PACKER COMPETITION, FORWARD CONTRACTING PRICE IMPACTS, AND THE RELEVANT MARKET FOR FED CATTLE

Marvin Hayenga and Dan O'Brien

September 1991

A report on research conducted
under contract with the Research
Institute on Livestock Pricing,
Marvin Hayenga, Iowa State University,
Research Director

Research Bulletin 5-91
Research Institute on Livestock Pricing
Agricultural Economics
Virginia Tech
Blacksburg, VA 24061

Packer Competition, Forward Contracting Price Impacts, and the Relevant Market for Fed Cattle

Marvin Hayenga and Dan O'Brien*

In recent years, several farm or commodity organizations have expressed concern about the declining number of packers competing for their livestock and the influence of packer forward contracting on farm-level prices. In this paper, we analyze those related issues in Colorado where the decline in the number of large packers located in the state has been more severe than in most major cattle feeding states. From 8 firms in the late 1970s, the Colorado industry is now down to 3 large plants owned by 2 packers. Others have used state or small regional markets for analysis of the impacts of the changing number of buyers, but the influence of contracting on price levels or volatility is a new area of inquiry.

Since we implicitly are making assumptions about the appropriate geographic market for fed cattle as we analyze the effect of forward contract deliveries or the changing number of packers on reported prices in a state, we simultaneously analyze the dynamics of the geographic market arbitrage process among the cattle feeding states. Correlation analysis, vector autoregression, cointegration estimates and associated unit root tests are employed to determine whether the price linkages among states are sufficiently strong and responsive to suggest that a state is not the appropriate geographic market for analysis of competition and pricing.

Relevant Literature

In the last decade, there have been studies addressing the influence of the number of competing buyers or procurement market concentration on prices paid to farmers in the beef or pork industries. The impact of pork plants opening or closing was studied by Hayenga, Deiter, and Montoya, and either temporary or no local producer price impact was found in Iowa, Wisconsin, and Oklahoma case studies. Miller and Harris analyzed the impact of state pork slaughter firm concentration on state price levels, and found marginally significant lower prices associated with higher concentration. Quail, Marion, Geithman and Marquardt analyzed the beef packer concentration-fed cattle price relationship in 13 regional fed cattle markets in the 1970s, and found statistically significant negative relationships. A recent update and extension of that study

---

*Professor of Economics and Extension Associate, respectively, Iowa State University. Senior authorship is not assigned. Financial support was provided by the Research Institute on Livestock Pricing, Agricultural Economics, Virginia Tech, and the Iowa State University Cooperative Extension Service and Agricultural and Home Economics Experiment Station.

found that the concentration-price relationship became more ambiguous in the 1980s, even though concentration levels have increased. The regional markets used in some of these studies had earlier been estimated by Willard Williams for the House Small Business Committee based primarily on his analysis of fed cattle movements during the 1970s.

The impacts of contracting, packer feeding, and the umbrella term of "captive supplies" is emerging as an issue warranting economic analysis. During the same time that this study was underway, Jones, et.al. studied the impact of contracted supplies on fed cattle price in Southwest Kansas over a six month period, and found a significant negative effect on prices.

Analysis of the relationships between market concentration indices and prices can be critically influenced by choice of the relevant market and the resulting level of concentration. The theory and procedures applicable to relevant product and geographic market determination have been discussed in most industrial organization textbooks and in many antitrust cases. Not all will be cited here. Recent contributions include Stigler and Sherwin, where they conclude that comparisons of price movements (correlation of direct or differenced time series) are essentially equivalent to the commonly recommended cross elasticities of demand and supply for relevant market analysis, and should be used in geographic and product market determination. They also argue that the physical shipment of a good or its absence may not provide reliable proof that two areas are or are not in the same relevant market. Slade utilized univariate time series techniques and Granger-Sims causality tests to determine the economic links between markets for petroleum. She used pairwise tests of market linkages, and suggested that multivariate analysis might be more appropriate. Schultz used trade areas, univariate time series, factor analysis and cross elasticities to analyze the relevant market for fed cattle. She concluded that the Midwest-Texas market seemed to constitute a relevant market, with weaker ties to coastal regions. Schroeder and Goodwin analyzed fed cattle geographic market price lead-lag relationships using Granger causality tests, and found significant 1-3 week lags among 11 markets, but the relevance of their results to determination of the correct geographic market was not considered. Goodwin and Schroeder later applied tests developed by Engle and Granger to determine whether state level weekly fed cattle prices were cointegrated, and concluded that such price series were highly interrelated.

