Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets

by

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Spatial price behavior in regional cattle markets is an important indicator of overall market performance. Markets that are not integrated may convey inaccurate price information that might distort producer marketing decisions and contribute to inefficient product movements. In recent years, cattle markets have undergone dramatic regional shifts in production, slaughtering, and processing (Ward). A concern associated with these shifts is that in this transition some regional markets may not react efficiently to evolving information (Tomek). Previous studies have examined lead-lag relationships among regional cattle prices (Bailey and Brorsen; Koontz, Garcia, and Hudson; Schroeder and Goodwin). Results have generally indicated that prices in the Western Cornbelt region tend to lead prices in other markets. With the disparity in market power between cattle producers and slaughter cattle procurers, there exists at least a potential for cattle buyers to exert influence on regional prices. In the presence of these influences, price changes across different regions may not fully reflect relevant economic conditions. The objective of this paper is to empirically evaluate cointegration and spatial price linkages for several regional slaughter cattle markets and to determine the impacts on cointegration of several market characteristics.

Regional markets may be linked through the competitive profit-seeking activities of commodity arbitragers. Regional arbitrage will ensure that a unique equilibrium is reached where local prices in alternative markets differ by no more than transportation and transactions costs. In this case, the expected returns to regional commodity price speculation are forced to zero and markets are spatially integrated. However, Takayama and Judge have noted that this sort of direct market linkage requires the assumption that all buyers and sellers are located at discrete points and thus that there are no intra-regional transportation costs.

Alternatively, regional markets may be linked through an oligopolistic interdependence whereby firms compete only within a limited service area (Benson and Faminow). In this case, transportation costs tend to limit the area relevant to interfirm competition. This situation may result in market linkages that follow noncompetitive basing-point pricing which is maintained through an organized oligopoly arrangement (Faminow and Benson). Under basing-point pricing, cooperation among firms leads to the establishment of a base price at a central location and the delivered price to any location is the base price plus transportation costs (Scherer). Under a basing-point pricing arrangement, markets will be spatially integrated as the collusive arrangement implies perfectly linked prices at all locations.

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*The authors are assistant professors, Department of Agricultural Economics, Kansas State University. The authors acknowledge the helpful comments of Andrew Barkley, David Bessler, Zach Lea, and Philip Garcia on an earlier version of this manuscript

Ardeni argued that the conventional approaches to testing spatial integration may be methodologically flawed. In particular, previous considerations of spatial market integration may be suspect in that they misrepresent the time series properties of regional price series. An ignorance of serial correlation in tests of market integration may result in tests which are inconsistent and biased. Furthermore, analyses making use of price differentials may suffer from the fact that such differencing and filtering is ad-hoc and inappropriate for a given price series.

Alternative procedures for evaluating spatial market linkages have been developed within the framework of cointegration tests by Granger, Engle and Granger, and Engle and Yoo. The general cointegration procedures appeal to the fact that deviations from equilibrium conditions for two economic variables, which are nonstationary when taken by themselves, should be stationary. The intuition is that, although significant short-run deviations may be observed, economic forces should prohibit persistent long-run deviations from equilibrium. An important implication is that, while individual economic variables may wander extensively, certain pairs of such variables should not diverge from one another in the long run.

Cointegration tests provide a suitable framework in which to consider long-run price relationships among regional cattle markets. Weekly prices in these markets are highly variable and often possess significant trends, suggesting the potential for nonstationarity in long-run price series. However, efficient arbitrage and basing-point pricing conditions in regional markets suggest that regional prices should be closely linked such that prices in alternative markets do not diverge from one another.

Cointegration Tests of Spatial Price Relationships

Consider two series of economic variables, y_t and x_t. Each series by itself is nonstationary and requires a single differencing transformation to produce a stationary series. However, a linear combination of the two series

$$y_t - \alpha - \beta x_t = e_t , \tag{1}$$

produces a residual series e_t which is stationary. In this case, the series y_t and x_t are said to be "cointegrated." More precisely, y_t and x_t are cointegrated of order (1,1) with a cointegrating parameter of β and the linear relationship given by (1) is the "cointegrating regression." A series is defined to be integrated of order (d) if it must be differenced d times to obtain stationarity. Two series are said to be cointegrated of order (d,b) if the individual series are integrated of order (d) and their linear combination is integrated of order (d-b) (Engle and Granger).

