Dominant-Satellite Relationships Between Futures and Selected Cash Prices for Live Cattle

by

Stephen R. Koonz, Michael A. Hudson, and Philip Garcia

DOMINANT-SATELLITE RELATIONSHIPS BETWEEN FUTURES AND SELECTED CASH PRICES FOR LIVE CATTLE

Stephen R. Koontz, Michael A. Hudson, and Philip Garcia[1]

Introduction and Background

Considerable research exists in the area of price discovery in the beef complex. A major thrust of this work has dealt with the temporal characteristics between cash prices at various levels of the marketing system and futures prices (e.g., Purcell, Flood, and Plaxico; Weaver and Banerjee; Oellerman and Farris; and Purcell and Hudson). The general conclusion of these studies is that flows of information between the cash and futures markets are fairly rapid and that the live cattle futures market performs an important price discovery function.

The spatial dimensions of the price discovery process in live cattle markets have received less attention. A notable exception is the work of Bailey and Brorsen which considered interactions between regional fed cattle prices. Further examination of the extent to which prices at different points in the marketing system reflect market information is important because it permits an assessment of the degree of market integration. Measurement of lead/lag relationships between spatial markets and the identification of markets which incorporate information most rapidly will indicate which markets are the most dominant in the price discovery process, may identify opportunities for arbitrage, and strategies to reduce basis risks.

The price discovery process for slaughter cattle can be better understood by considering changes in spatial price relationships across time. Structural changes in the U.S. livestock industry over the past several years have resulted in a shift in cattle feeding from the eastern cornbelt to southwest high plains regions. This shift could have impacts on the roles of various markets in the price discovery for cattle. Markets closer to principle feeding areas are likely to be more sensitive indicators of equilibrium values of cattle. The decreased use of terminal markets as an outlet for cattle may also have altered the informational exchange between the various markets.

This paper examines the lead/lag relationships among major cash markets in the U.S. and between these cash prices and live cattle futures prices. The analysis is performed for three separate time periods between the years 1977-1984 and focuses on three questions: (1) Are these markets highly integrated? (2) Does any market or subset of markets discover prices more rapidly than other markets? (3) How have the price relationships among cattle markets changed over time?

---

[1] The authors are, respectively, Graduate Research Fellow, Assistant Professor, and Associate Professor in the Department of Agricultural Economics, University of Illinois at Urbana-Champaign. The research reported herein was supported under HATCH Project Number 05-0352.

The remainder of the paper is structured as follows. Theoretical considerations are presented in the next section. Section three provides an overview of the data and methods used in the study. The results are discussed in section four. The paper concludes with a summary and discussion of the implications of the research.

Theoretical Considerations

The trading of similar commodities in different markets arises because of positive transportation and communication costs. The degree to which markets are interrelated depends largely on the costs of providing marketing services and the costs of information. At one extreme, prices in alternative markets may be unrelated (i.e., independent) when the costs are sufficiently high to preclude almost all intermarket communication and speculation. A reduction in marketing costs and communication costs combined with efforts of arbitragers can reduce intermarket price differences, thereby integrating the market prices across locations. In the limit, when costs are zero, prices should be identical across all markets. In equilibrium, a competitive marketing system with positive costs is characterized by price differences between markets over time, space and form consistent with the costs of the respective marketing services. If price changes in one market are mirrored by price changes in other markets then the markets are perfectly integrated.

The introduction of new supply and demand information may disrupt a market equilibrium situation. In a perfectly integrated system, all markets assimilate new information at the same instant and prices adjust simultaneously. In an imperfectly integrated system, the introduction of new information may result in prices which differ between markets for short intervals by more than the cost of marketing services. For example, due to the availability and cost of information, a terminal market may gather and assimilate information more rapidly than other markets. While prices in secondary markets, more distant localized marketplaces without cost or informational advantages, mirror the price changes in the terminal market.