Objectives and Data Sources

The primary objectives of this study are a) to determine the impact of the sharp decline in the number of plants and packers in several large cattle feeding states on fed cattle prices in those states, b) to analyze the appropriate geographic market for fed cattle, and c) to determine whether packer contracting of fed cattle influences cash market price levels or volatility.

To analyze these related issues, USDA reported Choice 1100-1300 lb. steer prices were acquired for a large number of geographically dispersed markets (weekly averages, 1973-1989; daily, 1987-1989). Arizona prices were for 900-1100 lb. steers due to insufficient price data on heavier cattle. In addition, Cattle-Fax estimates of weekly forward contract cattle deliveries to packers from 4 states (October, 1988 to December, 1989), USDA statistics on weekly state cattle slaughter for the same period, and USDA-FSIS statistics on the number of beef slaughter plants

above 100,000 head capacity in each state, annually for 1973-1989, were collected. While packer market shares and concentration indices might be preferred, the number of relatively large active competitors located in the state may serve as a reasonable index of the state-level packer concentration. Packers in and around Colorado were also surveyed to determine which packers acquired Colorado cattle, and the procurement area of Colorado packers. A small number of Colorado cattle feeders was also surveyed to determine which packers were active competitors in Colorado. The percentages of cattle marketed annually from feedlots with less than 1,000 head capacity and from feedlots with greater than 32,000 head capacity by states were calculated from January USDA Cattle on Feed reports and annual state livestock slaughter statistics. These data were used as a measure of changes in feedlot concentration and the countervailing power of cattle feeders in fed cattle markets.

Colorado Prices and the Number of Competing Packing Plants and Plant Owners

Has the decline in the number of large beef packing plants and the number of active beef slaughter firms located within a particular state led to lower prices paid for fed cattle? This has been a matter of concern among livestock producers in states that lost packing plants during the last 20 years. However, such concerns may be increased inappropriately if producers view their state as the relevant market. The appropriate geographic area or relevant market within which to consider the number of competitors may be much larger than the boundaries of a particular state. One way to test whether state boundaries define the appropriate relevant beef cattle markets is to find an extreme situation and determine whether structural changes in the state impacted market performance. Since Colorado is an important cattle feeding state on the fringe of the primary cattle feeding region, and since there are now only two resident packers with three large plants (versus a high of eight in the 1970s), the potential for changes in relative prices in Colorado appeared more likely there than in most other states.

An initial graphical analysis of the ratio of weekly average Colorado steer prices to the average price in eight other states during the 1973-89 period (Figure 1) showed little apparent change in relative prices between states. There was no statistically significant trend. Thus, a cursory analysis suggests that no change in Colorado prices relative to other state's prices occurred during the time that the decline in the number of large plants and owners within the state took place.

Have changes in the number of beef slaughter plants or the number of beef slaughter plant owners in Colorado and other major cattle feeding states had an effect on fed cattle prices in those states? While analysis of this issue based on the number of plants within a state or market area is relevant to market performance questions, analysis based on the number of plant owners may be more important. Two plants in the same relevant market with the same owner would not be expected to compete with each other for cattle but would be expected to coordinate their fed cattle procurement efforts. In Colorado, since 1988, there have been three large beef packing plants in operation, one at Greeley owned and operated by Monfort and the other two (at Fort Morgan and Sterling) owned and operated by Excel Corporation. Similar situations

