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AN EXAMINATION OF REGIONAL FED CATTLE PRICE DYNAMICS

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Department of Agricultural Economics
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Abstract

The lead-lag relationships present in the regional price discovery process are important indicators of market performance. Differences across markets in the speed of adjustment to evolving information may have implications for pricing efficiency within these markets. This study estimates intertemporal price relationships among 11 regional slaughter cattle markets. Larger-volume markets, located in the major cattle feeding regions, were the dominant price discovery locations. Price adjustments across markets were completed in one to two weeks in the large-volume markets located relatively close to each other and in two to three weeks in the more remote, smaller-volume markets.

An Examination of Regional Fed Cattle Price Dynamics

Commodity price at a particular location is determined by local supply and demand conditions. Spatial arbitrage should force the differences in prices across locations to be no greater than transportation costs. Thus, with efficient arbitrage activities, market prices will approach a unique spatial equilibrium. However, spatial arbitrage may not be instantaneous. That is, the physical arbitrage process may take time to complete, which contributes to lags in the spatial price discovery process. The purpose of this study is to determine the dynamic price relationships among regional slaughter cattle markets.

The lead-lag relationships present in the regional price discovery process are important indicators of market performance. Differences across markets in the speed of adjustment to evolving information may have implications for pricing efficiency within these markets. Garbade and Silber called cases of prices in one market leading those of another market a dominant-satellite relationship. If a dominant-satellite relationship exists, the satellite markets may be responding less efficiently to evolving information. Alternatively, some markets may be "sources" of significant amounts of evolving market information, whereas other markets may have insufficient activity to generate much new information. This also may cause price discovery at some markets to lead that of other markets.

The speed of information transmission may have important implications for market participants. To the extent that cattle feeders make short-term marketing decisions based upon current price signals, markets reacting "too slowly" to evolving information result in marketing inefficiencies. If markets react excessively slowly to new information, the potential for profitable arbitrage may exist. Thus, the speed of price adjustment provides information about the integration of the markets and may help define relevant market areas.

Considerable research has been done on price discovery in the beef complex. Several researchers investigated price transmissions between farm, wholesale, and retail beef prices (Boyd and Brorsen; Heien; Miller; Schroeder and Hayenga). These studies show that retail prices lagged behind prices at other market levels. Other research has examined the intertemporal relationships between slaughter cattle cash and futures prices (Oellerman and Farris; Koontz et al.; Weaver and Banerjee). The general conclusion of these studies is that information flows between cash and futures markets are fairly rapid.

Limited research has investigated the intertemporal nature of regional slaughter cattle prices. Bailey and Brorsen used multivariate autoregressive models to examine the dynamics of weekly slaughter steer prices from 1 January 1978 through 4 June 1983 in the regions of Utah-Eastern Nevada-Southern Idaho; Colorado-Kansas; Texas Panhandle; and Omaha, Nebraska. They found that the Texas Panhandle region prices led prices in the other three regions but that there was feedback from the Omaha market. They surmised that Texas prices were generating the clearest signals of market conditions. Koontz et al. performed pairwise Granger causality tests on nine weekly regional slaughter cattle markets over the 1973 through 1984 period. They concluded that, in general, the Central Iowa market reacted the fastest to evolving market information, though some markets exerted feedback to the Iowa market.

These previous studies provide evidence that certain markets react more rapidly to new information than others. However, two studies raise several questions. First, Bailey and Brorsen concluded that the Texas Panhandle prices were a leading source of price information. However, the findings of Koontz et al. suggest that the Iowa-Southern Minnesota price discovery process leads the Texas Panhandle region, particularly in the 1981-1984 period. Thus, although the two studies differed in several ways, there appears to be some evidence that the Texas Panhandle region may not be the dominant market when compared with the markets in the western cornbelt.[1] However, the conclusions reached by Koontz et al. may be dependent upon the pairwise nature of their tests as opposed to examining a complete multivariate system. The multivariate approach of Bailey and Brorsen accounts for the joint effects of all regions being examined.

This study expands upon and extends the work of these earlier studies in several important manners. First, more markets (11) are examined than Bailey and Brorsen (4) or Koontz et al. (9). Second, a multivariate vector autoregressive (VAR) empirical model (similar to what Bailey and Brorsen utilized) is employed to examine the temporal market price linkages. The multivariate VAR is a tool that allows for a dynamic analysis of the entire set of prices in a complete system. Third, the time period examined is more recent and includes prices through 1987, which allow us to investigate whether the continuing regional shifts in cattle feeding have affected the relative

[1] The two studies differ in three important ways 1) different time periods are analyzed (Bailey and Brorsen examined the 1978 to middle 1983 period, Koontz et al. examined the 1973-1984 period); 2) the empirical techniques differ (Bailey and Brorsen used a multivariate autoregressive model, Koontz et al. used pairwise Granger causality models); and 3) the markets examined differ (Bailey and Brorsen examined four market regions and Koontz et al. examined nine regions, the only markets common to the two studies were Omaha and Texas Panhandle).

importance of different regions in the price discovery process. Finally, we explicitly compare several centralized terminal markets and noncentralized direct trade markets to test for general differences in their influence on the price discovery process (Buccola).

Model Specification and Procedures

The procedure used to examine the dynamic nature of regional fed cattle markets utilizes a multivariate VAR system. A VAR system is often specified by modeling each variable as a function of all variables in the system in a distributed lag framework. This specification reduces spurious a priori restrictions on the dynamic relations (Sims). The VAR system is:

$$Y(t) = \sum_{k=1}^{K} \begin{bmatrix} a_{11}(k) \cdots a_{1n}(k) \\ . \\ . \\ . \\ a_{n1}(k) \cdots a_{nn}(k) \end{bmatrix} Y(t-k) + E(t) \qquad (1)$$

where t refers to time (t = 1,2, ...,T), Y(t) is an nx1 vector of prices, n is the number of markets in the system, K is the number of lags in the system, $a_{ij}(k)$ are parameters to be estimated (i,j = 1, ...,n), and E(t) is a vector of random errors. VAR systems have had widespread use in examination of dynamic systems in economic analyses (see for example, Bessler; Featherstone and Baker; Sims).

