30	0.32
Colorado and Texas-Oklahoma	0.19	0.21	0.30
Colorado and Nebraska	0.26	0.32	0.27
Kansas and Nebraska	0.10	0.35	0.21
Kansas and Iowa-Minnesota	0.09	0.30	0.16
Kansas and Texas-Oklahoma	0.40	0.48	0.58
Nebraska and Iowa-Minnesota	0.35	0.42	0.50
Nebraska and Texas-Oklahoma	0.12	0.23	0.10
Texas-Oklahoma and Iowa-Minnesota	0.10	0.26	0.14