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Short-Run and Long-Run Spatial Price Relationships of Selected U.S. Cattle Markets

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of Selected U.S. Cattle Markets

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August 1997

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Abstract

Utilizing weekly data from Cattle-Fax, the nature of spatial price relationships for six cattle classes was examined using several approaches, including the correlation approach, univariate, bivariate, and multivariate cointegration approaches, and bivariate and multivariate Granger-causality error correction approaches. Specifically, the study determined whether the twelve marketing regions for each of the six cattle classes, were integrated using both the necessary and sufficient conditions for market integration, determined whether deviations from the law of one price (LOP) were a short-run and/or long-run phenomena, and whether price adjustments were spontaneous or nonspontaneous regardless of whether markets were perfectly or imperfectly integrated in the long run.

Apart from the multivariate Granger-causality error correction approach, which was limited by inclusion of the same number of lags for all the elements in the system, all the other approaches indicated either imperfect market integration or perfect market integration (or equivalently LOP) for all the markets within classes, regardless of the cattle class and regions considered. Deviations from LOP were both short-run and long-run phenomena, but were more prevalent in the short run compared to the long run. Adjustments were necessarily spontaneous if LOP held in the short run. However, there were cases where adjustments were spontaneous even though LOP did not hold either in the short run and/or long run. Generally, adjustments were nonspontaneous for more than half of the cases.

Introduction

      Spatially separated markets are efficient if the law of one price (LOP) holds between two or markets. According to Muwanga and Snyder (1997a), two or more regions would be integrated if trade takes place between the regions, while the prices from these regions are cointegrated or correlated or cause each other. This implies that a price change in one region would partially or totally be transmitted to the price in the other region(s) either in the short run and/or long run. The law of one price holds if a price change in one region is perfectly transmitted (perfect market integration) to the other region(s). Imperfect market integration occurs if the price change is partially or imperfectly transmitted to the other region(s)—implying that two or more regions can be integrated even though LOP does not hold. Such a situation corresponds to regions that are integrated but with inefficient price transmission. Market segmentation occurs if price changes are not transmitted at all to the other region(s) either in the short run and/or long run.

      Several researchers have investigated the issue of market integration and spatial price efficiency using various approaches including cointegration, correlation, univariate unit roots, and causality approaches. The correlation approach was used by Protopadakis and Stoll (1983), Mundlak and Larson (1992), and Gardner and Brooks (1994). With this approach, market integration holds if the slope coefficient from a simple linear regression of one spatial price on another was equal to one. However, such a relationship could be spurious, since high correlations could be obtained when totally unrelated variables are regressed on each other. Also, McNew (1996) argued that not all integrated markets have a correlation coefficient of 1.

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The cointegration approach was used by Yoonbai (1990), Baffes (1991), Goodwin (1992), Bessler and Covey(1991), Cerchi and Havenner (1988), Goodwin and Schroeder (1991), and William and Bewley (1993). For this approach, a stable equilibrium is only assumed to exist if and only if the individual elements of a system are integrated of order d i.e., $I\ (d)$ where $d > 0$, while the residuals from such a system are integrated of order 0 or $I\ (0)$. Establishing market integration using this approach ensures that the relationships between different regions are not spurious, thus overcoming the limitation of the correlation approach. For multivariate systems, the advanced econometric procedures of Johansen (1988), and Stock and Watson (1988) may be used to analyze the cointegration and common trends of interdependent prices.

Engle and Yoo (1987) argued that simultaneity may be a problem if the markets shared the same information and if they belong to the same economy. As a result, they transformed the data by differencing the prices of the different regions to generate a new series, which was then tested for market integration using the univariate unit root approach. Market integration was assumed to exist if the transformed series was $I\ (0)$, otherwise the markets were segmented.

McCallum (1993) questioned the cointegration approach by arguing that a stable equilibrium relationship can exist without cointegration, implying that the residuals from a stable relationship can be integrated of any order other than zero. Also, Baulch (1995) argued that cointegration is only a necessary, but not a sufficient, condition for market integration, while the existence of a causal relationship forms the sufficient condition.

The causality approach was used by McNew (1996) , Ravallion (1986, 1987), Alexander and Wyeth (1994), Baulch (1995), and Engle and Granger (1978). According to Ravallion (1986) and Alexander and Wyeth (1994), market integration exists if a causality relationship in

the form of a Granger-causality error correction model exists. Unlike Ravallion (1986) who used a structural Granger-causality error correction model, Alexander and Wyeth (1994) used a reduced form general equilibrium Granger-causality error correction model. The reduced form general equilibrium model has advantages over the structural model because it can consistently be estimated using OLS, thus allowing for different optimal lags in the right hand variables, while the structural model has to be estimated using a simultaneous approach such as vector autoregression (VAR). Further, the reduced general equilibrium model can be used to determine the "cause-effect" relationships, while such relationships must be determined before hand for the structural model. However, the structural model can be used to distinguish between the short-run and long-run market integration, while the reduced form model does not distinguish between the two.

Since the above approaches emphasize different aspects of market integration, Muwanga and Snyder (1997a, 1997b, and 1997c) carried out several studies using cattle data for various market areas of the United States. Their main objective was to examine the various aspects of spatial price relationships using different approaches including the correlation, cointegration, univariate unit root, and the causality approaches. The purpose of this study is to compare and contrast the main findings and implications for spatial price relationships obtained using the various approaches, i.e., correlation, cointegration, univariate unit root, and causality approaches, to establish whether deviations from LOP are short-run or long-run phenomena, to determine whether price adjustments are spontaneous, and to determine the number of cointegration vectors and common trends for the six classes of cattle.

For purposes of this study, the definitions of market integration, market segmentation and the law of one price as defined by Muwanga and Snyder (1996a) are adopted. They state that markets are integrated if trade takes place at all between two or among more spatially separated markets, implying that prices in one market are related or correlated with the price(s) in the other market(s), i.e., a price change in one market is partially or totally (perfectly) transmitted to the price(s) in the other market(s) either in the short run and/or long run. The law of one price holds between the two spatially separated markets if any price changes in one market are perfectly transmitted to the other market in the short run and/or long run after adjusting for transaction costs and any other exogenous factors. Two or more spatially separated markets are segmented if price changes in one market are not transmitted at all to the price(s) in the other market(s) either in the short run or the long run. If partial transmission of price changes exists in the long run, then market integration holds but the LOP does not hold. If perfect transmission occurs between the markets, then both market integration and LOP hold.

Procedures

Several models will be used to examine the spatial price relationships. The models will include the simple Granger-causality (SGC), univariate unit-root tests (UURT), bivariate and multivariate cointegration relationships (CR), bivariate correlation models (BCM), and bivariate and multivariate Granger-causality error correction (GCECM) models. The procedures for each of the above approaches are discussed below.