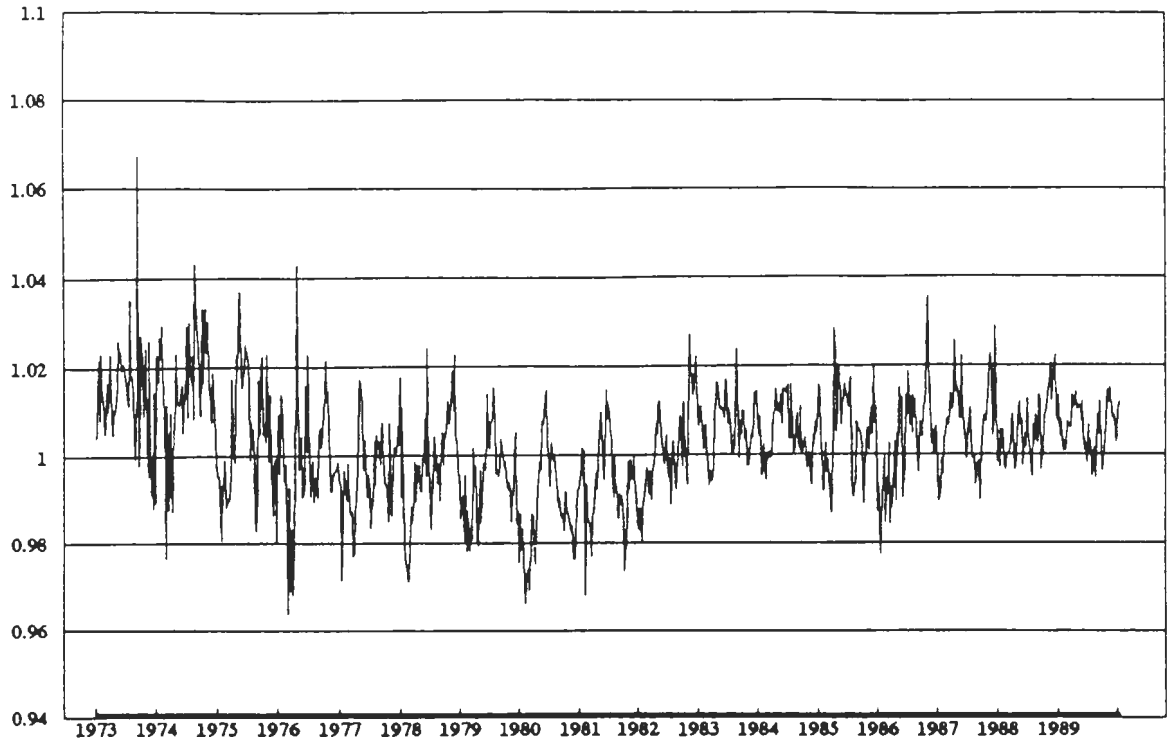

Figure 1. Colorado/Eight State Average Price Ratio

exist in other states where either IBP, Excel, or other beef packers either own or have owned at one time more than one beef packing plant. Of the states included in this study, Colorado and Iowa showed the greatest proportional decreases in both number of large beef packing plants and number of owners of large plants (see Table 1). The largest proportional decrease in the number of large beef packing plant owners was seen in Colorado.

The Effect on Number of Plant Owners and Size of Feedlots on Relative State Prices

Table 2 reports the results of regressions of relative annual state price ratios on annual plant ownership data and the changing relative concentration of fed cattle sellers (the annual percent of cattle marketed within a state from small feedlots under 1000 head capacity). Quadratic functional forms were specified to accommodate possible nonlinear or threshold relationships. The effect of changes in number of plant owners was essentially the same when using alternative specifications which use either the small or large feedlot's (over 32,000 head capacity) proportions of annual state fed cattle marketings as an additional explanatory variable. The plant owners impacts are reported only for the equations which incorporate the small feedlot variable.

Table 1. Number of Beef Packing Plants and Plant Owners With 100,000 Head Annual Slaughter Capacity in Major Cattle Feeding States, 1972-1988.

	Colorado		Kansas		Texas		Nebraska		Iowa	
Year	Plnt	Ownr	Plnt	Ownr	Plnt	Ownr	Plnt	Ownr	Plnt	Ownr
1972	8	7	5	5	6	6	11	11	16	8
1977	8	8	7	7	8	8	14	14	13	5
1982	5	5	5	5	6	6	13	13	9	5
1987	4	3	6	5	7	7	12	11	5	4
1988	3	2	6	5	7	5	11	9	5	5