To estimate the system, the lag length (K)(i.e., the order of the VAR system) must be selected. The order of the VAR system was determined using the modified log likelihood ratio test (Sims). This test was performed on increasing lags, and the largest lag length for which the null hypothesis was rejected was the lag length selected (Nickelsburg). The same number of lags was used for each variable in all equations. This lag length is used to infer the speed of price adjustment across the regional markets. The Ljung-Box Q statistic was used to test for significant serial correlation among the residuals of the estimated models. In the estimation all price data were first differenced to remove trends from the series.

Causal flows in price adjustments across regional markets were tested using the standard Granger F-tests. This procedure involves testing the null hypothesis for the parameters in equation (1) that $a_{12}(1) = a_{12}(2) =, \ldots, = a_{12}(K) = 0$. If the null is rejected, then discovery of variable 2 leads discovery of variable 1.

In addition, to test the influence of market volume, distance between markets, and type of market (direct vs. terminal) on the price dynamics, the following regression model is estimated:

$$F_{ij} = b_0 + b_1 \text{ Distance}_{ij} + b_2 \text{ Type}_{ij} + b_3 \text{ Volume}_{ij} + e_{ij} \qquad (2)$$

$$i,j = 1, \ldots, 11; \; i \neq j$$

where F_{ij} is the F-statistic testing the blockwise significance of the lagged prices from market i in the VAR equation with the price in market j as the dependent variable, Distance_{ij} is the logarithm of the approximate road miles between markets, Type_{ij} is a dummy variable equal to 1 if market i is a direct market and equal to zero if it is a terminal market, Volume_{ij} is the average annual volume in market i relative to market j over the period of analysis. Although F_{ij} is measured with error, least-squares estimation of equation (2) can provide consistent parameter estimates. Equation (2) is estimated using seemingly unrelated regression procedures, a more efficient method than ordinary least squares, in order to account for correlation among error terms across different time periods.

It is expected that distance between markets will have a negative influence on the F-statistic. That is, as the distance between markets increases it is expected that the degree of feedback in price will decline due to lessened opportunities for direct arbitrage between these markets. It is also expected that direct markets will have a stronger tendency to lead prices at terminal markets than vice versa. Though certainly subject to empirical testing, it would seem reasonable that given the declining importrance of terminal markets in slaughter cattle trade (Paul), it is likely that termial markets would be less significant in affecting prices in direct markets than the reverse. Thus, the sign of the coefficient on market type is expected to be positive. The $volume_{ij}$ variable in equation (2) is measured as the ratio of the average annual cattle volumes between market i and market j. If price leadership and generation of new price information tends to be present more in the larger-volume markets, then it is expected that $Volume_{ij}$ will have a positive influence on F_{ij}.

The results of the estimated VAR are further analyzed by converting the system to a moving-average representation, using Choleski factorization. This conversion allows us to use the VAR to forecast the time path response of the system to exogenous shocks to any one of the variables (Hakkio and Morris). These time path responses (referred to as impulse responses) are used to examine the adjustments across different markets to an unanticipated price shock in any one market. The conversion of the VAR to a moving-average representation also allows us to examine the forecast error decomposition. This decomposition explores the degree of exogeneity of a set of variables relative to another set of variables by computing the percentage of the expected k-steps-ahead squared prediction error of a variable produced by an innovation in another variable (Hakkio and Morris). In the problem at hand, the error decomposition allows us to examine which of, and to what extent, the regional cattle markets are exogenous or endogenous relative to each other in the short-run.

Data

Weekly average price data for 900-1100 pound, choice, yield grade 2-4, slaughter steers were collected for 11 U.S. regional markets over the 1977 through 1987 period from the Chicago Mercantile Exchange summaries of the USDA's Livestock Meat and Wool Market News. Price data were assembled for the direct trade cattle markets of California, Colorado, Illinois, Iowa-Southern Minnesota, Western Kansas, Eastern Nebraska, and Texas Panhandle. Price data also were obtained for terminal markets of Lancaster, Pennsylvania; Omaha, Nebraska; South St. Paul, Minnesota; and Sioux City, Iowa. The markets were selected to represent a geographic dispersion of locations that included the primary markets in the largest volume cattle feeding areas, as well as some smaller volume markets. Price data for both direct and terminal markets were collected (some covering the same general trade areas) to allow us examining differences in the price discovery process between these two marketing methods. Some of the price series had a small number of missing observations. The total number of missing prices was 28 which is less than 0.5% of the total data points. Proxies for the missing prices were determined by the predicted values from a regression of each series on the 1100 to 1300 pound steer price at the same location during the same week.

Results and Discussion

This section uses the VAR system presented in equation (1) to analyze the dynamic spatial price relationships between regional slaughter cattle markets. To examine whether regional price relationships have changed over time, given the shifts in regional cattle production and slaughter and the increases in beef packing and slaughtering industry concentration (Ward), the data were split into three subperiods of equal length. Period I covered 1976 through 1979, period II covered 1980 through 1983, and period III covered 1984 through 1987. The changing patterns in market volume that occured over these periods are reported in table 1. The markets that increased in total and relative cattle volume over the three periods included direct markets of Colorado, Western Kansas, Eastern Nebraska, and the Texas Panhandle. These four markets accounted for 57.4% of the cattle sold in the 11 markets examined in the 1976-1979 period, and they increased to representing 74.6% of the cattle volume in these markets in the 1984-1987 period. This suggests that significant movements of cattle feeding from the cornbelt markets to the plains and southwest plains were occurring during this period. All of the terminal markets examined declined in volume over the 1976 through 1987 period. This trend is consistent with more general findings of Paul that terminal markets have declined from handling saleable receipts for nearly one-third of all U.S. commercial cattle slaughtered during the 1975-79 period to handling less than 20% of commercial cattle slaughtered during the 1985-87 period.