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SGC Model

Given a price system, the SGC model is useful for determining the prices that are endogenous to the system and those that are exogenous to the system, especially if all the prices experience both the same macro- and micro- economic policies. According to Granger (1969), a scalar vector y fails to Granger-cause another scalar x if for all $s > 0$, the mean squared error (MSE) of a forecast of x_{t+s} based on $(x_t, x_{t-1}, \ldots)$ is less than or equal to the MSE of a forecast of x_{t+s} using both $(x_t, x_{t-1}, \ldots)$ and $(y_t, y_{t-1}, \ldots)$. For linear functions, y fails to Granger-cause x if

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$$MSE\ [E(\ x_{t+s}\ |\ x_t, x_{t-1}, \ldots\ )] \leq MSE\ [E(\ x_{t+s}\ |\ x_t, x_{t-1}, \ldots, y_t, y_{t-1}, \ldots)] \tag{1}$$

This would imply that x is exogenous in the time series sense with respect to y. The values of y are not informative about the future values of x. If x Granger-causes y, then the MSE of a forecast of y_{t+s} based on both $(x_t, x_{t-1}, \ldots)$ and $(y_t, y_{t-1}, \ldots)$ is less than the MSE of a forecast of y_{t+s} based on $(y_t, y_{t-1}, \ldots)$ only, i.e.,

$$MSE\ [E(\ x_{t+s}\ |\ x_t, x_{t-1}, \ldots, y_t, y_{t-1}, \ldots)] \tag{2}$$

$$MSE\ [(\ E\ (y_{t+s}|\ y_t, y_{t-1}, \ldots)]$$

In matrix notation, the bivariate system is written as

$$\begin{bmatrix} x_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \psi_{11}(L) & 0 \\ \psi_{21}(L) & \psi_{22}(L) \end{bmatrix} \begin{bmatrix} \epsilon_{11} \\ \epsilon_{21} \end{bmatrix} \tag{3}$$

where

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$$\psi_{ij}(L) = \psi_{ij}^{(0)} + \psi_{ij}^{(1)} L^1 + \psi_{ij}^{(2)} L^2 + \psi_{ij}^{(3)} L^{(3)} + \ldots + \epsilon_t \tag{4}$$

$$\psi_{11}^{(0)} = \psi_{22}^{(0)} = 1, \; \psi_{21}^{(0)} = 0$$

where η is the error term, b_j and d_j are defined as population projection coefficients, i.e., the values for which $E(\eta_t x_\tau) = 0$ for all t and τ. With this definition, y fails to Granger-cause x if and only if $d_j = 0$ for $j = 1, 2, \ldots$

To determine whether y_t Granger-causes x_t using the SGC model, equation (5) and (6) are estimated.

$$x_t = c_1 + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \ldots + \alpha_p x_{t-p} \tag{5}$$

$$x_t = c_1 + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \ldots + \alpha_p x_{t-p} + \beta_1 y_{t-1} + \beta_2 y_{t-1} + \ldots + \beta_p y_{t-p} \tag{6}$$

Equation (5) constitutes the univariate autoregressive model (the restricted model), while equation (6) constitutes the bivariate model (unrestricted model). The optimal lags in equations (5) and (6) for both x_t and y_t are determined using the Akaike Final Prediction Errors (FPE). The optimal lags for x_t in equation (6) are the same as those identified in equation (5).

To implement the SGC test, we calculate the unrestricted sum of squared residuals (RSS_1) from equation (6), and compare it with the restricted sum of squared residuals (RSS_0) from equation (5), where $RSS_1 = \Sigma_{t=1}^{T} v_t^2$, and $RSS_1 = \Sigma_{t=1}^{T} v_t^2$. Then we calculate the value of the test statistic S_1 as in equation (7).

$$S_1 = \frac{(RSS_0 - RSS_1)/P}{RSS_1/(T - np - 1)} \tag{7}$$

where p is the number of restrictions imposed by the hypothesis in the restricted model, n is equivalent to the number of endogenous variables in the system, while T is the total number of observations available. For a bivariate process, n = 2. If S_l is greater than the 5% critical value for an F(p, T- np-1) distribution, then the null hypothesis is rejected. We conclude that y does not Granger-cause x. It is important to note that Granger-causality tests can be sensitive to the choice of lag length (p), and/or the method used for detrending the series.

For a bivariate system, the SGC relationships can be one of three possibilities, i.e., an endogenous/endogenous, endogenous/exogenous or exogenous/exogenous relationship. An endogenous/endogenous relationship would imply that both the price series were endogenous to the system, and had predictive power for each other. An exogenous/exogenous system would imply that both the price series were exogenous to the system, and had no predictive power for each other. An endogenous/exogenous system would imply that one price series was endogenous, while the other was exogenous to the bivariate price system—implying that the exogenous series had predictive power for the endogenous system but the endogenous series had no predictive power for the exogenous system. However, it is important to note that the existence of "predictive power" would not imply a "cause-effect" relationship, and neither would it imply market integration.

Univariate Unit-root Tests (UURT)

The univariate unit-root test as described by Engle and Yoo (1987) will be applied. Given two price series, x_t and y_t, corresponding to two spatially separated markets x and y,

respectively, a new series, z_t is generated by subtracting one of the series from the other as in equation (8).

$$z_{t1} = x_t - y_t \qquad \text{or} \qquad z_{t2} = y_t - x_t \tag{8}$$

For cointegrated series, it is expected that z_{ti} does not contain a unit root, implying that z_{ti} would be integrated of order 0, or $I(0)$. The test on z_{ti} takes the form of a univariate unit root test (Engle and Yoo 1987), whereby the null hypothesis of a unit root, i.e., $z_{ti} \sim I(r)$ where $r \neq 0$), is tested against the alternative of no unit root, i.e., $z_{ti} \sim I(0)$ using the Dickey-Fuller and Augmented Dickey-Fuller tests (Fuller and Dickey, 1979, 1981; Fuller 1976) and the MacKinnon test (MacKinnon 1991).

Rejection of the null hypothesis of a unit root or nonstationarity implies that z_{ti} does not contain a unit root, which indicates that the series is stationary. A stationary z_{ti} would imply that the two price series x_t and y_t, used to generate the z_{ti} series are cointegrated, and that the true cointegration parameter can be estimated using a cointegration relationship of the two prices. Failure to reject the null hypothesis of a unit root implies that z_{ti} is integrated of order r, or $I(r)$ where $r > 0$, ruling out the cointegration of the two price series x_t and y_t.

Bivariate and Multivariate Cointegration Relationships (CR)

Cointegration is assumed to exist if the individual elements of a price system are integrated of the same order, while a linear combination which is stationary also exists. This implies that many economic activities could cause permanent changes in the individual elements of the price system, however, there is a long-run equilibrium relationship which ties the

individual components together. Such a long-run equilibrium relationship could be represented by a linear combination $\alpha'y_t$ (Hamilton 1994).

Given an (n x 1) vector of time series y, cointegration would exist if each of the series taken individually was integrated of order 1 or $I(1)$, while a linear combination of the same series is integrated of order zero, or $I(0)$. For a bivariate system of price series x_t and y_t (where μ_{yt} and μ_{xt} are uncorrelated white noise processes), such a system would be represented by equations (9) and (10).

$$y_t = \gamma x_t + \mu_{yt} \tag{9}$$

$$x_t = \gamma x_{t-1} + \mu_{xt} \tag{10}$$

where x_t is a random walk since $\Delta x_t = \mu_{xt}$ and y_t has a MA(1) representation or

$$\Delta y_t = v_t + \theta v_{t-1} \tag{11}$$

where v_t is a white noise process, $\theta_1 \neq -1$ when $\gamma \neq 0$ and $E(\mu^2_{xt}) > 0$, implying that y_t is $I(1)$.

If y_t and x_t are cointegrated, then the linear combination obtained by differencing equations (9) and (10) i.e., $\Delta y_t = \gamma \Delta x_t + \Delta \mu_{yt} = \gamma \Delta \mu_{xt} + \mu_{yt} - \mu_{y,t-1}$, would be a stationary combination, and a stable equilibrium relationship given by $\alpha'y$ holds the individual elements together. The cointegration vector in this case would be given by $\alpha' = (1, -\gamma)$. For a multivariate system, there could be up to n nonzero linearly independent (n x 1) vectors , for example, α'_1 to α'_i.