The possibility that one market leads others in the price discovery process leads to a classification of dominant and satellite markets (Garbade and Silber). This classification essentially derives from the identification of imperfectly integrated markets. Figure 1 illustrates the possible levels of interaction within such markets. Dominant markets have the ability to assimilate information quickly, therefore they drive the price discovery process and make little use of prices formulated elsewhere. Conversely, satellite markets rely on the dominant market as the primary source of information for price discovery. Also recognized is the case where there is no strict dominant-satellite relationship but rather markets share information through an informational feedback process. In this case, two further classifications can be identified: asymmetric feedback where one market follows changes in the second market closely, while having only a slight influence on prices in that second market; and symmetric feedback where the influence of price changes in each market upon the other is approximately equivalent.

Data and Methods

The data used to examine the lead/lag relationships consist of weekly prices for fed cattle from January 1973 to December 1984.[2] The specific locations used in the analysis are the terminal markets of: Omaha, Nebraska; Sioux City, Iowa; Greeley, Colorado; Peoria, Illinois; Joliet, Illinois; the direct marketing quotes of: Central Iowa; Kansas Direct; Amarillo, Texas; Illinois Direct; and a truncated nearby CME live cattle futures contract price series.[3] The cash markets in this group represent the primary markets for cattle and markets on the fringes of the primary cattle feeding areas. In addition, these price series reflect the delivery points on the CME live cattle contract.

Granger causality is used to examine the dominant-satellite relationships between the markets. This approach is well suited for the study of price discovery in agricultural commodities (see, for example, Bessler and Schrader, Heien, or Bessler and Brandt). Lead/lag relationships estimated are then examined within the conceptual framework developed in figure 1 to establish dominant-satellite relations between the markets.

The markets under consideration are analyzed in pairwise combinations as bivariate processes. This approach should not be interpreted as a test of the effectiveness of arbitrage between all of the markets under consideration. It is unlikely that physical shipments take place between some of the more distant markets. The focus is instead on examining how price changes between markets interact in the price discovery process. Price changes in any market can be viewed as revealing changes in underlying supply and demand conditions for beef. Dominant markets, by definition, are more able to assess this changing information set and discover new prices. The price changes in satellite markets will therefore lag price changes in the dominant markets, regardless of the distance or cost of arbitrage.

The causality tests were conducted using the direct Granger approach (see Bessler and Brandt for the test specifics). The approach was suggested by Granger and has subsequently been advocated by Geweke, Tjosthiem, and Hsiao. The monte carlo studies of Guilkey and Salemi; Geweke, Meese, and Dent; and Nelson and Schwert have shown this approach to be powerful in identifying lead/lag relationships. The general form of the model to be estimated is:

---

[2] The use of a weekly sampling interval may mask some of the variability in the live cattle markets. This sampling interval, however, provides for an analysis of the impacts of a futures market which trades throughout the week on the cash markets which are typically early week markets.

[3] The futures price series is made up of closing prices of the contract nearest to delivery, prior to that contract's delivery month, and rolls to the next contract upon the entry into a delivery month.

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} a_{11}(i) & a_{12}(i) \\ a_{21}(i) & a_{22}(i) \end{bmatrix} \begin{bmatrix} y_{t-i} \\ x_{t-i} \end{bmatrix} + \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{xt} \end{bmatrix} \tag{1}$$

where y_t and x_t are the differenced price series and the error structure, η, satisfies:

$$E(\eta_t \eta_s') = \begin{cases} \Sigma & t=s \\ 0 & t \neq s \end{cases} \quad \text{and} \quad \Sigma = \begin{bmatrix} \sigma_{yy}^2 & \sigma_{xy}^2 \\ \sigma_{xy}^2 & \sigma_{xx}^2 \end{bmatrix}$$

Causal flows between series are tested for via the standard F-tests. For example, the hypothesis of no causal flows from x to y is tested via the null hypothesis $a_{12}(1) = a_{12}(2) = \ldots = a_{12}(p) = 0$, and the hypothesis of no causal flows from y to x is tested via $a_{21}(1) = a_{21}(2) = \ldots = a_{21}(p) = 0$. These tests are then used to infer strict dominant-satellite relationships. From the example, (1) if there are causal flows between both x and y then there is a feedback relationship between markets, (2) if there is a causal flow x to y but not from y to x then x is a dominant and y a satellite market, (3) if there is a causal flow y to x but not from x to y then y is a dominant and x a satellite market, and (4) if there are no flows between x and y then x and y are independent markets. The importance of instantaneous relationships between prices is measured by the contemporaneous cross equation correlation of the errors of the two processes. If the markets are perfectly integrated, then there should be no leads or lags as all information should be incorporated in all markets within the one week sampling interval.