Source: USDA Food Safety and Inspection Service

Only in the Colorado/Texas equation in Table 2 was there found a significant effect from the changing number of plant owners. A slight decline in Texas owners was associated with lower prices in Texas relative to Colorado. This occurred even though the number of Colorado plant owners declined more than did Texas over that time period. All other plant owner variables had no significant effect on relative prices. Many economists or industry participants would expect that a decline in the number of competitors (buyers) in a farm commodity procurement market would lead to depressed farm prices when the number of competitors and therefore competition to buy the farm commodity falls below some critical level. The results in Table 2 indicate little if any effect from falling numbers of plant owners. This may be due to mis-specification of the plant owner variables as an index for packer competition, or due to the increased efficiency of the larger scale plants still remaining in Colorado or other states with the increased efficiency, compensating for any potential loss in competition. Alternatively, it may be due to the inappropriate use of the state as the relevant market area for structural market analysis, which could lead to spurious results. For example, our packer survey found a few packers in other states who at least occasionally purchase fed cattle from Colorado, but who do not have plants located in the state. Our survey indicated that the procurement area for Colorado likely extends beyond Colorado's borders into three other states. Also, the arbitrage process in the fed cattle market may extend significant market interactions well beyond that procurement area.

Table 2 also shows that changes in the proportion of cattle marketed in a state from the smallest USDA feedlot category reported (less than or equal to 1000 head capacity) had significant effects, though mostly with unexpected signs, in several equations. As the concentration of feedlot ownership increases, their market power and consequently their ability to obtain higher relative fed cattle prices would be expected to increase. A decrease in the proportion of cattle marketed from small feedlots in Colorado was associated with a lower Colorado price relative to Kansas--an unexpected result. A decrease in the proportion of cattle marketed from small

Table 2. Effects of Changes in the Number of Plant Owners and Feedlot Size Structure on Relative Colorado Prices.

Dependent Variable	Variable	Coefficient	Signif. Level	R-Squared
Colorado P/ Kansas P	Colorado Owners	-.0003	.923	.84
	Colorado Owners Sqrd	.0005	.711	
	Kansas Owners	.0018	.748	
	Kansas Owners Sqrd	.0031	.443	
	Colorado Small Fdlts	.0049	.047*	
	Col Small Fdlts Sqrd	.0007	.206	
	Kansas Small Fdlts	-.0002	.798	
	Kan Small Fdlts Sqrd	.0002	.082	
	Constant	.9506	.000**	
Colorado P/ Texas P	Colorado Owners	-.0017	.599	.78
	Colorado Owners Sqrd	-.0024	.239	
	Texas Owners	-.0089	.044*	
	Texas Owners Sqrd	.0021	.364	
	Colorado Small Fdlts	.0036	.273	
	Col Small Fdlts Sqrd	.0003	.748	
	Texas Small Fdlts	.0113	.038*	
	Tex Small Fdlts Sqrd	.0008	.863	
	Constant	1.0319	.000**	
Colorado P/ Nebr. P	Colorado Owners	-.0019	.645	.51
	Colorado Owners Sqrd	.0021	.314	
	Nebraska Owners	-.0009	.861	
	Nebraska Owners Sqrd	-.0010	.531	
	Colorado Small Fdlts	.0063	.131	
	Col Small Fdlts Sqrd	.0012	.427	
	Nebraska Small Fdlts	-.0002	.912	
	Neb Small Fdlts Sqrd	-.0000	.839	
	Constant	0.985	0.000**	
Colorado P/ Iowa P	Colorado Owners	.0042	.222	.84
	Colorado Owners Sqrd	-.0011	.344	
	Iowa Owners	-.0002	.967	
	Iowa Owners Sqrd	-.0019	.447	
	Colorado Small Fdlts	-.0053	.224	
	Col Small Fdlts Sqrd	.0001	.885	
	Iowa Small Fdlts	.0006	.031*	
	Iowa Small Fdlts Sqrd	.0000	.004**	
	Constant	0.9657	.000**	

feedlots in Texas reduced the Texas price relative to Colorado, also not expected. A decrease in the proportion of cattle marketed from small feedlots in Iowa had a similar impact on Iowa prices relative to Colorado. When the proportion of cattle marketed from larger feedlots was substituted for the small feedlot variable in the equations, the explanatory power generally declined, and only one feedlot variable exhibited any significant effect. Kansas had the expected negative sign.