Bivariate Cointegration Tests (BCT)

To implement the bivariate cointegration test for market integration, equation (11) would be estimated, and the residuals series would be tested using the augmented Dickey-Fuller test

(Fuller and Dickey, 1979; 1981; Fuller, 1976), and MacKinnon tests (MacKinnon 1991), to determine whether it contains a unit root.

$$y_t = \alpha_0 + \alpha_1 x_t + \epsilon_t \tag{12}$$

If the prices are integrated of order d, $I(d)$, $d > 0$, while the residuals ϵ_i is integrated of order 0, $I(0)$, then the error term obtained from the price system can be represented by a stationary autoregressive moving average process, implying that the two series, y_t and x_t, are cointegrated and that the cointegration parameters are consistently estimated (Ardeni 1989). If cointegration exists, then the markets are integrated. However, according to Baulch (1995), cointegration is a necessary but not a sufficient condition for market integration.

Multivariate Cointegration Tests (MCT)

Given a multivariate system $\alpha' y_t$ for which cointegration exists for some or all the elements in the system, it is expected that $\alpha' y_t = Z_t$ would be stationary for some $(n \times 1)$ cointegration vector α. If all the variables are integrated of the same order and α is truly a cointegration vector, then $Z_t = \alpha' y_t$ will be $I(0)$. The multivariate cointegration test (MCT Test) for market integration would be implemented by estimating a multivariate VAR system and testing for market integration using the Johansen full information maximum likelihood tests (Johansen 1988). The number of cointegration vector would be determined using either the trace or the maximum eigen value tests.

The trace test is used to determine whether the number of cointegration vectors is greater than $k = 1, 2$ or 3. The null hypothesis for this test states that the number of cointegrating vectors is less than or equal to k vectors, while the alternative hypothesis states that there are more than k

cointegrating vectors. For example, let $k=1$, then the null hypothesis of one cointegration vector (H_0: $k \leq 1$) is tested against the alternative hypothesis of more than one cointegration vector (H_a: $k > 1$). If the null hypothesis is rejected, then more than one cointegrating vector would be assumed to exist. The next step would be to test for more than one cointegration vector, i.e., testing the null hypothesis of two cointegration vectors (H_0: $k \leq 2$), against the alternative of more than two cointegration vector (H_a: $k \rangle 2$), and so forth. However, if we fail to reject the null hypothesis, then we conclude that there are k cointegrating vectors, where k corresponds to the number assigned in the null hypothesis that we failed to reject. The maximum possible number of cointegration vectors is equal to the number of variables in the equation system.

The maximum eigen value test is also used to determine the number of cointegration vector in a multivariate system. For this test, the null hypothesis, which states that there are k cointegration vectors, is tested against the alternative that there are greater than k cointegrating vectors. In this case, k would take on values of 0, 1, 2, 3, . . . depending on the number of variables that have been included in the price system. Initially, the null hypothesis of no cointegration (H_0: $k=0$), is tested against the alternative of cointegration (H_a: $k \rangle 0$). If we reject the null hypothesis, we repeat the test using a higher value of k, until we fail to reject the null hypothesis. The number of cointegration vectors in the price system would correspond to the value of k in the null hypothesis that would not be rejected.

The number of common trends between the two prices will be given by $p - r$, where p is the number of variables in the model or the maximum possible number of cointegrating vectors and r is the number of cointegrating vectors, regardless of whether the trace or maximum eigen value was used to determine the cointegration vectors.

Bivariate Correlation Relationships (BCM)

If x_t and y_t, the prices of a given commodity in two spatially separated markets are integrated in the long run, then the correlation relationship in equation (13) exists.

$$y_t = \alpha_0 + \alpha_1 x_t + \epsilon_t \tag{13}$$

The correlation coefficient ranges between 0 and 1. If the correlation coefficient is equal to 1, then the law of one price (LOP) holds. However, if the coefficient ranges between 0 and 1, then the two markets are integrated, but the law of one price does not hold. If the coefficient is equal to 0, then the two markets are segmented. With this approach, markets are perfectly integrated in the long run if the correlation parameter is not significantly different from 1, imperfectly integrated if the coefficient ranges between 0 and 1, while markets are segmented if the correlation parameter is not significantly different from 0.

Market Integration/Market Segmentation

To establish whether markets are segmented or integrated using the correlation approach, equation (13) is estimated and the null hypothesis of market segmentation $(H_0: \alpha_1 = 0)$ is tested against the alternative of market integration $(H_0: \alpha_1 \neq 0)$. Rejection of the null hypothesis would imply that the two markets are integrated and that the prices in the two markets have a long-run equilibrium relationship.

Imperfect Market integration/Perfect Market Integration (or LOP)

Having determined that the two markets are integrated, the null hypothesis of $H_0: \alpha_1 = 1$ would be tested against the alternative of $H_a: \alpha_1 \neq 1$, assuming that x_t is exogenous. Rejection of the null hypothesis would imply that the markets are imperfectly integrated, while failure to

reject the null hypothesis would imply perfect market integration. Perfect market integration would necessarily imply that the LOP holds in the long run. If LOP holds, theory states that $\alpha_1 = 1$, unity being the only value of the correlation coefficient for which LOP holds in the long run.

Spontaneous/Nonspontaneous Adjustments

To determine whether adjustments are spontaneous or nonspontaneous, the null hypothesis of H_0: $\alpha_0 = 0$, is tested against the alternative of H_a: $\alpha_0 \neq 1$. Rejection of the null hypothesis in favor of the alternative hypothesis would imply that adjustments are nonspontaneous and that LOP does not hold in the short run. Failure to reject the null hypothesis would imply that price adjustments are spontaneous and that the LOP holds in the short run.

Short-Run and/or Long-Run Deviations from LOP

To determine whether deviations from LOP are short-run and/or long-run deviations, the joint null hypothesis of H_0: $\alpha_0 = 0$, $\alpha_1 = 1$, is tested against the joint alternative hypothesis of H_0: $\alpha_0 \neq 0$, $\alpha_1 \neq 1$. Failure to reject the null hypothesis would imply that LOP holds both in the short run and the long run, and that adjustments are spontaneous. Rejection of the null hypothesis would imply that LOP does not hold either in the short run or the long run, and that adjustments are nonspontaneous or that adjustments are be incomplete and take a long time to achieve the possible adjustment. However, if $\alpha_1 = 1$, while $\alpha_0 \neq 0$, then LOP holds in the long run but does not hold in the short run, implying deviations from LOP would be a short-run but not a long-run phenomena; and that the short-run correlation/cointegration parameter would range between 0 and 1 since price adjustments would still be in progress, while the long-run cointegration parameter would be equal to 1, since adjustments would be complete. Also, if $\alpha_0 = 0$, while $\alpha_1 \neq$

1, then adjustments would be spontaneous but incomplete, implying that LOP would not hold either in the short run or the long run, i.e., deviations from LOP are both a short-run and long-run phenomena.

Granger-Causality Error Correction Models (GCECM)

The Granger-causality error correction models can be one of two types, i.e., a general equilibrium reduced form similar to that used by Alexander and Wyeth (1994), and a structural form similar to that used by Ravallion (1986). For purposes of this study, the reduced form model was selected because it can be used to determine the "cause-effect" relationships, while varying the optimal lags for the various elements, and can consistently be estimated using OLS. For the structural model, the "cause-effect" relationships must be determined a priori (i.e., the central market must be identified outside the model), the same number of lags must be included for all the elements in the system, and the model cannot be consistently estimated using OLS.

The test for market integration using the reduced Granger-causality error correction models will be determined using either of two tests. For the first test, market integration is determined using the combined effect of the lagged price level and the lagged price changes of region x on the current price change in region y (referred to as GCECM test 1, hereafter). For the second test, market integration is determined using the effect of the lagged price changes of region x on the current price change in region y (referred to as GCECM test 2, hereafter). For purposes of this study, market integration was assumed to exist if either test indicated Granger-causality.