The symmetry of a feedback relationship can be inferred by examining the magnitude which a change in one price series influences changes in the second price series. For markets which exhibit feedback, the magnitudes are used to make inferences about the degree of a weak form dominant-satellite relationship. If the coefficients measuring the effect of price changes in market x on price changes in market y are greater than the coefficients measuring the effects of market y on market x, then market x can be viewed as the more dominant market. In essence, this can be tested by examining whether the sum of the absolute value of the above diagonal coefficients in equation (1) are equal to the sum of the absolute value of the coefficients below the diagonal. More specifically:

$$H_0: \sum_{i=1}^{p} |a_{12}^*(i)| - \sum_{i=1}^{p} |a_{21}^*(i)| = 0 \tag{2}$$

where the stars denote coefficients which are significant by individual t-tests. An F-test is used to examine this hypothesis.

Changes in the structure of the price discovery processes over time are examined through subdividing the data into three periods: 1973 through 1976, 1977 through 1980, and 1981 through 1984. The overall time period was selected because it is sufficiently long to reveal the changes in the structure of the price discovery process through time. The first period reveals the structure of the price discovery process which persisted in the early 1970s, up through the herd liquidation of that period. The second and third periods provide a perspective on the price discovery processes during the recent evolution of the industry. In particular, the declining role of terminal markets, the increased use of direct buying, and increased packer concentration are major forces which may have influenced price discovery in these periods.

Empirical Results

The bivariate models were fit to an AR(2) structure and estimated via ordinary least squares. Several information criteria were used to examine the lag structure for a subset of the models under consideration, including Schwarz's Bayesian Information Criterion, Akaike's Information Criterion, and Akaike's Final Prediction Error. The consensus of these techniques suggested an AR(1) or AR(2) specification as optimal. All models were fitted with an AR(2) specification for convenience. For the subsample of models used in selecting this lag length the differences between the AR(1) and the AR(2) specification do not change the conclusions drawn from causality tests.

The Q-statistics (Box-Ljung) for the error structures of the models revealed no significant serial correlation in the estimated models. Cross equation correlations of the error structures for the models were examined to establish the presence of instantaneous relationships between price changes. These are presented in table 1. For all periods and all models the contemporaneous correlations are above 0.51, with the majority centered around 0.85, and all are significant at the $\alpha = 0.01$ level. Thus, there appear to be strong information flows between markets within the week.

Given these strong instantaneous relationships, the absence of a lagged relationship between prices can have two interpretations. If there is no lagged relationship from one price series to a second series it could be that no information flows take place in specific direction considered <u>or</u> that all adjustments occur within the week and are therefore masked by the sampling interval (see footnote 2 above).

Tables 2 and 3 provide information on the feedback relationships between the price series. In table 3 results of the F-test regarding the hypothesis in equation (2) are presented for the markets exhibiting informational feedback. Also presented are ratios which show the relative strength of the feedback relationship. The ratio is calculated as follows:

$$[a_{12}^{*}(1) + a_{12}^{*}(2)] \;/\; [a_{21}^{*}(1) + a_{21}^{*}(2)] \qquad (3)$$

where the star denotes the parameter is significant based on individual t-tests. For example, feedback exists between Kansas Direct and Central Iowa in the second period. The calculated ratio is 1.020 and the F-statistic testing (2) is 1.146 with a P-value of 0.2851. The hypothesis of symmetry cannot be rejected and the ratio confirms the influence of Kansas Direct on

Central Iowa is only 2% greater in magnitude than the influence of Central Iowa on Kansas Direct.

Cash Market Relationships

Examining the lead/lag results between the cash markets reveals several interesting patterns (table 2). There are no feedback relationships between markets at the $\alpha = 0.05$ level during the 1973-76 time period. There appears to be a hierarchy of markets in terms of the contribution of individual markets in price discovery process. The Omaha market leads all other markets and is clearly the dominant market during this period. In order of respective dominance, the other markets are Sioux City, Kansas Direct, Amarillo, Central Iowa, Joliet, Illinois Direct, Greeley, and Peoria. Each of these markets dominates the markets which follow it in the list and is a satellites of the markets which precede it.