The VAR systems were estimated using OLS. The adjusted R-square values for the models ranged from 0.35 for the Iowa-Southern Minnesota market to 0.55 for the St. Paul market in period I, from 0.18 for the California market to

0.38 for the Colorado market in period II, and from 0.22 for the Eastern Nebraska market to 0.40 for the Texas Panhandle market in period III.

The estimated VAR systems had similar structures for the three periods examined. The 1976-79 and 1980-83 models were both third order (three lags of each variable), indicating that the system as a whole took three weeks to adjust to changing price information. The 1984-87 model was a second order model indicating that the majority of the price adjustments occurred within two weeks during this period. These adjustment periods are longer than the one-week adjustments found by Bailey and Brorsen. However, we examined more markets spread across a much broader geographic region so it seems reasonable that longer adjustment periods could be present. Koontz et al. settled upon two-week lags in their bivariate models which is consistent with the most recent period of our analysis.

The Ljung-Box Q-statistics indicated that no significant residual autocorrelation was present in any of the equations of the models. The contemporaneous correlations of the residuals of the models are reported in table 2. All contemporaneous correlations were significant at the one percent level, indicating that generally a large portion of information is reflected in price adjustments between markets within the week. The cross correlations ranged from a low of 0.42 to a high of 0.95, with most being in the 0.75 to 0.90 range. The magnitudes of the correlations appeared to be related to the relative volumes of markets and the distance between regions. Relatively close market regions with high volume (e.g., Texas Panhandle and Western Kansas) had relatively large instantaneous correlations, whereas low-volume, geographically dispersed markets (e.g., California and Lancaster) had small correlations.

To identify the dominant-satellite market relationships, Granger causality tests were performed on the estimated equations of the VAR systems. The summary F-statistics from the Granger tests are reported in table 3. Three markets, Iowa-Southern Minnesota direct, Eastern Nebraska direct, and the Omaha terminal, appear to be dominant markets in the price discovery process throughout the three time periods. This result is consistent with Koontz et al., who found that the Omaha and Interior Iowa markets led the cash market price discovery process.

In the more recent years (1984-87) additional markets have evolved as leading price discovery locations. The Western Kansas Direct market has become more dominant in the price discovery process in 1984-87 which may be due to its large increase in relative volume during this period (table 1). The Texas Panhandle market also led the price discovery of more locations in the 1984-87 period than it did in the earlier periods. This result seems reasonable, given the westward shifts in regional cattle feeding. In 1976, Kansas and Texas together accounted for approximately 35.5% of the fed cattle marketed in the 13 largest-volume cattle feeding states, but by 1987 they accounted for more than 44% (U.S. Department of Agriculture). The increase in relative volume of cattle feeding (and slaughtering) in these regions means that more market information is originating there and contributing to their importance in the slaughter cattle price discovery process.

Several market regions had little influence on any of the other markets. California, Colorado, Illinois, Lancaster, and St. Paul all appeared to have limited influence on the prices in subsequent weeks at other regions. These low-volume markets include those on the fringes of concentrated cattle feeding areas and also those located the farthest from the majority of larger-volume markets. Thus, these markets appear to react as satellites to the western corn belt and western plains markets.

The estimates of equation (2) are reported in table 4. As expected the distance between markets had a negative and statistically significant influence on the extent of price influence between markets. This implies that the farther apart the markets are, the less direct influence they have on each other. Market type was found to have a positive and at least marginally singnificant impact on the F statistic (being significant at the .05, .10, and .15 levels in the 1976-79, 1980-83, 1984-87 periods, respectively). Thus, it appears as though direct markets have a stronger influence on price discovery than do the declining terminal markets. Finally, relative volume was not found to have a significant impact on the F statistics. Thus, the larger-volume markets had no greater influence on the smaller volume markets than vice versa as measured by the F statistics.

The response of the prices in the system to innovations in each of the variables (one at a time) allows us to examine the dynamic adjustment process in the system. The impulse response shows the price reaction paths over time following a one standard deviation increase in one of the variables. To calculate the impulse response (and the forecast error decomposition reported later), the error correlation matrix is transformed into an orthogonal form. To accomplish this, the system was triangularized with the market prices ordered as Eastern Nebraska, Iowa-Southern Minnesota, Omaha, Western Kansas, Texas Panhandle, Illinois, Colorado, Sioux City, St. Paul, California, and Lancaster for the 1976-79 and 1980-83 periods. For the 1984-87 period, the ordering was Iowa-Southern Minnesota, Eastern Nebraska, Omaha, Western Kansas, Texas Panhandle, Illinois, St. Paul, Colorado, Sioux City, California, and

Lancaster. The ordering implies causality from the first through the last variable contemporaneously but not vice versa. The specific ordering reported was selected based upon the Granger causality results. Since several of the markets appeared to be leading the price discovery process, and several others seemed to be responding to price changes in these leading markets, alternative orderings were examined. Similar implications resulted, although relative price responses were slighlty different.

The impulse responses for selected markets are reported in figures 1, 2 and 3, for the 1976-79, 1980-83, and 1984-87 periods, respectively. Figures 1 and 2 illustrate the response of the Iowa-Southern Minnesota, Texas Panhandle, St. Paul, and Lancaster prices to one standard deviation shocks in the Eastern Nebraska market. Figure 3 shows the response of the Omaha, Texas Panhandle, St. Paul, and Lancaster prices to a one standard deviation increase in the Iowa-Southern Minnesota price. The market responses reported in the graphs were selected to include representative larger-volume markets (Iowa-Southern Minnesota, Texas Panhandle, and Eastern Nebraska) and smaller-volume markets (St. Paul, Omaha, and Lancaster). The remaining markets' responses followed patterns similar to those illustrated, with the magnitudes of the impulse responses falling between those of the large-volume and small-volume markets illustrated.