Bivariate GCECM Test 1

For this test, market integration for markets y and x is determined using either the combined effects of lagged price level and lagged price changes of market x on the current price change in market y or the combined effects of the lagged price level and lagged price changes of market y on the current price change in market x. For the combined effect of the lagged price level and the lagged price changes of market x on the current price change in market y, equations (14) and (15) are estimated. Equation (14) constitutes the univariate error correction model or restricted form model, while equation (15) constitutes the bivariate error correction models or unrestricted model.

$$\Delta y_{1,t} = \delta_{1,1}\, \Delta y_{1,t-1} + \delta_{1,2}\, \Delta y_{1,t-2} + \ldots + \delta_{1,p-1}\, \Delta y_{1,t-p+1} + \rho_{1,1}\, y_{1,t-1} + v_t \qquad (14)$$

$$\Delta y_{1,t} = \delta_{1,1}\, \Delta y_{1,t-1} + \delta_{1,2}\, \Delta y_{1,t-2} + \ldots + \delta_{1,p-1}\, \Delta y_{1,t-p+1} + \rho_{1,1}\, y_{1,t-1} + \alpha_{1,1}\, \Delta x_{1,t-1}$$

$$+\ \alpha_{1,2}\, \Delta x_{1,t-2} + \ldots + \alpha_{1p,p-1}\, \Delta x_{1,t-p+1} + \theta_{1,1}\, x_{1,t-1} + \epsilon_t \qquad (15)$$

The optimal number of lags for each of those equations are identified using the modified final prediction error (MFPE) procedure as described in Muwanga and Snyder (1997b).

Existence of an error correction form, such as that in equation (15), implies that Granger-causality exists and that the sufficient condition for market integration is satisfied. Prices in market x are assumed to Granger-causality prices in market y, if the variables on the right hand side of equation (15) explain more of the variation in the current price change in market y, compared to the variation explained by the right hand variables in equation (14). This implies that the lagged price levels and lagged price changes in both markets, x and y, explain more variation in the current price change in market y compared to that explained by the lagged price level and the lagged price changes in market y alone. Similarly, equations (16) and (17) can be

estimated and a similar test performed to determine whether prices in market y Granger-cause

prices in market x.

$$\Delta x_t = \beta_1 \Delta x_{t-1} + \beta_2 \Delta x_{t-2} + \ldots + \beta_{p-1} \Delta x_{t-p+1} + \eta_1 x_{t-1} + \upsilon_t \qquad (16)$$

$$\Delta x_t = \beta_1 \Delta x_{t-1} + \beta_2 \Delta x_{t-2} + \ldots + \beta_{p-1} \Delta x_{t-p+1} + \eta_1 x_{t-1} + \sigma_1 \Delta y_{t-1}$$
$$+ \; \sigma_2 \Delta y_{t-2} \; + \ldots + \; \sigma_{p-1} \Delta y_{t-p+1} \; + \lambda_1 y_{t-1} \; + \; \epsilon_t \qquad (17)$$

If prices in both markets x and y Granger-cause each other, bidirectional causality is said to exist.

However, if x Granger-causes y, while y does not Granger-cause x, or vice versa, unidirectional

causality is said to exist.

For the GCECM test 1, the joint null hypothesis of market segmentation (no Granger-

causality) is tested against the alternative of market integration (Granger-causality) for the two

regions. If the null hypothesis is rejected in favor of the alternative hypothesis, we conclude that

Granger-causality exists and that markets are integrated. Failure to reject the null hypothesis

implies that Granger-causality does not exist and that the markets are segmented.

To implement the test, the restricted and unrestricted residual sum of squares (RSS_0) from

equation (15) (or equation (17)), and the restricted sum of squares (RSS_1) from equation (14) (or

equation (16)), respectively, are computed. The test statistics S_1 for the F-test and S_2 for χ^2-test

are computed by setting $\quad S_1 = \dfrac{(RSS_0 - RSS_1) \, / \, P}{RSS_1 \, / \, (\, T - np - 1)}$ and $S_2 = \dfrac{T \, (RSS_0 - RSS_1) \, / \, P}{RSS_1}$,

where $RSS_1 = \Sigma \, \epsilon^2$ and $RSS_0 = \Sigma v^2$ for equations (14) and (15), P is the number of restrictions

imposed by the hypothesis in the restricted model, n is equivalent to the number of endogenous

variables in the system and T is the total number of observations available. For a bivariate

process, $n = 2$.

For the χ^2 test, the null hypothesis of no Granger-causality is rejected if S_2 is greater than the 5% critical value for $\chi^2(p)$ variable, while for the F-test, the null hypothesis is rejected if S_1 is greater than the 5% critical value for an $F(p, T - np - 1)$ distribution. For both tests, Granger-causality holds if the null hypothesis is rejected, and vice versa. However, the F-test has the disadvantage of being valid asymptotically.

Bivariate GCECM Test 2

For this test, market integration for markets y and x is determined using the effect of the lagged price changes of market x on the current price change in market y or the effect of the lagged price changes of market y on the current price change in market x. To determine whether the lagged price changes in region x Granger-cause the current price changes in region y, equation (18) and (19) are estimated, where equation (18) forms the restricted form, while equation (19) forms the unrestricted form. (N.B. The unrestricted form is the same for both the GCECM tests, i.e., equation (15) is the same as equation (19)).

$$\Delta y_t = \delta_1 \Delta y_{t-1} + \delta_2 y_{t-2} + \ldots + \delta_{p-1} \Delta y_{t-p+1} + \rho_1 y_{t-1} + \theta_1 x_{t-1} + \upsilon_t \tag{18}$$

$$\Delta y_{1,t} = \delta_{1,1} \Delta y_{1,t-1} + \delta_{1,2} \Delta y_{1,t-2} + \ldots + \delta_{1,p-1} \Delta y_{1,t-p+1} + \rho_{1,1} y_{1,t-1} + \alpha_{1,1} \Delta x_{1,t-1}$$
$$+ \alpha_{1,2} \Delta x_{1,t-2} + \ldots + \alpha_{1p,p-1} \Delta x_{1,t-p+1} + \theta_{1,1} x_{1,t-1} + \epsilon_t \tag{19}$$

To test for market integration using the effect of the lagged price changes of x on y, we test the null hypothesis of no Granger-causality against the alternative of Granger-causality. For this test, Granger-causality exists if the lagged changes in region x significantly influence the current price changes in region y. To test for market integration using this procedure, we use the F-test and χ^2-

tests, as described earlier, but equation (18) forms the restricted model, while equation (19) forms the unrestricted model.

Data

The data used for the empirical analysis included prices of six classes of cattle from Cattle-Fax, including slaughter utility cows, 800-, 600- and 400-lb steers, and 700- and 400-lb heifers. For each class of cattle, prices were obtained for the twelve regions indicated below: Washington /Oregon/ Idaho (WOI), Montana/ Wyoming (MW), California (CA), Nevada/Utah (NU), Arizona/New Mexico (ANM), Colorado (CO), Iowa (IO), Kansas/Missouri (KM), North/South Dakota (NSD), Nebraska (NE), Oklahoma (OK) and Texas (TX). The actual series used for the studies were obtained by computing the simple arithmetic mean of the lower and upper price series for each region.

Results and Discussion

The results are presented in subsections depending on the specific procedure used. The sub-sections begin with the SGC model and end with the GCECM multivariate models.

Simple Granger-Causality Relationships (SGC Model)

A simple bivariate Granger-causality test was applied to all the price series for the twelve marketing regions. It was necessary to identify the prices which were endogenous and those which were exogenous since all the price series included experienced the same macroeconomic and microeconomic policies. The results (table 1) indicated that all the three possible relationships, i.e., endogenous/endogenous, endogenous/exogenous, and exogenous/exogenous,

existed depending on the type of cattle and the regions considered, for example 72.7% of the cases for slaughter utility cows were endogenous/endogenous, 25.7% were endogenous/exogenous, while 1.52% of the cases were exogenous/exogenous.