The lead/lag analyses of the second period reveal many feedback relationships. The dominance of the two major terminal markets, Omaha and Sioux City, in the first period disappears. There is a feedback relationship between the two largest direct markets, Kansas Direct and Central Iowa, with the flows between the two being symmetric. There are also feedback relationships between Amarillo and Omaha, Amarillo and Sioux City, Greeley and Kansas, Greeley and Central Iowa, Omaha and Central Iowa, Sioux City and Kansas, and Sioux City and Central Iowa.

The markets in the top and the middle of the hierarchy in the first period are characterized by feedback relationships in the second with Greeley assuming greater importance in the discovery of cattle prices. Considerable feedback has emerged between the markets in the high plains and western cornbelt areas. The Illinois markets, however, remain satellite markets of the western cornbelt and high plains states. From table 3, it can be observed that generally within the feedback relationships the direct markets dominate the cash markets in the weak form. There is symmetric feedback between Amarillo and Omaha while Amarillo dominates Sioux City, also, Kansas Direct dominates Greeley and Sioux City, while Central Iowa dominates Greeley, Omaha, and Sioux City.

The results of the lead/lag analyses of the third period reveal the emergence of a new hierarchy of market prices. The weak dominant-satellite structure found in the second period becomes more pronounced. Kansas Direct and Central Iowa are the dominant series and all other markets are satellites. The results reveal no flows between these two large direct markets, but the level of contemporaneous correlation between the errors in the models of the price series is above 0.88, suggesting such flows take place within the week and can not be identified here. Amarillo, Texas is next in terms of dominance. Although feedback is evident between Amarillo and Omaha, the flow from Omaha to Amarillo is marginal in magnitude. Greeley follows Amarillo in the hierarchy. Greeley is led by Kansas, Iowa and Amarillo, while it leads Sioux City in a straight forward fashion and dominates Omaha in terms of strength in the feedback relationship. In this time period all direct marketings price series play a dominant role in price discovery while the terminal markets play a much reduced role, even the

Illinois Direct price series leads Sioux City and Omaha. Sioux City and Omaha finalize the hierarchy, these two markets lead only Joliet and Peoria.

Note that while some feedback between the terminal markets of Sioux City and Omaha with the direct marketing price series of Kansas and Central Iowa exists, the flows from the terminal to the direct markets are relatively weak. This further suggests the terminal markets have lost much of their dominance in the price discovery process in the recent time period, and that their roles have been replaced by the two large direct markets and the direct market in Amarillo.

Cash Markets / Futures Market Price Relationships

The relationships between the cash price series and the futures price series are straightforward. In the first period, feedback exists between the live cattle futures market and the cash market prices. Examining the magnitudes of these feedback relationships reveals the strong influence of futures on price discovery in cash markets (table 3).

In the second and third period the futures market dominates all cash price series. These results must be tempered by understanding the nature of the series. Previous research (Hudson and Purcell) using shorter sampling intervals has shown considerable feedback between cash and futures to exist during these time periods. The reason for its absence here may be due to the use of weekly data which only reflects trading in the cash markets during the early portion of the week. Nevertheless, these findings illustrate that week-to-week cash cattle markets are adjusting to futures prices from the previous week while the reverse is not true. Within the beef complex, it may be rational for cash market participants to use more than one week of futures prices to determine the prices at which they are willing to trade. Futures prices are inherently noisy and cash market traders may lessen the influence of this noise by using more than the current futures price. On the other hand, the most recent cash prices are a reflection of current supply and demand conditions and may be the most relevant to price discovery in the futures market. In summary, on a week-to-week time frame, the live cattle futures market is a dominant force in the price discovery process for cattle, with all cash markets being satellites of the futures market.

The contemporaneous correlations between the error structures of the cash-futures models are also reported in table 2. These measures are noticeably less than those between the cash markets. This may be due to the inherent noise in the futures price, the fact the futures price is for a commodity to be delivered one-to-two months in the future and therefore has an anticipatory component, or the already mentioned temporal differences in the available information. This may cause the movements between the cash and futures prices to be less harmonious than between cash prices.