The larger-volume markets generally had larger immediate responses to the price shocks than did the smaller-volume markets. In most instances, the larger-volume markets responded with instantaneous (same week) reactions, which were 80% to 90% of the magnitude of the initial shock. The smaller-volume markets on the other hand, responded with instantaneous price adjustments of generally less than 70% (and as low as 40%) of the initial shock. The smaller-volume markets typically had significant price adjustments occurring for one to two weeks longer than the larger volume markets. In most cases, the larger volume markets had significant price adjustments occurring for one to two weeks after the initial shock, whereas the smaller-volume markets took two to three weeks to fully respond. Thus, it appears as though the larger-volume markets adjust more rapidly and with a larger initial adjustment to evolving market information than the smaller-volume markets. The Omaha market prices tended to follow the larger-volume market prices more closely than the other small-volume markets, possibly because its location causes it to be heavily influenced by the Eastern Nebraska and Iowa-Southern Minnesota direct markets.

The forecast error decompositions for the 1983 through 1987 period are reported in table 5. The within-sample forecasts are reported for 1-, 5-, and 10-weeks ahead. The forecast error decompositions are essentially unchanged beyond 10 weeks. Truly exogenous variables would explain 100% of their own k-step-ahead forecast error variance. For the Iowa-Southern Minnesota market, 72.07% of the variance in 5-week-ahead forecast error is due to innovations in its own price; 13.89% is due to innovations in the Omaha market; 2.77% is due to innovations in the Eastern Nebraska market, etc. It appears that the Iowa-Southern Minnesota market is relatively exogenous in the 1984 through 1987 period, since it explains more than 70% of its own 10-weeks-ahead forecast error. The majority of the remaining markets generally explain less than 30% of their 5-week-ahead forecast error variances. An interesting exception is the Lancaster market, which had 42% of its forecast error variance explained by innovations in its own price series. This seems to imply that, given its location and small market volume, the Lancaster market reacts more to its own price movements over time than do many of the other markets and is not highly integrated with the remaining markets.

Conclusions

This study examined the intertemporal price relationships among eleven regional slaughter cattle markets. Three vector autoregressive systems were estimated, Granger causality tests were performed, and impulse response functions and forecast error decompositions were used to identify the dominant markets. In general, distance between markets appeared to be the primary force affecting the speed of price adjustment across markets. The leading price discovery locations, none of which clearly dominated the others, were Iowa-Southern Minnesota, Eastern Nebraska, and Omaha. The Western Kansas and Texas Panhandle markets have become more important in slaughter cattle price discovery in recent years, reflecting the shifts that have occurred in regional cattle feeding and slaughtering from the cornbelt to the southwestern plains states.

In the eleven markets examined in this study, regional price adjustments took from one to three weeks to complete. The larger-volume markets, located near concentrated cattle feeding and slaughtering regions, fully reacted to price changes at the other major markets usually within one or two weeks. Whereas, the smaller-volume markets, located on the fringes of the major cattle feeding regions, took two to three weeks to fully respond to price changes in the larger markets. Thus, the larger-volume markets appear to be dominant in the short-term pricing process, with the smaller-volume markets reacting as satellites to price changes in the larger markets.

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Table 1. Summary of Average Annual Cattle Volumes at Selected Markets over Three Subperiods, 1976 through 1987.

Market	1976-1979[1] Average Annual Volume (1000 head)	1976-1979[1] Percent of Eleven Markets (%)	1980-1983 Average Annual Volume (1000 head)	1980-1983 Percent of Eleven Markets (%)	1984-1987 Average Annual Volume (1000 head)	1984-1987 Percent of Eleven Markets (%)
California Direct	688.2	5.5	456.9	3.9	519.0	4.2
Colorado Direct	761.9	6.1	703.2	5.9	1,014.9	8.3
Illinois Direct	693.2	5.5	550.9	4.6	391.0	3.2
Iowa-So. Min. Direct	1,413.7	11.3	1,975.8	16.7	1,050.8	8.6
Western Kansas Direct	2,221.7	17.7	2,170.8	18.3	2,863.1	23.3
Lancaster Terminal	142.5	1.1	113.9	1.0	104.0	0.8
Eastern Nebraska Direct	1,116.6	8.9	1,131.7	9.5	1,342.5	10.9
Omaha Terminal	831.4	6.6	659.0	5.6	360.2	2.9
So. St. Paul Terminal	828.4	6.6	569.9	4.8	401.3	3.3
Sioux City[2] Terminal	737.5	5.9	494.1	4.2	281.1	2.3
Texas[3] Panhandle Direct	3,093.3	24.7	3,040.5	25.6	3,938.1	32.1

[1]Direct markets include 1977-1979 only.

[2]Includes both cattle and calves.

[3]Includes New Mexico, Texas, and Oklahoma Panhandle.

Source: USDA, Agricultural Marketing Service, Livestock Meat Wool Market News, Weekly Summary and Statistics, various issues.

Table 2. Correlations for Residuals of VAR Systems, 1976 through 1987.[a]