Endogenous/endogenous relationships were the most common, while exogenous/exogenous relationships were almost nonexistent. Overall, 70.22%, 29.53% and 0.25% of the bivariate systems had endogenous/endogenous, endogenous/exogenous, and exogenous/exogenous relationships, respectively. The bivariate systems for steers and heifers had either an endogenous/endogenous or endogenous/exogenous relationship, while the slaughter utility cows also had an exogenous/exogenous relationship. The bivariate systems for slaughter utility cows, 600- and 400-lb steers, and 700- and 400-lb heifers were mostly endogenous/endogenous, while those for 800-lb steers were either endogenous/endogenous or endogenous/exogenous with almost the same proportions (48.5% and 51.5%, respectively). These results indicate that prices of cattle in most regions were simultaneously determined implying that simultaneity could not simply be assumed away if cattle price data are used for empirical analysis.

Univariate Unit Root Tests (UURT)

In order to ensure that markets were integrated over and above the effects of simultaneity, we used the univariate unit root test for market integration as described by Engle and Yoo (1987). Each of the price series was differenced from the other eleven price series for each class to generate 132 new variables, which were then tested using the unit root test to determine whether they were $I(0)$.

The null hypothesis of a unit root was tested against the alternative of no unit root using the Dickey-Fuller and augmented Dickey-Fuller tests (Fuller and Dickey, 1979, 1981; Fuller 1976). The null hypothesis was rejected for all the transformed series implying that all the transformed series were I(0), regardless of the class of cattle and regions considered. The same results were obtained regardless of whether price series x_t was subtracted from price series y_t or vice versa. These results indicate that all the price series used to generate the transformed series within classes were cointegrated (implying market integration) regardless of the class, region and the source of the shock to the price systems. Also, these results indicate that the true cointegration parameter could be estimated using a cointegration relationship.

Bivariate Cointegration Results (BCT)

Having determined that market integration existed, even though the prices were simultaneously determined for most of the regions, market integration was tested for using the bivariate cointegration approach. With this approach, all possibilities of spurious correlations that may arise if totally unrelated variables are regressed on each other could be ruled out.

All the price series were tested for a unit root to determine the order of integration, using the augmented Dickey-Fuller (Fuller and Dickey, 1979, 1981; Fuller, 1976), and MacKinnon test (1991) tests. All the price series were I(1), regardless of the class and region considered. Since all the price series were integrated of the same order, the long-run cointegration relationship in equation (12) was estimated for each of the bivariate systems within classes, and the residuals were tested to determine whether they were $I(0)$. All the residuals were $I(0)$ regardless of the class of cattle, region and origin of shock, implying that all the markets were integrated

regardless of the cattle class, the regions considered and the origin of the shock; and that the

cointegration parameter(s) estimated in equation (13) were true long-run parameters and could

consistently be estimated (Ardeni, 1989). However, the cointegration results based on the

presence or absence of a unit root in the residual series, did not establish whether the coefficient

on x_t (obtained by regressing y_t on x_t) or that on y_t (obtained by regressing x_t on y_t), was the true

cointegration parameter. It only indicated that at least one of the two relationships was not

spurious, implying that markets were integrated, but did not indicate whether both or only one of

the relationships was the true cointegration relationships. Also, since the approach emphasizes

cointegration as determined by the order of the residuals from equation (1), this approach could

not be used to distinguish between perfect market integration (LOP) and imperfect market

integration. It could only be used to distinguish market integration and market segmentation.

Also, we could not establish whether, deviations from LOP were a short-run or long-run

phenomena.

Multivariate Cointegration Tests (MCT)

Since the residuals obtained from the OLS regression of y_t on x_t were different from those

obtained by regressing x_t on y_t, the tests could yield different cointegration parameters. To

overcome this limitation, multivariate cointegration tests (MCT), based on full information

maximum-likelihood test of Johansen (1988, 1991) which is invariant to the ordering of the

variables, was applied. The number of cointegration vectors for the multivariate system were

identified using the Johansen maximum eigen value tests on a vector autoregression system of

the twelve price variables for each of the six classes of cattle. The optimal number of lags for

each system were identified using both the Akaike information criteria (AIC) (Hsiao 1982) and

Schwarz criteria. A constant as well as a deterministic trend variable was included in the

cointegration equations since all the variables under consideration contained a deterministic

trend. Including the deterministic trend variable accounted for the trend which was evident in all

the price variables, and ensured that the appropriate test statistics were used for the hypothesis

tests.

Having determined the number of cointegration vectors, the number of common trends

were obtained by computing $p - r$, where $p = 12$, the number of elements in the price system and r

is equal to the number of cointegration vectors identified. The number of cointegration vectors

and common trends identified for each of the six cattle classes are presented in table 2. All the

price systems had an optimal lag of one, regardless of the class. The price system for utility cows

had at most eleven cointegration vectors, implying that all the eleven linear combinations of the

twelve price variables were stationary, and that these cointegration vectors furnished at most

eleven constants and eleven cointegration coefficients. Also, it implies that there was only one

common deterministic trend which could be driven by the same factor, e.g. inflation. On the

other hand, all the price systems corresponding to all the other classes had at most ten

cointegration vectors, implying that at most ten constants and ten cointegration coefficients

existed. Further, each of the price systems had two deterministic trends that were common to the

twelve price variables under each class for steers and heifers. The above results indicated the

existence of long-run equilibrium relationships which tied the individual price components

together, implying that the individual price variables for each cattle class were not independent of

each other, but moved together to attain an equilibrium.

Bivariate Correlation Approach (BCM)

Equation (13) was estimated for each of the bivariate pairs for the twelve price series under each class. The hypothesis tests for market segmentation, perfect and imperfect market integration, spontaneity, and short-run and/or long-run LOP were performed as described in the procedure. The details of the results are presented in appendix tables 1 through 6, inclusive.

The null hypothesis of market segmentation was rejected for all the bivariate series, regardless of the class, region, and origin of the shock, implying that all the markets within classes were integrated. Appendix tables 1 through 6 show the actual correlation parameters and give an indication as to which specific relationship had perfect market integration (LOP) and those that had imperfect market integration.

Overall, 35.83% of the bivariate systems considered for all cattle classes, adhered to LOP in the long run, while 64.17% exhibited imperfect market integration. In all cases, LOP did not hold for more than half of the bivariate systems regardless of the cattle class. The LOP was more likely to hold in the long run for slaughter utility cows (47%) and 400-lb heifers (45%), but least likely to hold for 800-lb steers (16.0%). The LOP held in the long run for almost the same percentages for 600- and 400-lb steers, and 700-lb heifers. Table 3 shows a summary in terms of percentages of the bivariate series that adhered to LOP and imperfect market integration in the long run.

The LOP was more likely to hold both in the short run and long run for slaughter utility cows (31.06%), but least likely to hold for 800-lb steers (3.79). Also, LOP held in the long run but not the short run for at least 12.12% of the class cases, as occurred for 800-lb steers, but at

most for 27.27% of the class cases, as occurred for 400-lb heifers. Overall, LOP held in the short run for 16.29% of the cases for all classes but held for 35.86% of the cases in the long run. These results indicate that deviations from LOP occurred both in the short run and the long run, however, deviations from LOP were more likely to occur in the short run compared to the long run.

Table 4 shows a summary in terms of the percentages of the cases for which LOP held both in the short run and long run, LOP held in the long run only, spontaneous adjustment but imperfect market integration existed, and for which nonspontaneous and imperfect market integration existed.