Conventional analyses of spatial market integration typically posit a parity relationship between markets in which price changes in one market are reflected by equilibrating changes to prices in alternative markets. Such an equilibrium relationship can be written as:

$$p_t^1 - \alpha - \beta p_t^2 = u_t , \tag{2}$$

where p_t^1 and p_t^2 represent logarithmic commodity prices in two alternative regional markets. The residual error term u_t represents proportional deviations from price parity. If the logarithmic price series are nonstationary but their combination in (2) produces a stationary series for u_t, the series are cointegrated. This suggests an approach for evaluating the spatial price linkages between a pair of regional markets through the use of OLS estimation in connection with the cointegration analysis.

Engle and Granger have proposed a two-step procedure for evaluating the cointegrating properties of a concurrent pair of nonstationary economic time series. The first stage involves estimating the parameters of the cointegrating regression by using standard OLS regression. Estimates of the parameters of the cointegrating regression can then be used to calculate estimates of the residual errors, $\hat{e}_t$, where:

(3) $$\hat{e}_t = y_t - \hat{\alpha} - \hat{\beta}x_t .$$

Upon obtaining estimates of the first stage residual errors, Engle and Granger propose seven tests for cointegration. They also provide critical values for a sample of 100 observations for each proposed test statistic. Each test has as its null hypothesis the case of no cointegration. Rejections of the tests lend support for cointegration in the regional markets. The existence of a variety of tests follows from problems associated with unit root tests and parameters which are unidentified under the null, and because the power of any individual test may vary across empirical circumstances (Engle and Granger).

The first test for cointegration suggested by Engle and Granger involves the use of the standard Durbin-Watson test statistic from the first stage OLS estimate of the cointegrating regression (CRDW):

(4) $$CRDW = (\Sigma_{t=2}^{T} (\hat{e}_t - \hat{e}_{t-1})^2) \ / \ (\Sigma_{t=1}^{T}\hat{e}_t^{\,2}) .$$

The null hypothesis of no cointegration is rejected for values of CRDW which are significantly different from zero.

The second and third cointegration tests proposed by Engle and Granger utilize Dickey-Fuller (1979, 1981) type regressions to consider whether the autoregressive parameter for the estimated residuals from the cointegrating regression is significantly different from one. If there is a unit root, then the two series are not cointegrated. The first Dickey-Fuller type test depends on estimates of:

(5) $$\Delta\hat{e}_t = -\phi\hat{e}_{t-1} + \epsilon_t ,$$

where $\hat{e}_t$ is the first stage estimate of the residual from the cointegrating regression and Δ implies the first difference. A test statistic (DF) is constructed from the ratio of the estimated ϕ to its standard error (a 't-ratio'). The null hypothesis of no cointegration is rejected for values of ϕ which are significantly different from zero. The second Dickey-Fuller type test is analogous to the first except that it is augmented by the addition of p lagged values of the difference residual errors:

(6) $$\Delta\hat{e}_t = -\phi\hat{e}_{t-1} + \theta_1\Delta\hat{e}_{t-1} + \ldots + \theta_p\Delta\hat{e}_{t-p} + \epsilon_t .$$

The addition of the lagged differences is to ensure that the second stage residuals of the augmented Dickey Fuller regression, ϵ_t, are serially uncorrelated. A test statistic (the ADF) is constructed from this regression by again taking the 't-ratio' for the estimate of ϕ.

The fourth and fifth cointegration tests involve the estimation of a vector error correction mechanism for the cointegrating regression:

(7)
$$\Delta y_t = \beta_1 \hat{e}_{t-1} + \epsilon_{1t} , \text{ and}$$
$$\Delta x_t = \beta_2 \hat{e}_{t-1} + \gamma \Delta y_t + \epsilon_{2t} .$$

A test of no cointegration is based on the joint significance of the coefficients β_1 and β_2. A test statistic (RVAR) is calculated by taking the sum of the squared 't-ratios' of β_1 and β_2. If β_1 and β_2 are jointly different from zero, the null hypothesis of no cointegration is rejected. The fifth cointegration test statistic (the ARVAR) is constructed in an analogous manner from an augmented system with added lagged values of differences of the economic variables to ensure white noise in the error terms.