Market	Time Period[b]	California Direct	Colorado Direct	Illinois Direct	Iowa So. Min. Direct	Western Kansas Direct	Lancaster Terminal	Eastern Nebraska Direct	Omaha Terminal	So. St. Paul Terminal	Sioux City Terminal	Texas Panhandle Direct
California	I	1.00	0.84	0.79	0.76	0.84	0.62	0.76	0.80	0.46	0.78	0.84
Direct	II	1.00	0.78	0.73	0.73	0.77	0.51	0.74	0.72	0.66	0.72	0.77
	III	1.00	0.73	0.72	0.76	0.76	0.49	0.64	0.72	0.72	0.72	0.77
Colorado	I		1.00	0.87	0.86	0.92	0.69	0.85	0.88	0.49	0.86	0.91
Direct	II		1.00	0.82	0.88	0.90	0.52	0.81	0.84	0.78	0.83	0.91
	III		1.00	0.84	0.87	0.91	0.53	0.78	0.83	0.79	0.83	0.91
Illinois	I			1.00	0.91	0.88	0.79	0.87	0.90	0.61	0.89	0.86
Direct	II			1.00	0.86	0.79	0.55	0.77	0.83	0.80	0.83	0.81
	III			1.00	0.90	0.86	0.64	0.77	0.85	0.84	0.82	0.86
Iowa-So.	I				1.00	0.89	0.75	0.90	0.91	0.58	0.90	0.87
Min. Direct	II				1.00	0.86	0.54	0.84	0.85	0.83	0.84	0.87
	III				1.00	0.89	0.59	0.82	0.87	0.88	0.86	0.89
Western	I					1.00	0.67	0.89	0.89	0.53	0.87	0.95
Kansas	II					1.00	0.49	0.81	0.79	0.74	0.78	0.92
Direct	III					1.00	0.53	0.78	0.83	0.82	0.81	0.95
Lancaster	I						1.00	0.67	0.73	0.42	0.71	0.65
Terminal	II						1.00	0.51	0.57	0.52	0.55	0.50
	III						1.00	0.49	0.60	0.57	0.53	0.53
Eastern	I							1.00	0.89	0.52	0.88	0.89
Nebraska	II							1.00	0.78	0.76	0.78	0.80
Direct	III							1.00	0.79	0.77	0.73	0.77
Omaha	I								1.00	0.56	0.94	0.86
Terminal	II								1.00	0.82	0.85	0.77
	III								1.00	0.86	0.87	0.83
So. St.	I									1.00	0.58	0.50
Paul	II									1.00	0.85	0.77
Terminal	III									1.00	0.86	0.84
Sioux City	I										1.00	0.84
Terminal	II										1.00	0.77
	III										1.00	0.84
Texas	I											1.00
Panhandle	II											1.00
Direct	III											1.00

[a]All correlations are significantly different from zero at the .01 level.

[b]Roman numerals denote time periods, I is 1976 through 1979, II is 1980 through 1983, and III is 1984 through 1987.

Table 3. Summary F-Statistics for Causal Flows between Selected U.S. Slaughter Steer Weekly Cash Market Prices, 1976 through 1987.

		Lagged Independent Variables[a]										
Dependent Variable	Time Period[b]	California Direct	Colorado Direct	Illinois Direct	Iowa So.Min. Direct	Western Kansas Direct	Lancaster Terminal	Eastern Nebraska Direct	Omaha Terminal	So. St. Paul Terminal	Sioux City Terminal	Texas Panhandle Direct
California	I	0.24[c]	1.05	0.99	3.41*[d]	0.39	1.97	4.58**	2.76*	0.05	1.95	1.78
Direct	II	0.29	0.54	1.06	4.59**	0.24	0.73	2.47	3.76*	0.79	0.90	0.09
	III	1.55	1.26	3.55*	9.20**	7.25**	2.09	2.08	10.26**	2.74	0.23	3.07*
Colorado	I	1.01	4.61**	1.03	3.82**	0.51	1.08	6.84**	2.93*	0.41	1.93	3.21*
Direct	II	0.49	3.21*	1.81	4.39**	3.79*	0.23	9.38*	7.79**	0.45	1.87	1.71
	III	0.45	5.18**	3.31	13.03**	13.02**	1.32	6.38**	12.44**	2.65	1.17	2.89
Illinois	I	1.49	1.90	0.44	6.12**	0.78	0.60	7.64**	3.07*	0.65	2.58*	1.29
Direct	II	1.20	1.15	2.93*	9.54**	2.19	0.24	7.18**	4.72**	0.61	1.89	1.24
	III	0.76	1.89	5.70**	16.61**	3.97*	3.22*	5.60**	12.35**	3.15*	1.06	2.07
Iowa-So.Min	I	0.90	1.69	0.84	1.27	0.99	0.99	5.50**	2.64*	0.82	1.69	1.10
Direct	II	0.59	2.05	1.32	2.60	2.14	0.39	6.23**	6.52**	1.00	1.04	0.69
	III	0.59	0.57	2.58	5.39**	4.84**	1.04	7.42**	9.60**	1.52	0.34	2.29
Western	I	0.94	1.79	1.21	4.60**	0.97	0.64	6.71**	3.20*	0.46	2.26	3.15*
Kansas	II	0.58	0.75	0.83	2.95*	3.33*	0.15	6.25**	5.91**	0.42	3.38*	1.93
Direct	III	0.10	0.24	3.53*	13.85**	6.31*	1.36	4.23*	10.57**	3.04	1.30	3.18*
Lancaster	I	1.49	1.59	1.18	6.70**	1.02	3.86**	3.72**	3.72**	0.29	2.25	0.75
Terminal	II	0.59	0.53	0.32	3.17*	0.34	3.26*	5.25**	2.99*	0.12	3.25*	1.65
	III	0.55	1.67	0.21	8.76**	2.22	10.40**	3.75*	8.87**	1.47	1.47	1.71
Eastern	I	1.42	1.82	0.64	2.91*	1.12	0.89	3.45**	1.96	0.62	1.83	1.33
Nebraska	II	0.63	2.11	1.37	2.43	1.88	0.74	6.15**	3.33*	0.36	2.30	0.57
Direct	III	0.96	0.09	2.89	10.47**	1.80	0.54	2.39	9.46**	2.69	0.68	4.38*
Omaha	I	0.82	3.32*	0.63	5.48**	1.32	0.77	8.59**	7.70**	0.63	1.81	2.81*
Terminal	II	1.07	1.35	0.73	4.89**	0.99	0.61	8.99**	8.25**	0.27	3.95**	2.02
	III	0.43	0.93	1.62	10.70**	5.71**	0.81	5.57**	15.91**	2.84	0.73	3.16*
So. St.	I	0.52	0.36	1.03	1.36	1.24	1.60	4.24**	1.23	3.49**	1.10	1.45
Paul	II	1.47	1.77	0.36	6.23	0.83	0.47	6.71**	6.20**	0.64	2.04	1.41
Terminal	III	1.49	1.39	3.43**	12.56**	5.45**	1.14	9.04**	14.47**	4.28*	0.67	4.05*
Sioux	I	0.65	2.19	0.61	4.32**	1.28	1.20	5.26**	3.00*	0.78	3.71**	1.88
City	II	1.03	2.75	0.34	3.84*	3.29*	0.35	5.56**	6.65**	0.35	4.54**	1.43
Terminal	III	0.00	0.82	1.72	14.58**	6.92**	0.92	6.19**	11.27**	2.17	3.37*	2.46
Texas	I	0.56	0.95	1.28	4.26**	0.58	0.76	5.99**	3.03*	0.56	2.73*	1.52
Panhandle	II	0.10	1.93	1.39	4.36**	3.71*	0.07	7.52**	6.68**	0.53	3.02*	1.05
Direct	III	0.24	0.28	3.42*	12.99**	15.76**	0.85	4.92**	10.00**	3.16*	1.47	8.02**

[a]System lag lengths were selected using the modified likelihood ratio test, and were 3 weeks, 3 weeks, and 2 weeks, for periods I, II, and III, respectively.