One interesting observation about the contemporaneous correlations between cash and futures is that in the early period the measures between futures and the large terminal markets (Omaha and Sioux City) and between futures and the large direct markets (Central Iowa and Kansas Direct) are roughly the same size, with Sioux City being the largest. However, in the second and third periods, the contemporaneous correlations between futures and the direct markets are larger than between futures and the terminal markets. Although the significance of the differences is open to argument, the pattern persists. This result is consistent with the idea that the futures market is interacting must closely with the more dominant cash markets.

Some General Findings

Examining the contemporaneous correlations across the three time periods for all markets both cash and futures, reveals an interesting pattern. In 44 of the 45 blocks of correlations, the measures decline between the second and the third time period. This may indicate an increasing degree of regionalization in these markets. The development of market centers around the country suggests that prices within these centers, although linked to dominant markets, are becoming increasingly separated from the national supply and demand picture. This slight market fragmentation may be due to limited arbitrage opportunities in the most recent time period.[4]

Summary and Implications

The analyses reported here suggest that the relationships between terminal markets, direct markets, and live cattle futures in the price discovery process have evolved over time mirroring changes in the cattle industry. As the importance of direct selling has increased, so has the influence of direct prices. There has also been a decline in the influence of terminal markets on other a markets, coincident with the declining volumes moving through those outlets. The reliance on the futures market as a primary source of price discovery appears to have increased in recent years. However, during this recent period, local markets seem to have become slightly more regionalized in the discovery process.

An observation supported by these results is that the cash markets have increased their reliance on the futures market as a price discovery mechanism. While it is seems reasonable that the futures market is being looked on to register information which emerges late in the week and that this information is then reflected in the cash markets the following week, further investigation with daily data would allow a more complete identification of the spatial interaction of futures and cash cattle prices.

The results have implications for risk management and for analysis of price discovery and price determination in the cattle complex. First with regards to risk management, they emphasize the need to examine the changing nature and causes of basis movements. More localized cash markets may

---

[4] Examining the data series reveals that variability of the price <u>levels</u> is highest in the second period and lowest in the third. Perhaps this additional variability across locations in the second period gave rise to profitable arbitrage opportunities. Effective arbitrage would tie these markets together tightly.

result in increased basis risk and a reduction in hedging effectiveness of futures market activities.

The second implication relates to overall effectiveness of the evolving system in discovering the true equilibrium prices. If the packing industry continues to become more concentrated and futures prices continue to exhibit a large influence on all cash market prices, additional concern is likely to emerge over the representativeness of futures and direct market prices. It would appear that in this environment the price determination processes in futures market and in the direct cash markets deserve special attention.