The final two cointegration tests use a vector autoregression which is not constrained to satisfy the cointegration constraints. The first regresses differenced values of each of the variables on levels of the variables:

(8)
$$\Delta y_t = \theta_1 y_{t-1} + \theta_2 x_{t-1} + \epsilon_{1t} , \text{ and}$$
$$\Delta x_t = \theta_3 y_{t-1} + \theta_4 x_{t-1} + \gamma \Delta y_t + \epsilon_{2t} .$$

The null hypothesis of no cointegration is rejected if parameters θ_1 and θ_2 of the first equation and θ_3 and θ_4 of the second equation are jointly found to be significantly different from zero. A convenient test statistic (the UVAR) can be constructed by taking twice the sum of the F tests of joint significance of the θ_i's in each equation. The final cointegration test statistic (the AUVAR) is constructed in an analogous manner from an augmented system with an additional p lags of Δy_t and Δx_t added.

Factors Affecting Cointegration and Spatial Arbitrage Opportunities

Cointegration tests provide evidence of how closely prices at different markets are linked. Cointegration is not absolute but is present to a degree. For a given time period, two markets' price series which move together will be highly cointegrated. Conversely, two price series which diverge for extended periods will have a low degree of cointegration. Of interest are factors that influence the degree of cointegration among regional cattle markets.

A primary factor which would be expected to influence cointegration is an agent's cost and risk associated with trade between markets (Buccola, 1989). In general, we would expect all markets to be linked with one another through intermediary markets. However, these linkages are expected to weaken as the distance between markets increases. Mulligan and Fik have formalized the decaying nature of spatial price linkages as distance between markets increases in an analytical model of spatial competition. The costs associated with trade between spatially separated cattle markets will be directly related to the road distance between the markets. Thus, it is expected that distance between markets will have a negative influence on the level of cointegration.

A second factor contributing to arbitrage risk between markets, and thereby influencing the degree of cointegration, is the amount of market information reflected in prices at a particular market. Liquid terminal markets have a more complete set of market information in each trade than do decentralized direct trade markets (Lang and Rosa). Price discovery in terminal markets occurs by the interaction of several well-informed packer buyers and commission selling agents. Conversely, direct trades are often made between a single buyer and a single (often times less informed) seller. Buccola (1985) finds that centralized discovered market prices are more efficient than decentralized market prices. Thus, with all else constant, terminal markets may be more highly cointegrated than direct trade markets.

Market volume is also expected to influence trade activity across market areas. A concern with low-volume markets is that they have a higher potential for exhibiting unwarranted price behavior (Tomek). However, the concentration of cattle feeding and the existence of alternate outlets in the immediate geographic region are arguably more important influences on regional trade activities than the absolute volume traded at a particular location. Thus, the concentration of cattle feeding in a particular region could have an impact on the degree of cointegration. The influence of market volume on cointegration however is not clear. That is, the thin market issue would imply that markets with higher volume could tend to be more highly cointegrated. However, market regions with higher concentrations of cattle feeding may also operate independently of markets in other regions.

A final factor which may influence spatial cointegration in regional cattle markets is the degree of packer concentration. Carlton has shown that price stability increases with concentration in industrial markets. With increased concentration of cattle packers operating across several markets, cointegration of these markets could increase. This is especially likely if the highly concentrated firms compete in the same market regions, as is currently the case in the slaughter cattle markets (Ward).