Adjustments were spontaneous but imperfect for at least 6.82% of the class cases as with slaughter utility cows, but at most for 39.39% of the class cases as occurred with 400-lb steers. Also, the adjustments were nonspontaneous and imperfect for at least 23.48% of the class cases, as with 400-lb steers, but at most for 62.12% of the class cases as occurred for 800-lb steers. Overall, price adjustments were spontaneous, but imperfect for 25.13% for all cattle classes, but nonspontaneous and imperfect for 39.02% of the cases for all cattle classes.

Granger-Causality Bivariate Error Correction Models (GCECM Bivariate Model)

Having determined that the necessary condition for market integration was satisfied for all the price series, regardless of the class, the reduced general equilibrium Granger-causality error correction model was estimated for each of the bivariate systems to determine whether the sufficient condition, following Baulch (1995), was satisfied. Existence of Granger-causality was determined using the GCECM test 1 and GCECM test 2, as described in the procedures.

Prices of 400-lb steers were the most integrated with 92.4% of the cases having bidirectional causality, while those of 800-lb steers were the least integrated with only 70% of the cases having bidirectional causality. For all cattle classes, 79.7% of the bivariate systems had bidirectional causality, while 20.3% had uni-directional causality. These results indicate that cattle markets were integrated within classes, for all regions. However, the direction of causality or the origin of the shock was an important factor in determining whether a given price shock in one market would be transmitted to the other market in the bivariate system.

All the bivariate systems had either bidirectional causality or unidirectional causality. As a result, Granger-causality was indicated for all the price series within classes, at least in one direction for all the bivariate systems regardless of the cattle class, implying that the sufficient condition for market integration was satisfied for all the markets, and that all the markets were integrated within classes. Table 5 shows the a summary of the results by classes. For details about the direction of causality, see Muwanga and Snyder (1997b).

Granger-Causality Multivariate Error Correction Models (GCECM Multivariate Model)

In order to determine whether the sufficient condition would be satisfied in a multivariate setting, vector autoregression was used to estimate a multivariate error-correction system for each of the twelve price series for the six cattle classes. The same procedure for the bivariate error correction approach was used, except for the fact that a twelve-variable system, rather than a two-variable system was estimated. Also, two lags were included for price differences for all the price variables. The GCECM test 1 was modified in such a way as to suite a multivariate setting, whereby, eleven lagged price levels, and two lags of the price changes of each of the eleven price

levels, and the lagged price level and two lags of the prices changes of the dependent price level, were included in the unrestricted mode. The restricted model was modified by including the lagged price level and two lags of the lagged price changes of the dependent variable. The GCECM test 2 was modified by including lagged price levels of the eleven independent price levels, the lagged price level and two lags of the price changes in the dependent price variable, in the restricted model. The unrestricted model was the same as that for the GCECM test 1. The F-test and χ^2-tests were performed following the same procedure as for the bivariate Granger-causality model.

As with the bivariate error correction tests, market integration was assumed to exist if one or both the GCECM tests indicated Granger-causality. The results obtained for the first test (GCECM test 1) indicated market segmentation for all the price systems regardless of the class. However, the second test (GCECM test 2) indicated market integration for some systems and market segmentation for the others. The results for GCECM test 2 indicated that all the regions were integrated for slaughter utility cows, but were segmented for 400-lb heifers, while markets were integrated for 83.33%, 83.33%, 16.67% and 8.33% for 800-, 600-, and 400-lb steers, and 700-lb heifers, respectively. This implies that the markets for slaughter utility cows, 800- and 600-lb steers were more integrated compared to those for 400-lb steers, and 700-lb heifers, while those for 400-lb heifers were not integrated at all.

The results obtained using the multivariate Granger-causality VAR approach contrast with those obtained using the other approaches, possibly indicating the consequence of including the same number of lags for all the elements in the multivariate price system. Table 6 is a summary of the results obtained by testing for market integration using the GCECM test 2.

Summary and Conclusions

Several approaches were used to study the nature of spatial price relationships and market integration for the cattle markets in select United States [U.S.] markets. The approaches included the univariate unit root approach, the cointegration approach, Johansen maximum likelihood test for cointegration, the correlation approach, and bivariate and multivariate reduced forms of the general equilibrium Granger-causality error correction models.

Apart from the multivariate reduced form Granger-causality error correction models, all the other approaches indicated that markets were integration within classes, for all the classes and all regions. Overall, the results indicated that none of the approaches was [were] necessarily superior to the others in all aspects. In addition to detecting market integration, each of the approaches had a special role in unfolding the nature of the spatial price relationships.

The univariate unit root approach was useful in ruling out the effects of simultaneity because all the price variables used in the study were mostly characterized by simultaneous relationships which could have biased the results if not adjusted for. The cointegration approach was used to rule out the effects of spurious regressions. The Johansen maximum likelihood approach was used to determine the number of cointegration vectors and common trends for the twelve price variable systems.

The correlation approach was used to distinguish between perfect market integration (LOP), imperfect market integration and market segmentation. Also, the correlation approach was used to determine whether the deviations from LOP were long-run and/or short-run phenomena, and whether price adjustments were spontaneous or non spontaneous. The reduced

form of the general equilibrium Granger-causality model was used to determine the " cause-effect" relationships or direction of causality, as well as the strength of the causality. The multivariate error correction models indicated that the number of lags included in the model, had among other things, a significant effect on the implications for market integration. No extra attention was given to the multivariate error correction results because they differed from those obtained using all the other approaches.

Apart form the multivariate results, both the necessary and sufficient conditions for market integration were satisfied for all the six cattle classes within classes, for all regions, implying that all the spatially separated markets were integrated with classes. However, the cattle markets were either perfectly integrated or imperfectly integrated within classes, depending on the class and the regions under consideration. Overall, imperfect market integration was indicated for more than half of the cases (64.17%) for all classes taken together. For all classes, LOP held for 35.83% of the cases in the long run but for only 16.29% of the cases in the short run implying that deviations from LOP were both short-run and long-run phenomena, but with more deviation in the short run. Price adjustments were nonspontaneous for 39.02% of the cases for all classes. Bidirectional and uni-directional causality existed for 79.7 and 20.3% of the markets, respectively. This implies that the source of the shock was an important factor in those cases with uni-directional causality. (N.B. In some cases, causality was not indicated at the 5% level of significance but was indicated at the 10% level of significance). Endogenous/endogenous relationships existed for 70.22% of the cases for all classes implying that prices of cattle were simultaneously determined for the most part.

At least ten cointegration vectors were indicated for all the twelve price systems for each class, implying that shocks to the system could cause the prices to wander in different directions, however, the same prices could not wander a way from each other forever, a stable long-run equilibrium relationships would always be achieved. Only one common trend was identified for slaughter utility cows, while two common trends were identified for all the other cattle classes considered.

Table 1. Simple Granger-causality relationships for selected classes of cattle

	Percentages of Different Relationships		
Cattle Class	**Endogenous/Endogenous**	**Endogenous/Exogenous**	**Exogenous/Exogenous**
Utility cows	72.7	25.7	1.52
800-lb steers	48.5	51.5	0.0
600 lbs steers	78.8	21.2	0.0
400-lb steers	95.5	4.6	0.0
700 lbs heifers	57.6	42.4	0.0
400-lb heifers	68.2	31.8	0.0
ALL CLASSES	70.22	29.53	0.25

Table 2. Number of Cointegration vectors and common trends for the six classes of cattle

Cattle Class Trends (r)	Number of Cointegration vectors (p)	Number of Common ® = n - p)
Slaughter utility cows	11	1
800-lb steers	10	2
600-lb steers	10	2
400-lb steers	10	2
700-lb heifers	10	2
400-lb heifers	10	2

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Table 3. Proportions of bivariate systems with perfect and imperfect market integration in the long run.