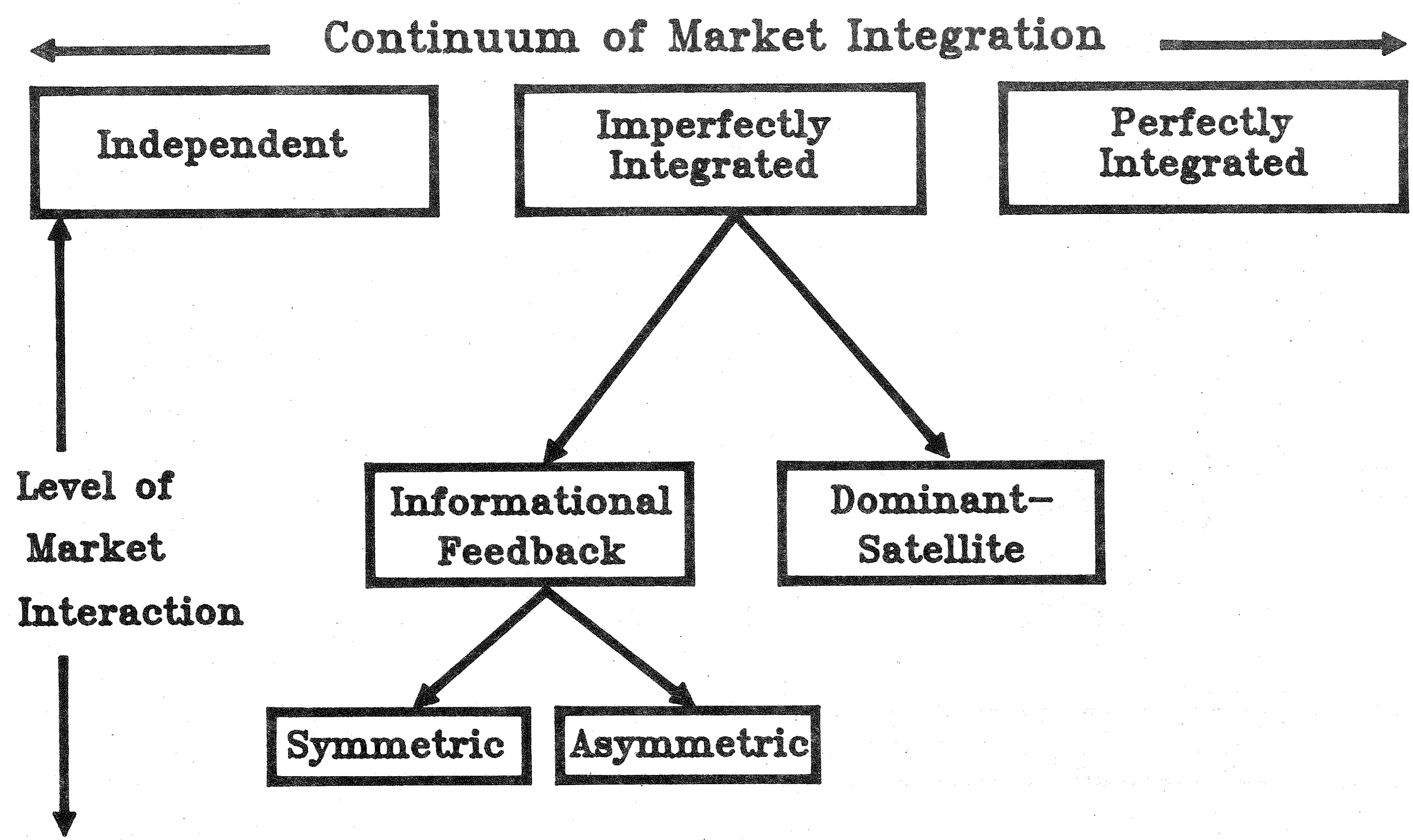

Figure 1. Market Relationships in the Dominant–Satellite Framework.

Table 1. Contemporaneous Correlations Between the Error Structures of the Bivariate Lead/lag Models.

First Market & Time Period	Second Market								
	Greeley	Omaha	Sioux City	Kansas Direct	Central Iowa	Illinois Direct	Peoria	Joliet	Futures
Amarillo I[a]	0.8720[b]	0.7296	0.8360	0.8972	0.8230	0.8195	0.7864	0.8046	0.5906
Amarillo II	0.9312	0.8905	0.8681	0.9638	0.8904	0.8923	0.8255	0.8283	0.7743
Amarillo III	0.9282	0.8500	0.8485	0.9441	0.8744	0.8579	0.7427	0.7537	0.6282
Greeley I		0.7284	0.8617	0.9202	0.8549	0.8572	0.8374	0.8743	0.5342
Greeley II		0.9154	0.8978	0.9430	0.8775	0.8928	0.8499	0.9078	0.7225
Greeley III		0.8662	0.8711	0.9172	0.8823	0.8675	0.7458	0.8334	0.5676
Omaha I			0.8411	0.8019	0.7877	0.7965	0.7016	0.8022	0.6165
Omaha II			0.9562	0.9003	0.9139	0.9253	0.9001	0.8904	0.6871
Omaha III			0.9119	0.8256	0.8460	0.8744	0.8219	0.8211	0.5047
Sioux City I				0.8979	0.9318	0.9167	0.8461	0.9077	0.6551
Sioux City II				0.8795	0.8976	0.9157	0.9007	0.8934	0.6742
Sioux City III				0.8320	0.8641	0.8671	0.8346	0.8104	0.5400
Kansas Direct I					0.8942	0.8895	0.8311	0.8681	0.6285
Kansas Direct II					0.8974	0.9038	0.8339	0.8082	0.7724
Kansas Direct III					0.8825	0.8368	0.7165	0.7386	0.6527
Central Iowa I						0.9178	0.8361	0.8909	0.6128
Central Iowa II						0.9199	0.8428	0.8415	0.7409
Central Iowa III						0.8818	0.7137	0.7531	0.5848
Illinois Direct I							0.8520	0.9154	0.5867
Illinois Direct II							0.8989	0.9089	0.6916
Illinois Direct III							0.8028	0.8271	0.5290
Peoria I								0.8463	0.5211
Peoria II								0.8442	0.6596
Peoria III								0.7721	0.4796
Joliet I									0.6444
Joliet II									0.6177
Joliet III									0.5114

[a] Roman numerials denote time periods used, I: 1973-76, II: 1977-80, and III: 1981-84.
[b] All values are significant at the 5% level.