Assessment of the effects of these factors can be considered through:

$$TS^j_{ikt} = \beta_0 + \beta_1 Type_i + \beta_2 CR_t + \beta_3 Volume_{ikt} + \beta_4 Distance_{ik} + e^j_{ikt} , \quad (9)$$

$$\text{for } i = 1,\ldots,10; \quad j = 1,\ldots,7; \quad \text{and } t = 1,\ldots,T;$$

where TS^j_{ikt} represents the j^{th} cointegration test statistic between markets i and k ($j = 1,\ldots,7$ for CRDW,...,AUVAR), $Type_i$ is an indicator variable equal to one if market i is direct and zero if it a terminal market, CR_t is the four-firm beef slaughter concentration ratio in time t, $Volume_{ikt}$ is slaughter cattle volume in market i's region relative to that of market k in time t, $Distance_{ik}$ is miles between market i and market k, and e^j_{ikt} is a residual error. The preceding discussion, hypothesizes the parameters of equation (9) having the following signs: $\beta_1 < 0$, $\beta_2 > 0$, β_3 is uncertain, and $\beta_4 < 0$.

Data Description

Weekly price series for Choice, yield grade 2-4, 900-1100 pound slaughter steers were assembled for eleven U.S. regional markets over the period January 1980 through September 1987, yielding a total of 400 weekly observations. The data were collected from the Chicago Mercantile Exchange and from the U.S. Department of Agriculture's Livestock, Meat, and Wool Market News. Prices were collected for direct cattle markets of California, Colorado, Illinois, Iowa-Southern Minnesota, Western Kansas, Eastern Nebraska, and Texas Panhandle and for terminal markets of Lancaster, Pennsylvania; Omaha, Nebraska; South St. Paul, Minnesota; and Sioux City, Iowa. These markets were selected to include a geographic dispersion of markets which differ in pricing methods (direct versus terminal) and cattle volumes. Several of the price series had a small number of missing observations (less than 0.6% of the total data points). Missing prices were proxied by predicted values from a regression of the series on the 1100 to 1300 pound steer price at the same location during the same week.

Empirical Results for Cointegration Tests

The empirical tests of cointegration are constrained in that the relevant critical values have been defined by Engle and Granger only for samples of 100 observations. In this light, our applications are to four subsets of the overall data consisting of 100 observations each, which roughly correspond to the two year periods 1980-1981, 1982-1983, 1984-1985, and 1986-1987. This approach, while being consistent with the data requirements for the statistical tests of cointegration, also allows us to test the impact of changes in industry concentration and relative cattle feeding concentrations across regions.

The empirical tests of cointegration outlined in the preceding section must be preceded by a test which verifies that the individual economic variables under consideration are nonstationary. The Dickey-Fuller unit root test was utilized to test the null hypothesis of a unit root in each of the price series for each period. The test was conducted utilizing lag orders selected by the minimum value of Akaike's final prediction error (FPE). The results supported the presence of a unit root in every case and thus provided strong evidence of nonstationarity in each of the price series.

Cointegration regressions of the form given by equation (2) were estimated using OLS. In that we are considering eleven principal markets, 110 different pairwise comparisons are conceivable. For the sake of brevity, we limit our considerations of spatial cointegration to integration comparisons between ten of the regional markets and the Eastern Nebraska direct, Western Kansas direct, and Omaha terminal markets. While these choices are arbitrary, these markets are especially interesting because of their central location and relatively large marketing volumes. In addition, this consideration allows us to examine differences which exist in spatial price relationships between terminal and direct markets. We report only the results for Eastern Nebraska. However, in the following discussions, we highlight any differences between Eastern Nebraska and the other markets.

Cointegrating parameters and standard error estimates for the Eastern Nebraska market are presented for each of the four periods in Table 1. In that there is no a priori choice of which price should be the dependent variable in a cointegration regression, each comparison is conducted under two alternative specifications. The first specification regresses prices in each of the i regional markets on the Eastern Nebraska price. The designation is reversed in the second specification with the Eastern Nebraska price being regressed on each of the remaining i market prices. It is essential to again

Table 1. OLS Estimates of Cointegrating Parameters[a]