[b]Roman numerals denote time periods, I is 1976 through 1979, II is 1980 through 1983, and III is 1984 through 1987.

[c]Numbers reported are F-statistics for H_o: All coefficients associated with the respective market jointly equal zero. A significant F-statistic indicates that changes in the independent market's price lead changes in the dependent market's price.

[d]Single asterisk indicates significantly different from zero at the .05 level, double asterisk indicates significantly different from zero at the .01 level.

Table 4. Estimated Coefficients for Regressions of F-Statistics.[a,b]

Independent Variable	Period I 1976-1979	Period II 1980-1983	Period III 1984-1987
Intercept	6.495**	10.889**	16.811**
	(5.33)	(7.08)	(5.62)
Distance	-0.771**	-1.361**	-2.019**
	(-4.07)	(-5.73)	(-4.38)
Market Type	0.870**	0.541*	0.872
	(2.69)	(1.32)	(1.06)
Relative Volume	-0.006	-0.036	-0.030
	(-0.11)	(-0.70)	(-0.39)

[a]Values reported in parentheses are t-statistics and single and double asterisks indicate significantly different from zero at the .10 and .05 levels, respectively, using a one-tailed t-test.

[b]Number of observations for system = 330, system R^2 = .13.

Table 5. Percentages of k-Weeks-Ahead Forecast Error Attributed to Innovations in Respective Market Price Series, 1984 through 1987.

Market	Weeks Ahead (k)	Standard Error ($/cwt)	Percentages of Forecast Error Explained by: Iowa So. Min. Direct	Eastern Nebraska Direct	Omaha Terminal	Western Kansas Direct	Texas Panhandle Direct	Illinois Direct	So. St. Paul Terminal	Colorado Direct	Sioux City Terminal	California Direct	Lancaster Terminal
Iowa-So.	1	0.95	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Min. Direct	5	1.15	72.07	2.77	13.89	2.12	2.06	3.03	0.37	1.79	0.14	0.47	1.28
	10	1.15	71.89	2.77	13.99	2.14	2.06	3.05	0.38	1.80	0.15	0.49	1.29
Eastern	1	1.03	67.75	32.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nebraska	5	1.23	52.16	23.54	12.66	1.02	2.90	3.53	1.48	0.49	0.45	0.97	0.81
Direct	10	1.23	52.03	23.48	12.70	1.09	2.89	3.54	1.49	0.49	0.47	0.99	0.84
Omaha	1	0.87	75.09	1.93	22.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terminal	5	1.13	54.52	2.40	31.85	2.18	2.40	3.20	0.76	1.40	0.23	0.21	0.84
	10	1.14	54.35	2.41	31.81	2.22	2.41	3.22	0.78	1.40	0.29	0.27	0.85
Western	1	0.97	78.17	1.27	1.00	19.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kansas	5	1.23	55.79	2.11	16.74	14.13	2.39	4.82	1.19	0.86	0.54	0.14	1.28
Direct	10	1.23	55.52	2.13	16.76	14.14	2.41	4.83	1.21	0.86	0.60	0.22	1.31
Texas	1	0.87	78.63	0.92	1.28	11.10	8.07	0.00	0.00	0.00	0.00	0.00	0.00
Panhandle	5	1.18	54.65	2.03	14.32	10.43	9.50	5.82	0.95	0.64	0.38	0.23	1.03
Direct	10	1.19	54.47	2.04	14.28	10.46	9.48	5.82	0.97	0.65	0.46	0.31	1.06
Illinois	1	0.82	80.79	0.29	1.90	0.91	0.16	15.95	0.00	0.00	0.00	0.00	0.00
Direct	5	1.10	57.36	0.99	17.07	1.81	1.53	14.57	0.78	2.17	0.53	0.55	2.65
	10	1.10	57.08	1.00	17.11	1.83	1.57	14.52	0.81	2.16	0.59	0.67	2.66
So. St. Paul	1	0.86	77.02	0.57	3.56	0.08	0.26	0.25	18.26	0.00	0.00	0.00	0.00
Terminal	5	1.15	51.98	2.40	20.03	1.53	3.32	4.45	11.73	1.98	0.33	1.01	1.24
	10	1.15	51.87	2.42	20.02	1.55	3.32	4.48	11.71	1.98	0.34	1.06	1.25
Colorado	1	0.99	74.62	1.84	1.21	8.11	0.72	0.02	0.21	13.28	0.00	0.00	0.00
Direct	5	1.31	49.35	2.68	17.54	7.48	3.55	5.22	0.56	11.64	0.78	0.22	1.39
	10	1.31	49.16	2.70	17.55	7.52	3.55	5.22	0.59	11.60	0.42	0.29	1.41
Sioux	1	0.94	72.73	0.39	6.52	0.37	1.03	0.01	0.85	0.89	17.21	0.00	0.00
City	5	1.23	52.77	1.81	21.18	2.47	3.45	2.79	1.27	1.98	11.46	0.12	0.70
Terminal	10	1.24	52.48	1.82	21.19	2.50	3.47	2.80	1.29	2.00	11.48	0.24	0.73
California	1	1.00	55.18	0.24	1.82	3.44	1.01	0.06	0.21	0.07	0.08	37.89	0.00
Direct	5	1.24	40.84	0.71	14.66	4.78	3.61	4.28	1.32	2.15	0.14	25.88	1.62
	10	1.25	40.67	0.77	14.76	4.82	3.60	4.29	1.33	2.15	0.17	25.79	1.65
Lancaster	1	1.04	36.00	0.04	3.07	0.02	0.25	3.76	0.06	0.00	0.12	0.09	56.59
Terminal	5	1.33	29.05	0.42	17.08	1.30	1.68	4.00	0.39	1.94	1.33	0.50	42.31
	10	1.33	28.88	0.47	17.17	1.30	1.77	4.03	0.43	2.00	1.34	0.59	42.03