Table 2. Causal Flows from Selected U.S. Fed Cattle Markets for Three Subperiods Encompassing 1973 Through 1984.

First Market & Time Period	Second Market: Greeley	Omaha	Sioux City	Kansas Direct	Central Iowa	Illinois Direct	Peoria	Joliet	Futures
Amarillo I[a]	--->[b]	<---	<---	<---	--->	--->	---	--->	<--->
Amarillo II	--->	<--->	<--->	---	<--->	--->	<--->	--->	<---
Amarillo III	--->	<--->	--->	<---	<---	--->	--->	<--->	<---
Greeley I		<---	<---	<---	<---	<---	--->	<---	<--->
Greeley II		---	--->	<--->	<--->	---	--->	--->	<---
Greeley III		<--->	--->	<---	<---	--->	--->	--->	<---
Omaha I			--->	--->	--->	--->	--->	--->	<--->
Omaha II			---	<---	<--->	<---	--->	--->	<---
Omaha III			<---	<--->	<--->	<---	--->	--->	<---
Sioux City I				---	--->	--->	--->	---	<--->
Sioux City II				<--->	<--->	<---	--->	--->	<---
Sioux City III				<--->	<--->	<---	--->	--->	<---
Kansas Direct I					--->	--->	--->	---	<--->
Kansas Direct II					<--->	--->	--->	--->	<---
Kansas Direct III					---	--->	<--->	--->	<---
Central Iowa I						--->	--->	---	<--->
Central Iowa II						--->	<--->	<--->	<---
Central Iowa III						<--->	<--->	--->	<---
Illinois Direct I							--->	<---	<--->
Illinois Direct II							--->	<--->	<---
Illinois Direct III							<--->	--->	<---
Peoria I								<---	<--->
Peoria II								--->	<--->
Peoria III								<--->	<---
Joliet I									<--->
Joliet II									<--->
Joliet III									<---

[a] Roman numerials denote time periods used, I: 1973-76, II: 1977-80, and III: 1981-84.
[b] The arrows denote flows which were significant at the 5% level. The arrow ---> represents a flow from the first to the second market, <--- represents a flow from the second market to the first, the double arrow <---> represents feedback, and --- denotes no significant flows.

Table 3. Test Statistics Examining the Hypothesis that the Feedback Between Markets is Symmetric and Ratios Summarizing the Relative Strength of the Components of the Feedback Relationships.

Markets with Feedback and Time Period Under Consideration			F Statistic[a]	P Value	Ratio[b]
Futures	Amarillo	I	10.007	0.0017	2.421
Futures	Greeley	I	16.816	0.0001	2.565
Futures	Sioux City	I	4.250	0.0399	1.839
Futures	Kansas Direct	I	13.238	0.0003	2.638
Futures	Central Iowa	I	6.012	0.0146	1.706
Futures	Illinois Direct	I	6.360	0.0121	2.183
Futures	Peoria	I	13.376	0.0001	2.506
		II	6.372	0.0120	1.627
Futures	Joliet	I	3.684	0.0557	1.884
		II	8.368	0.0040	1.693
Amarillo	Sioux City	II	10.264	0.0015	2.185
Amarillo	Central Iowa	II	1.241	0.2659	0.832
Kansas Direct	Greeley	II	7.279	0.0073	2.438
Kansas Direct	Central Iowa	II	1.146	0.2851	1.020
Central Iowa	Greeley	II	3.646	0.0569	2.123
Amarillo	Omaha	II	1.127	0.2890	1.461
		III	4.555	0.0334	2.185
Central Iowa	Omaha	II	5.338	0.0214	1.977
		III	10.793	0.0011	2.248
Central Iowa	Sioux City	II	5.549	0.0190	1.994
		III	8.804	0.0032	3.122
Kansas Direct	Sioux City	II	12.978	0.0004	2.865
		III	3.851	0.0502	2.568
Kansas Direct	Omaha	III	17.767	0.0001	1.442
Omaha	Greeley	III	1.962	0.1620	0.625
Central Iowa	Illinois Direct	III	5.350	0.0212	2.043
Central Iowa	Peoria	III	12.648	0.0004	6.727
Kansas Direct	Peoria	III	19.912	0.0001	2.172
Illinois Direct	Peoria	III	4.113	0.0432	2.558
Peoria	Joliet	III	0.548	0.4596	1.342