Market	Period	β_I	Standard Error	β_{II}	Standard Error
California Direct	I	.6419	.0395	1.1369	.0699
	II	.8647	.0284	1.0459	.0344
	III	.9080	.0241	1.0301	.0274
	IV	.9080	.0336	.9707	.0360
Colorado Direct	I	.9247	.0333	.9595	.0346
	II	.9166	.0233	1.0258	.0261
	III	.9656	.0188	.9986	.0194
	IV	.9590	.0245	.9800	.0250
Illinois Direct	I	.9822	.0234	.9643	.0230
	II	.9983	.0241	.9477	.0229
	III	1.0407	.0176	.9346	.0158
	IV	.9734	.0246	.9669	.0244
Iowa-S. Minn. Direct	I	1.0331	.0224	.9254	.0201
	II	.9921	.0207	.9667	.0202
	III	1.0473	.0160	.9335	.0143
	IV	.9685	.0105	.9986	.0186
Lancaster Terminal	I	.7435	.0636	.7837	.0670
	II	.7446	.0243	1.2156	.0397
	III	1.0387	.0334	.8741	.0281
	IV	.9923	.0385	.8780	.0341
Omaha Terminal	I	.9968	.0245	.9473	.0232
	II	.9330	.0195	1.0276	.0215
	III	1.0028	.0213	.9552	.0203
	IV	.9430	.0185	1.0218	.0201

[a]Each market is compared with Eastern Nebraska. β_I refers to estimated cointegrating parameters from Specification I ($p_i = \alpha + \beta_I p_{Nebraska}$) and β_{II} refers to estimated cointegrating parameters from Specification II ($p_{Nebraska} = \alpha + \beta_{II} p_i$).

Table 1. (continued)[a]

Market	Period	β_I	Standard Error	β_{II}	Standard Error
St. Paul Terminal	I	1.0528	.0277	.8894	.0234
	II	.9718	.0217	.9812	.0219
	III	1.0016	.0171	.9707	.0166
	IV	.9946	.0200	.9673	.0194
Sioux City Terminal	I	1.0391	.0291	.8936	.0250
	II	.9905	.0207	.9678	.0203
	III	1.0158	.0199	.9489	.0185
	IV	1.0218	.0212	.9389	.0195
Texas Panhandle Direct	I	.8747	.0290	1.0323	.0342
	II	.9169	.0232	1.0262	.0260
	III	.9538	.0219	.9971	.0229
	IV	.9203	.0262	1.0068	.0286
W. Kansas Direct	I	.8727	.0326	1.0083	.0376
	II	.9113	.0243	1.0259	.0274
	III	.9286	.0202	1.0289	.0224
	IV	.9290	.0261	.9991	.0281

[a]Each market is compared with Eastern Nebraska. β_I refers to estimated cointegrating parameters from Specification I ($p_i = \alpha + \beta_I p_{Nebraska}$) and β_{II} refers to estimated cointegrating parameters from Specification II ($p_{Nebraska} = \alpha + \beta_{II} p_i$).

note that, while the estimates of the cointegrating parameters are consistent, the verification of nonstationary price series implies that the estimated standard errors are not consistent. This necessarily precludes using these results for formal hypothesis testing in regard to the value of the cointegrating parameters.

The seven cointegration tests were conducted for each specification of the ten market comparisons over each of the four periods. The augmented tests were conducted with p=4 lagged values of Δy_t and Δx_t. The cointegration test results for the first specification are presented in Table 2. In general, the results would appear to question the existence of cointegration in the regional cattle markets. Cointegration is supported by 155 of the 280 different cointegration tests for the Eastern Nebraska market. As might be expected, cointegration seems to be the strongest for the markets which are in relatively close proximity to Eastern Nebraska. However, cointegration appears to diminish as the distance between an individual market and the Eastern Nebraska reference market increases. Cointegration appears to be strongest between Eastern Nebraska and the Omaha, St. Paul, Sioux City, Iowa-Southern Minnesota, Illinois, and Lancaster, Pennsylvania markets. In each of these cases, 17 or more of the 28 tests across the four time periods reject the null hypothesis of no cointegration. The Texas Panhandle, California, and Western Kansas markets display a limited degree of cointegration with the Eastern Nebraska market with 10 or less of the 28 tests supporting cointegration. Schroeder and Goodwin and Koontz, Garcia, and Hudson found that price changes in Eastern Nebraska and Iowa lead price changes in Illinois, Lancaster, Omaha, St. Paul, Sioux City, and other markets. This result is consistent with cointegration among these markets.