Cattle Class	Percentages of the Bivariate Systems with	
	Perfect Market Integration	**Imperfect Market Integration**
Slaughter utility cows	47	53
800-lb steers	16	84
600-lb steers	35	65
400-lb steers	37	63
700-lb heifers	35	65
400-lb heifers	45	55
ALL CLASSES	36	64

Table 4. Percentages for short-run, long-run, spontaneous and nonspontaneous price adjustments.

Cattle Class	Perfect Market Integration		Imperfect Market Integration	
	Both Short run and Long run (%)	Long run Only (%)	Spontaneous Adjustments (%)	Nonspontaneous Adjustments (%)
Utility cows	31.06	15.91	6.82	46.21
800-lb steers	3.79	12.12	21.97	62.12
600-lb steers	20.45	14.39	29.55	35.61
400-lb steers	14.39	22.73	39.39	23.48
700-lb heifers	9.85	25.00	32.58	32.58
400-lb heifers	18.18	27.27	20.45	34.09
ALL CLASSES	16.29	19.57	25.13	39.02

Table 5. Proportions of the bivariate systems with bidirectional and unidirectional causality.

Class	Bi-directional Causality (%)	Unidirectional Causality (%)
Utility cows	79.5	20.5
800-lb steers	70.0	30.0
600-lb steers	84.8	15.2
400-lb steers	92.4	7.6
700-lb heifers	72.7	27.3
400-lb heifers	78.8	21.2
ALL CLASSES	79.7	20.3

Table 6. Proportions of multivariate systems with market integration and market segmentation (GCECM test 2).

Cattle Class	Market Integration (%)	Market Segmentation (%)
Utility cows	100.00	0.00
800-lb steers	83.33	16.67
600-lb steers	83.33	16.67
400-lb steers	16.67	83.33
700-lb heifers	8.33	91.67
400-lb heifers	0.00	100.00
ALL CLASSES	48.61	51.39

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Appendix C

Appendix Tables

Table 1. True short-run and long-run cointegration parameters and implications of hypothesis tests for slaughter utility cows

Dep. Var.	Ind. Var.											
	WOI	MW	CA	NU	ANM	CO	IO	KM	NSD	NE	OK	TX
WOI		0.963!	**0.995^***	**0.994^***	0.952!	**0.958^**	0.973*	0.954!	0.958!	0.968!	0.950!	0.900!
MW	**0.992^***		**0.995^***	**0.992^***	0.967!	**0.992^***	**0.992^***	0.979*	**0.990^***	**1.000^***	0.981!	0.925!
CA	**0.989^***	0.961!		**0.991^**	0.951!	0.956!	0.970!	0.952!	0.958*	0.967!	0.949!	0.898!
NU	**0.992^***	0.961!	**0.994^***		0.950!	0.957*	0.970*	0.953!	0.958*	0.967*	0.948!	0.900!
ANM	1.028*	**1.014^**	1.033!	1.029!		**1.009^**	**1.017^**	**1.001^**	**1.009^**	**1.018^**	**1.001^***	0.946!
CO	**0.994^***	**0.999^**	**0.998^***	**0.995^***	0.969!		**0.995^***	**0.983^**	**0.994^***	**1.004^***	**0.983^**	0.929!
IO	**0.983^***	0.974!	**0.987^***	**0.984^**	0.952!	0.968!		0.976!	0.977*	**0.987^***	0.969!	0.914!
KM	**1.002^***	**0.998^***	**1.005^***	**1.002^***	0.973!	**0.994^***	1.013!		**1.004^**	1.015!	**0.996^**	0.938!
NSD	**0.988^***	**0.991^**	**0.992^***	**0.989^***	0.963!	**0.988^***	**0.995^***	0.986!		**1.008^***	**0.988^**	0.931!
NE	**0.976^**	0.978!	**0.980^**	**0.977^**	0.950!	0.976!	**0.984^**	0.975!	0.985!		0.977!	0.919!
OK	**0.994^***	**0.996^***	**0.998^***	**0.993^***	0.969!	**0.991^***	**1.002^***	**0.992^***	**1.002^**	1.014!		0.934!
TX	1.047!	1.044!	1.049!	1.049!	**1.019^***	1.041!	1.050!	1.039!	1.049!	1.060!	1.039!	

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Table 2. True short-run and long-run cointegration parameters and implications of hypothesis tests for 800-lb steers

Dep. Var.	WOI	MW	CA	NU	ANM	Ind. Var. CO	IO	KM	NSD	NE	OK	TX
WOI		0.922!	**1.004^***	0.990!	0.932!	0.909!	0.948!	0.934!	0.895!	0.882!	0.900!	0.909!
MW	1.059!		1.064!	1.048*	**0.998^**	0.986!	1.088!	1.010!	0.970*	0.956!	0.974!	0.985*
CA	**0.987^***	0.912!		0.979!	0.924!	0.900!	0.936!	0.924!	0.885!	0.874!	0.892!	0.899!
NU	**1.005^**	0.930!	1.011*		0.940!	0.916!	0.955*	0.842!	0.903!	0.890!	0.908!	0.917!
ANM	1.061!	**0.989^**	1.070!	1.053!		0.978!	**1.016^**	**1.003^**	0.963*	0.950*	0.969*	0.977*
CO	1.069!	1.009*	1.075!	1.061*	**1.010^**		1.033!	1.023!	0.984*	0.969!	0.987!	**0.997^**
IO	1.024*	0.961!	1.027*	**1.013^**	0.963!	0.949!		0.981!	0.938!	0.925!	0.942!	0.951!
KM	1.042*	0.981!	1.045*	1.032*	0.981!	0.970!	1.012!		0.958!	0.943!	**0.993^**	0.971!
NSD	1.077!	1.016*	1.081*	1.067*	**1.016^**	**1.007^***	1.044	1.033!		0.982!	**0.997^**	**1.008^**
NE	1.096!	1.033*	1.101!	1.086*	1.035!	1.023*	1.062!	1.050!	1.013!		1.014*	1.023*
OK	1.080!	1.017*	1.085!	1.069!	1.020!	**1.007^**	1.045!	1.033!	**0.994^**	0.980*		**1.007^**
TX	1.063!	**1.002^***	1.067!	1.069!	**1.002^**	**0.991^***	1.029!	1.018!	0.980*	0.964*	0.982!	

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Table 3. True short-run and long-run cointegration parameters and implications of hypothesis tests for 600-lb steers.

Dep. Var.					Ind. Var.							
	WOI	MW	CA	NU	ANM	CO	IO	KM	NSD	NE	OK	TX
WOI		0595!	1.000^*	1.005^	0.960!	0.934!	0.957*	0.943!	0.904!	0.901!	0.938!	0.944!
MW	1.008^		1.009^	1.016^	0.987^	0.975*	0.988^*	0.979!	0.944!	0.940!	0.978!	0.982!
CA	0.992*	0.948*		1.000^	0.955!	0.927!	0.951	0.936!	0.898!	0.895!	0.933!	0.938!
NU	0.989*	0.947!	0.992^*		0.952!	0.927!	0.950*	0.935 !	0.898!	0.894!	0.931!	0.937!
ANM	1.024!	0.998^	1.027!	1.032!		0.977!	0.995^	0.984!	0.945*	0.941*	0.983!	0.987^
CO	1.028*	1.017*	1.029*	1.037*	1.090^		1.010^*	1.002^*	0.968!	0.963!	1.002^*	1.005^*
IO	1.011^*	0.989^*	1.013^*	1.019^*	0.985^	0.970!		0.981!	0.941!	0.936!	0.974!	0.981!
KM	1.026*	1.009^*	1.027*	1.034*	1.003^	0.990^*	1.010^*		0.960!	0.955*	0.995!	1.001!
NSD	1.053*	1.041*	1.054*	1.062*	1.032!	1.023*	1.037*	1.027*		0.994*	1.027*	1.031*
NE	1.059*	1.047*	1.060*	1.068*	1.038!	1.028*	1.042*	1.031*	1.003*		1.031*	1.031*
OK	1.022^*	1.009^*	1.024^*	1.030*	1.004^	0.991^*	1.004^*	0.997^*	0.961*	0.956*		1.001*
TX	1.017^	1.002^	1.018^	1.025*	0.996^*	0.983*	0.999^*	0.990^*	0.953!	0.948*	0.989^	

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Table 4. True short-run and long-run cointegration parameters and implications of hypothesis tests for 400-lb steers.