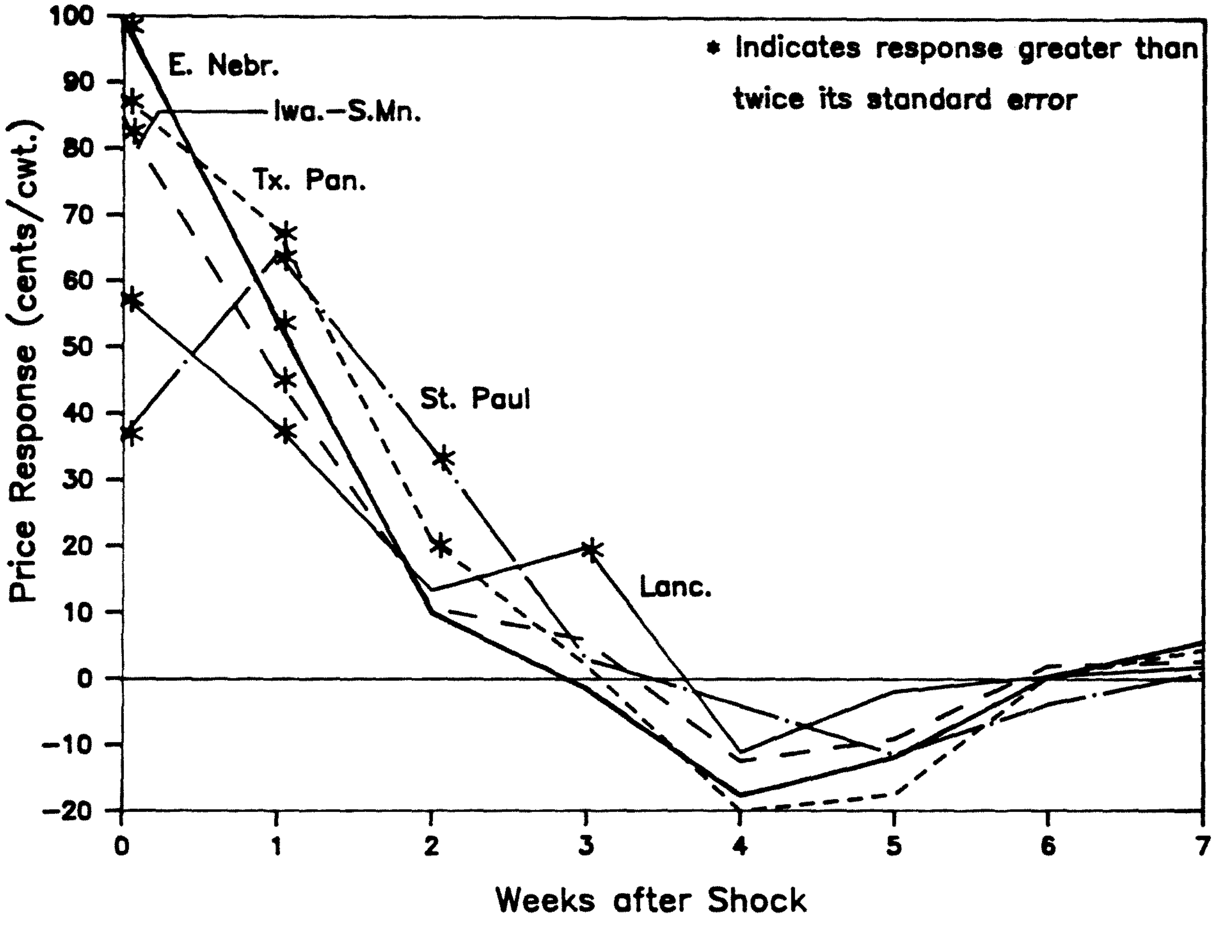

Figure 1. Price Responses of Selected Markets following a One–Standard Deviation Shock in the Eastern Nebraska Direct Price, 1976–79.