The Western Kansas direct and Omaha terminal markets had similar results to those of Eastern Nebraska. Of the 280 cointegration tests, 111 supported cointegration with Western Kansas and 176 supported cointegration with Omaha. The Western Kansas market was primarily cointegrated with the nearby Colorado and Texas markets. The Omaha market was, for the most part, cointegrated with the same markets as Eastern Nebraska.

Changes in the degree of cointegration over time in the regional markets are apparent with the degree of cointegration in regional cattle markets increasing over the past several years. In the first two periods (1980-81 and 1982-83), only 34 of the 70 cointegration tests support cointegration. However, in the 1984-85 and 1986-87 periods, respectively, 38 and 49 of the 70 tests support cointegration. This suggests that regional market cointegration was enhanced during a time when increased concentration of the beef industry was occurring.[1] These results were similar for Western Kansas and Omaha.

In all, the empirical applications suggest that cointegration of regional cattle prices is limited. This may suggest the existence of segmented markets over which arbitrage opportunities are necessarily precluded by barriers such as high transactions costs. Alternatively, the results may

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[1]Cointegration test results for the alternative specification in which the designations of independent and dependent variables are reversed are not reported here. Although subtle differences existed, the overall results appear to be transparent to the particular specification used in the cointegration tests.

Table 2. Cointegration Test Results: Specification I ($p_i = \alpha + \beta p_{Nebraska}$)[a]

Market	Test	Test Statistics: Period I	Period II	Period III	Period IV
California Direct	CRDW	.357	.454*	.469*	.389*
	DF	4.111*	3.894*	3.604*	3.226
	ADF	2.621	2.605	2.820	2.516
	RVAR	18.595*	15.531*	12.635	11.144
	ARVAR	8.242	7.829	7.740	7.540
	UVAR	19.235*	17.190	14.090	12.846
	AUVAR	10.563	10.607	11.745	10.198
Colorado Direct	CRDW	.338	.458*	.564*	.636*
	DF	3.840*	3.675*	3.995*	4.307*
	ADF	3.013	2.335	2.464	3.372*
	RVAR	14.326*	17.891*	16.595*	20.435*
	ARVAR	8.863	6.157	6.693	10.933
	UVAR	14.762	20.160*	18.165	21.756*
	AUVAR	10.697	10.007	10.569	12.514
Illinois Direct	CRDW	.658*	.501*	.685*	.503*
	DF	4.451*	3.751*	4.470*	3.820*
	ADF	3.698*	2.116	3.385*	3.058
	RVAR	29.806*	14.721*	30.208*	27.860*
	ARVAR	10.989	5.333	10.808	20.474*
	UVAR	32.526*	16.526	32.658*	31.438*
	AUVAR	13.845	9.710	16.644	25.518*
Iowa-S. Minn. Direct	CRDW	.493*	.506*	.778*	.685*
	DF	3.726*	3.727*	4.758*	4.641*
	ADF	2.901	2.200	3.216*	4.063*
	RVAR	14.078*	14.770*	23.973*	22.328*
	ARVAR	7.899	5.588	11.833*	23.868*
	UVAR	14.761	16.628	25.557*	23.826*
	AUVAR	9.327	8.941	17.938*	26.881*
Lancaster Terminal	CRDW	.243	.922*	.603*	.485*
	DF	2.572	5.388*	4.350*	3.668*
	ADF	1.973	2.933	2.538	2.837
	RVAR	19.755*	33.055*	18.234*	26.295*
	ARVAR	11.756	7.386	6.415	16.387*
	UVAR	26.503*	34.540*	19.775*	29.556*
	AUVAR	25.091*	10.413	11.215	21.615*

Table 2. (continued)[a]