Dep. Var.	WOI	MW	CA	NU	ANM	CO	IO	KM	NSD	NE	OK	TX
							Ind. Var					
WOI		**0.980^***	**0.996^***	**0.995^***	0.967	0.932*	0.969*	0.954*	0.942*	0.931*	0.967*	0.939
MW	**0.979^**		**0.976^**	0.975	0.961	0.942	0.978*	0.968	0.955*	0.943*	0.984*	0.946
CA	**0.992^***	0.972*		**0.990^***	0.964	0.927*	0.962*	0.948*	0.935*	0.924*	0.961*	0.933
NU	**0.999^***	**0.980^***	**0.998^***		0.969	0.932*	0.969*	0.955*	0.942*	0.932*	0.966*	0.938
ANM	1.016*	**1.011^**	1.018*	**1.014^***		0.962*	**0.997^**	**0.984^***	0.973	0.962	**1.001^**	0.969*
CO	1.032*	1.045*	1.031*	1.028*	**1.015^**		1.028*	1.017*	1.008	0.995	1.036*	0.997
IO	**0.982^**	**0.993^***	**0.980^**	**0.978^**	0.962	0.941		0.977	0.954*	0.943*	0.984*	0.952
KM	**1.003^***	1.018*	**1.001^**	**0.999^**	**0.984^**	0.965*	1.013		0.978*	0.965*	1.009*	0.974
NSD	**1.017^**	1.032*	**1.014^**	**1.013^**	**0.999^**	0.982	**1.015^***	**1.004^**		0.985*	1.024*	**0.987^**
NE	1.030	1.044*	**1.027^**	**1.026^**	**1.012^**	**0.993^**	1.028*	**1.016^**	1.010*		1.036*	**0.998^**
OK	**0.983^**	**1.002^***	**0.982^**	**0.978^**	0.969	0.951	**0.987^***	0.977	0.965*	0.953*		0.960
TX	**1.018^***	1.027	**1.016^***	**1.013^***	**1.000^**	0.976*	**1.018^**	**1.005^***	**0.991^**	0.979	1.024	

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Table 5. True short-run and long-run cointegration parameters and implications of hypothesis tests for 700-lb heifers.

Dep. Var.	Ind. Var.											
	WOI	MW	CA	NU	ANM	CO	IO	KM	NSD	NE	OK	TX
WOI		0.966*	**0.992^**	**1.003^***	0.952!	0.938!	0.972*	0.965*	0.946*	0.925!	0.941*	0.954!
MW	**1.011^**		**1.004^**	**1.017^**	0.775!	0.970!	**0.997^***	**0.993^***	0.978*	0.956!	0.974!	0.983!
CA	**0.999^**	0.966*		**1.006^**	0.955!	0.937*	0.970*	0.964*	0.944!	0.923*	0.941*	0.952*
NU	0.990*	0.959*	0.985!		0.946!	0.932*	0.963*	0.957*	0.940*	0.919*	0.934!	0.947!
ANM	1.037!	1.015!	1.033!	1.044!		**0.986^**	**1.016^**	**1.012^**	**0.993^**	0.971!	**0.990^**	**1.000^**
CO	1.035*	1.022*	1.026!	1.042*	**0.999^**		1.022*	1.020*	**1.005^**	0.982*	**1.000^**	**1.010^***
IO	**1.001^**	0.982!	**0.992^**	**1.005^**	0.962!	0.955!		0.985*	0.966*	0.945!	0.960!	0.970
KM	**1.014^**	**0.997^**	**1.007^**	1.019!	0.976!	0.972!	**1.005^**		0.981*	0.959!	0.975!	**0.986^**
NSD	1.023!	**1.010^**	**1.013^**	1.030!	**0.986^**	0.985!	**1.013^***	**1.009^***		0.975!	0.989!	**0.999^**
NE	1.047*	1.035*	1.038	1.054*	**1.010^**	**1.009^***	1.039*	1.033*	1.021!		1.014!	1.023*
OK	1.030*	1.019*	**1.023^**	1.037*	**0.996^**	**0.993^***	1.020!	1.017!	**1.002^**	0.980*		**1.007^***
TX	**1.015^***	**0.999^***	**1.006^**	**1.021^**	0.977!	0.974*	**1.001^***	**0.998^***	0984*	0.961*	0.978*	

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Table 6. True short-run and long-run cointegration parameters and implications of Hypothesis Tests for 400-lbs heifers.

Dep. Var.	Ind. Var.											
	WOI	MW	CA	NU	ANM	CO	IO	KM	NSD	NE	OK	TX
WOI		0.962*	**0.991ˆ**	**0.999ˆ***	0.952!	0.928*	0.936!	0.940!	0.933*	0.915*	0.941!	0.922!
MW	**0.997ˆ**		**0.989ˆ**	**0.998ˆ**	0.968!	0.957!	0.960!	0.966!	0.962!	0.944!	0.975!	0.945!
CA	**0.996ˆ***	0.959*		**1.000ˆ***	0.953!	0.927*	0.931!	0.937!	0.932*	0.912*	0.937!	0.92!
NU	**0.994ˆ***	0.958*	**0.989ˆ**		0.950!	0.926*	0.931!	0.936!	0.931*	0.911*	0.937!	0.916!
ANM	1.032!	**1.013ˆ**	1.029!	1.036!		0.978!	**0.980ˆ***	**0.987ˆ**	**0.984ˆ**	0.963!	**0.993ˆ***	0.966*
CO	1.037*	1.031*	1.030!	1.039*	**1.006ˆ**		**0.997ˆ**	**1.004ˆ**	**1.001ˆ***	0.980*	**1.011ˆ**	**0.979ˆ**
IO	**1.016ˆ***	**1.007ˆ***	**1.006ˆ**	**1.017ˆ***	**0.981ˆ**	0.970!		**0.991ˆ**	**0.991ˆ**	0.960*	**0.986ˆ**	0.963!
KM	1.025*	**1.016ˆ**	**1.017ˆ***	1.026*	**0.992ˆ**	0.980*	**0.994ˆ***		**0.986ˆ**	0.968!	**0.999ˆ***	0.972!
NSD	**1.023ˆ**	**1.017ˆ***	**1.017ˆ**	**1.026ˆ**	**0.994ˆ**	0.982!	**0.985ˆ**	**0.992ˆ**		0.972!	**1.001ˆ**	0.970!
NE	1.048!	1.043*	1.039!	1.049!	**1.016ˆ**	**1.004ˆ**	**1.012ˆ**	1.017!	1.016*		1.024!	**0.996ˆ**
OK	**1.012ˆ***	**1.012ˆ**	**1.003ˆ***	**1.013ˆ***	**0.985ˆ**	0.974*	0.977*	**0.986ˆ***	0.983!	0.962!		0.963!
TX	1.034*	**1.022ˆ**	**1.027ˆ***	1.033*	**0.998ˆ***	**0.983ˆ***	**0.995ˆ***	**1.000ˆ***	**0.992ˆ**	0.975!	**1.004ˆ***	

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