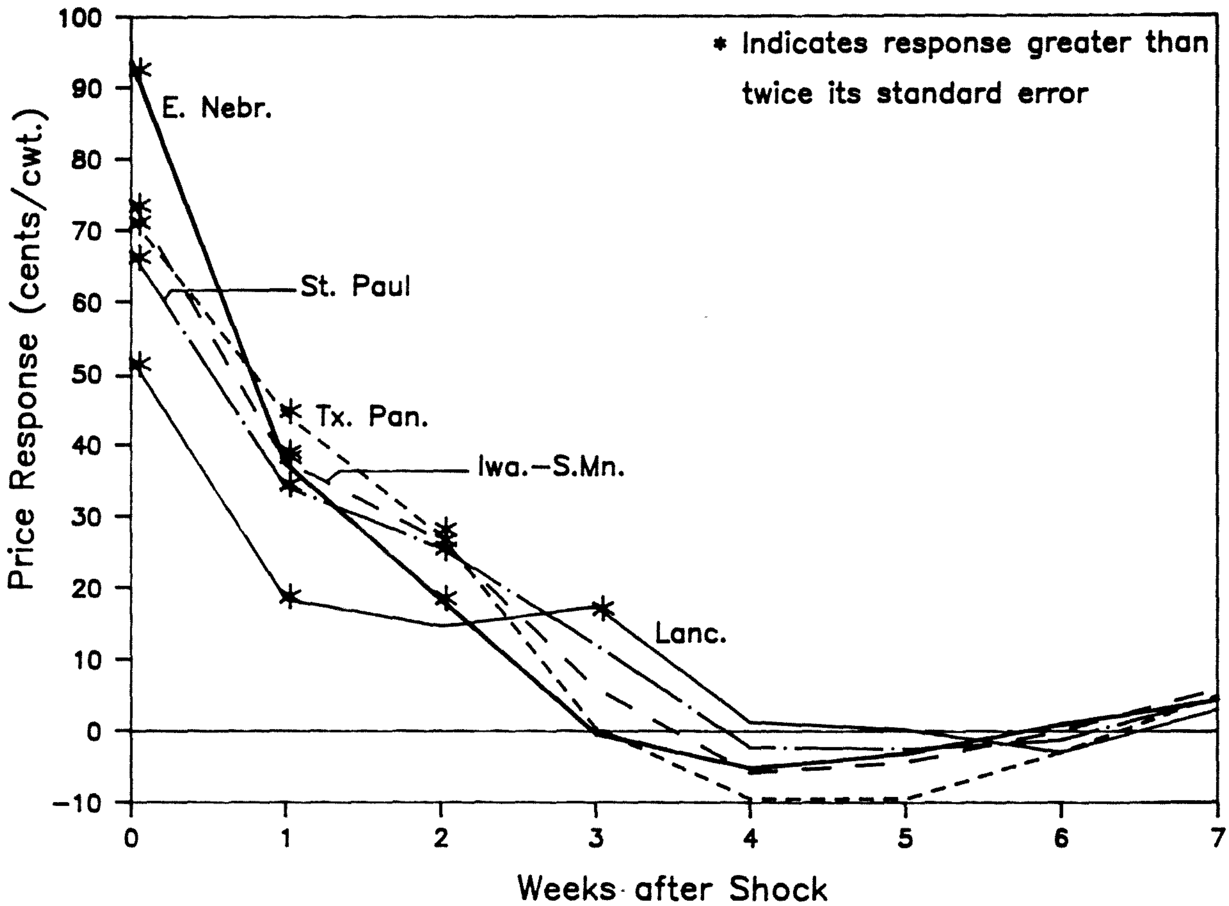

Figure 2. Price Responses of Selected Markets following a One–Standard Deviation Shock in the Eastern Nebraska Direct Price, 1980–83.

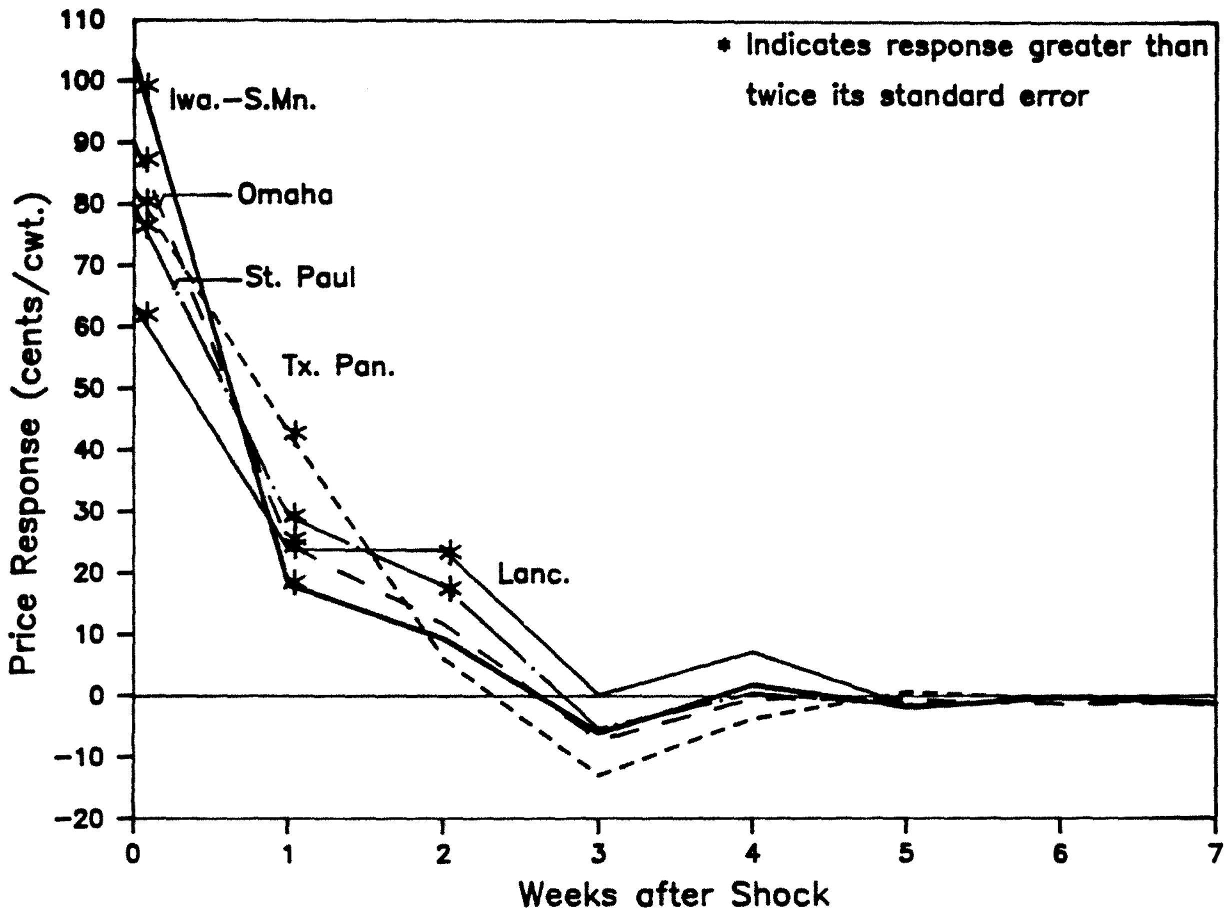

Figure 3. Price Responses of Selected Markets following a One–Standard Deviation Shock in the Iowa–Southern Minnesota Direct Price, 1984–87