Market	Test	Period I	Period II	Period III	Period IV
		Test Statistics			
Omaha Terminal	CRDW	.552*	.713*	.405*	.743*
	DF	3.959*	4.611*	3.072	4.829*
	ADF	2.813	2.052	2.855	3.605*
	RVAR	21.858*	36.220*	28.602*	42.119*
	ARVAR	8.277	4.277	12.209*	20.886*
	UVAR	24.013*	38.839*	32.827*	45.062*
	AUVAR	10.212	9.010	19.591*	24.789*
St. Paul Terminal	CRDW	.633*	.621*	.761*	.694*
	DF	4.280*	4.217*	4.783*	4.726*
	ADF	2.815	1.985	3.082	3.879*
	RVAR	21.305*	18.901*	43.104*	38.599*
	ARVAR	6.649	4.288	15.767*	26.195*
	UVAR	22.468*	20.773*	45.699*	41.496*
	AUVAR	9.396	7.670	23.784*	31.090*
Sioux City Terminal	CRDW	.480*	.618*	.677*	.941*
	DF	3.777*	4.239*	4.471*	5.534*
	ADF	2.420	1.979	2.614	4.302*
	RVAR	15.490*	24.684*	23.466*	34.830*
	ARVAR	5.009	3.287	6.822	18.213*
	UVAR	16.329	26.968*	25.193*	36.573*
	AUVAR	6.380	6.733	10.834	20.679*
Texas Pan. Direct	CRDW	.395*	.463*	.392*	.439*
	DF	3.888*	3.619*	3.212	3.477*
	ADF	3.280*	2.790	2.258	3.151
	RVAR	14.869*	14.661*	11.882	11.864
	ARVAR	9.736	8.555	6.062	9.198
	UVAR	15.366	16.516	13.724	13.209
	AUVAR	11.043	11.622	10.375	10.722
W. Kansas Direct	CRDW	.390*	.415*	.389*	.400*
	DF	3.765*	3.404*	3.244	3.292
	ADF	2.651	2.770	2.262	2.808
	RVAR	14.243*	13.241	10.743	12.559
	ARVAR	7.264	8.192	5.915	7.785
	UVAR	15.041	15.150	12.324	14.142
	AUVAR	10.340	11.264	9.917	9.410

[a]Eastern Nebraska is the central market. A '*' denotes rejection of the null hypothesis of no cointegration at the 5% level. Critical (5% level) values of test statistics are CRDW 0.386; DF 3.37; ADF 3.17; RVAR 13.6; ARVAR 11.8; UVAR 18.6; AUVAR 17.9.

indicate the absence of collusive basing-point pricing behavior. However, the results also indicate that structural changes in the beef industry throughout the 1980s may have been paralleled by increased cointegration of spatial prices. This may imply increased pricing efficiency or an increased tendency toward coordinated basing-point pricing by meatpackers.

An Analysis of Factors Influencing Spatial Price Linkages

The preceding evaluation indicated that regional cattle markets are less than fully cointegrated. In this section, a formal assessment of factors which may influence cointegration is considered. In particular, a regression-type analysis of equation (9) is undertaken to evaluate the effects of market type, industry concentration ratios, relative slaughter volumes, and spatial distances on cointegration relationships.

Ordinary regression estimates of equation (9) cannot be utilized to provide inferences regarding the influences of such factors on cointegration because the test statistic TS^j_{ikt} is a generated regressand which follows a nonstandard (nonnormal) distribution. In this light, an alternative estimation using bootstrapping techniques (Efron) is undertaken. Bootstrapping is a nonparametric procedure which requires only that the residual errors be independently and identically distributed, regardless of their distribution (Prescott and Stengos). Bootstrapped coefficient estimates and standard errors can be used to provide consistent inferences regarding the significance of the aforementioned factors.

Bootstrapped coefficient estimates and implied t-ratios for each of the seven cointegration test statistics from the application to Eastern Nebraska are reported in Table 3. The estimates were obtained from 1,000 replications. The equations explained from 29% to 54% of the variation in the cointegration test statistics. The coefficient on market type is negative for six of the seven tests (three are significantly different from zero at the 5% level), suggesting that direct markets are less likely to exhibit cointegration with the Eastern Nebraska market. This result was not consistent for cointegration test statistics obtained from the Kansas and Omaha market comparisons. The coefficient on market type was not statistically different from zero (5 % level) for any of the 14 test statistics for these two markets. Thus, it does not appear as though a general difference is present in cointegration market linkages between terminal and direct markets.