[a] An explicit statement of the hypothesis tested is given in equation (2).
[b] This ratio of the sum of the absolute value of the significant coefficients measuring the flows from the first market listed on a given line to the second market over the analogous sum measuring the flows from the second market to the first market.

References

Bailey, D. and B. W. Brorsen. "Dynamics of Regional Fed Cattle Prices." Western Journal of Agricultural Economics 10(1985): 126-33.

Bessler, D. A. and J. A. Brandt. "Causality Tests in Livestock Markets." American Journal of Agricultural Economics 64(1982): 140-44.

Bessler, D. A. and L. F. Schrader. "Relationships Between Two Price Quotes for Eggs." American Journal of Agricultural Economics 62(1980): 766-71.

Garbade, K. D. and W. L. Silber. "Dominant and Satellite Markets: A Study of Dually Traded Securities." The Review of Economics and Statistics 61(1979): 455-61.

Geweke, J. B. "Inference and Causality in Economic Time Series Models." in Handbook of Econometrics, eds. Z. Griliches and M. Intriligator, Chapter 17. North Holland, 1980.

Geweke, J. B., R. Meese and W. Dent. "Comparing Alternative Tests of Causality in Temporal Systems: Analytic Results and Experimental Evidence." Journal of Econometrics 11(1983): 161-94.

Granger, C. W. J. "Investigating Causal Relationships by Econometric Models and Cross-Spectral Methods." Econometrica 37(1969): 424-38.

Guilkey, D. K. and M. D. Salemi. "Small Sample Properties of Three Tests for Granger-Causal Ordering in a Bivariate Stochastic System." The Review of Economics and Statistics 64(1982): 668-97.

Heien, D. M. "Markup Pricing in a Dynamic Model of the Food Industry." American Journal of Agricultural Economics 62(1980): 10-18.

Hsiao, C. "Autoregressive Modeling and Causal Ordering of Economic Variables." Journal of Economic Dynamics and Control 4(1982): 243-59.

Hudson, M. A., and W. D. Purcell. "Price Discovery Processes in the Cattle Complex: An Investigation of Cash-Futures Interactions." Virginia Agricultural Experiment Station Bulletin 85-12, Virginia Polytechnic Institute and State University, Fall 1985.

Nelson, C. R. and G. W. Schwert. "Tests for Predictive Relationships Between Time Series Variables: A Monte Carlo Investigation." Journal of the American Statistical Association 77(1982): 11-18.

Oellerman, C. M. and P. L. Farris. "Futures or Cash: Which Market Leads Live Beef Cattle Prices?" Journal of Futures Markets 5(1985): 529-38.

Purcell, W. D., D. Flood and J. S. Plaxico. "Cash-Futures Interrelationships in Live Cattle: Causality, Variability, and Pricing Processes." in Livestock Futures Research Symposium, eds. R. M. Leuthold, and P. Dixion, Chicago Mercantile Exchange, 1979, pp. 135-156.

Purcell, W. D. and M. A. Hudson. "The Economic Roles and Implications of Trade in Livestock Futures." in Futures Markets: Regulatory Issues, ed. A. E. Peck, American Enterprise Institute, 1986, pp. 329-376.

Tjostheim, D. "Granger Causality in Multiple Time Series." Journal of Econometrics 17(1981): 151-76.

Weaver, R. D. and A. Banerjee. "Cash Price Variation in the Live Beef Cattle Market: The Causal Role of Futures." Journal of Futures Markets 2(1982): 367-89.