The four-firm packer concentration ratio is highly significant in most cases and is positive in every case for the Eastern Nebraska market. Similar results were obtained for Western Kansas and Omaha. This result provides empirical evidence that increasing concentration in the beef-slaughter industry paralleled enhanced spatial market cointegration. This may suggest that increased concentration has enhanced the spatial efficiency of regional cattle markets. Alternatively, this may imply an increased tendency toward the use of basing-point pricing strategies in regional cattle markets.

Relative slaughter volume in the region appears to have a negative effect on cointegration, suggesting that larger markets exhibit a greater degree of price independence than do smaller markets. The impacts of relative slaughter volume in the Omaha market were consistent with those of Eastern Nebraska. Conversely, none of the relative slaughter volume coefficients were

Table 3. Bootstrapped Coefficient Estimates for Cointegration Test Statistics[a]

Independent Variable	Dependent Variable						
	CRDW	DF	ADF	RVAR	ARVAR	UVAR	AUVAR
Market Type	-0.0924	-0.2708	0.1723	-8.9350	-0.6149	-9.9856	-1.9948
	(-2.20)*	(-1.47)	(1.00)	(-4.12)*	(-0.44)	(-4.30)*	(-1.13)
Packer CR_4	0.0055	0.0128	0.0296	0.2822	0.3812	0.3065	0.3828
	(2.43)*	(1.27)	(3.09)*	(2.30)*	(4.68)*	(2.52)*	(3.89)*
Relative Slaughter	-0.1812	-0.7988	-0.4108	-6.9376	-4.3527	-7.1615	-5.4025
	(-2.95)*	(-2.90)*	(-1.60)	(-2.18)*	(-1.96)*	(-2.11)*	(-2.07)*
Distance[b]	-0.0001	-0.0005	-0.0004	-0.0058	-0.0027	-0.0057	-0.0022
	(-3.05)*	(-2.38)*	(-1.98)*	(-2.45)*	(-1.61)	(-2.21)*	(-1.10)
Intercept	0.4918	4.1960	1.6280	19.0730	-5.5408	20.4230	-0.7694
	(3.92)*	(7.45)*	(3.05)*	(2.87)*	(-1.24)	(3.04)*	(0.14)
R-Squared	.47	.34	.29	.53	.44	.54	.40

[a]Numbers in parentheses are t-ratios. A "*" indicates significance at the five percent level.
[b]Approximate Distance from the Eastern Nebraska Market.

significant for the Western Kansas market. Finally, the most consistent result across all markets was that the degree of price cointegration between two markets is negatively influenced by the spatial distance between the markets. Twenty of the 21 coefficients on the distance variable were negative with 14 of the 20 being significant at the 5% level. This result is consistent with the decaying nature of spatial linkages over increasing distances which is predicted by spatial competition models (Mulligan and Fik).

Concluding Comments

Overall, cointegration appears to be somewhat limited in regional cattle markets. Empirical tests indicate that regional fed cattle prices have not been fully cointegrated during the 1980s. That is, the prices across different market regions have exhibited periods of at least some degree of divergence between one another. Does this suggest that these markets are inefficient? Or, does this imply the absence of non-competitive basing-point pricing practices? Finally, can we explain why certain pairs of markets are highly cointegrated while others are not?

The intensity of cointegration is related to distance between markets. Markets separated by long distances have lower degrees of cointegration than do markets in close proximity. Markets separated by long distances are most likely linked in an indirect distance-decaying type of relationship through markets located between them. In this regard, a series of price changes may feed across spatial markets with a degree of lag. Given the high costs and risks associated with transporting fed cattle over long distances, markets separated by long distances may have prices which tend to diverge from each other for extended periods. This divergence however, may be warranted by market conditions and may not be large enough to permit profitable trade through regional movements of cattle.

Over time, cointegration has increased in the markets analyzed in this study. This increase in cointegration has paralleled increasing concentration in cattle slaughtering. Based on these results, one cannot conclude that increased concentration implies increased cointegration of markets. However, given that the largest packers compete for fed cattle in the same market regions, it seems reasonable that increased concentration reduces trade and information costs across markets and may contribute to spatial cointegration in the markets in which these firms compete. It is also possible that packers have coordinated price behavior across regions as market concentration has increased.

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