Seemingly Unrelated Regressions Analysis of the Effect of Changing Packer Structure

An alternative way to examine the impact of structural changes on relative prices is to determine the changes in fed cattle prices which have occurred over time that are associated with changes in the supply of beef and competing products, income, and population. After accounting for these major price influencing factors, then the effect of the changing number of state level plant owners and of changing feedlot structure on state fed cattle prices could be determined.

The effects on annual state average fed cattle prices of changes in the annual number of owners of large beef packing plants and the percent of cattle marketed from feedlots within a state from both the smallest (under 1000 head annually) and largest (32,000 head or more annually) USDA reporting categories were estimated for a system of state price equations using the Seemingly Unrelated Regressions (SUR) technique. Within the SUR system of equations for five states, the factors used to explain barometric changes in annual state average fed cattle prices were annual per capita beef, pork, and poultry production (retail weight) and U.S. annual per capita disposable income (1982 dollars).

The SUR technique is appropriate to use when there is same-period (contemporaneous) correlation between the error terms from otherwise separate equations in a simultaneous system of equations. If some of the endogenous variables appear in all the equations within the system and their effect is thought to be equal across all equations, then across-equation equality restrictions can be placed on these regression coefficients. In this study, it seems likely that annual state beef prices in Colorado, Iowa, Nebraska, Kansas and Texas are equally affected by annual per capita beef, pork, and poultry production and annual per capita disposable income. Preliminary tests confirmed that. The equation system to be estimated subject to cross equation equality restrictions for the effect of beef, pork, poultry and income on prices in all states was as follows:

$$\begin{aligned} \text{Price}_{\,i} = \quad & B_{i0} + B_{i1}\,(\text{BeefQ}) + B_{i2}\,(\text{PorkQ}) + B_{i3}\,(\text{PoulQ}) + B_{i4}\,(\text{Incm}) \\ & + B_{i5}\,(\#\text{State-i Owners}) + B_{i6}\,(\%\ \text{Small Feedlot Mktgs}) \\ & + \text{Bi7}\,(\%\ \text{Large Feedlot Mktgs}), \end{aligned}$$

where: i = Colorado #1, Kansas #2, Texas #3, Nebraska #4, Iowa #5,
BeefQ = Per capita Beef Production,
PorkQ = Per capita Pork Production,

PoulQ = Per capita Poultry Production,
Incm = Per capita Disposable Income,

% Small Feedlot Mktgs = Small feedlot annual marketings as a proportion of annual state feedlot marketings, and

% Large Feedlot Mktgs = Large feedlot annual marketings as a proportion of annual state feedlot marketings.

The results of the SUR analysis are reported in Table 3. The across-equation restricted coefficient for per capita beef consumption was negative and significant at the 1% level, implying that an increase in annual per capita beef production had a significant negative affect on annual state fed cattle prices. The effects of per capita pork and poultry supplies were not significant. Per capita disposable income had a small positive significant effect on beef prices.

Changes in the number of owners of larger beef packing plants in each state over time had no significant effect on state average beef prices. Only in the case of Texas did changes in the number of cattle marketed from the largest and/or smallest feedlots have any significant effect on prices. Decreases in the quantity of cattle marketed from small Texas feedlots had a significant (5%) positive effect on annual Texas fed cattle prices whereas increases in the quantity of cattle marketed from the largest Texas feedlots had a significant negative impact on Texas prices. The small feedlot result is consistent with the idea that as feedlot ownership becomes more concentrated they should be able to command a higher price for cattle through increased market power. The large feedlot result for Texas is not consistent with a priori expectations.

Forward Contract Deliveries and Market Prices

Conceptually, forward contracts reduce the quantity needed and the quantity supplied on the spot market equally, so no change in price level should be expected due to forward contracted cattle deliveries. However, some cattle feeders argue that high levels of contract deliveries reduce the interest of bidders in their cattle, and weaken cash price bids. Further, some suggest that the effect is more pronounced on the fringe (and presumably higher transportation cost) procurement areas for packers with high volumes of contract deliveries. The effect would be expected to be strongest on prices for cattle to be delivered in the same time period as the contract deliveries, but since cattle purchased today often are delivered 3 to 7 days later, the price effect may be most noticeable one week earlier than contracted deliveries. Cash market variability might be increased if high volumes of contract deliveries take some packers out of the cash market temporarily. In this case, price incentives must increase to bring fringe area packers to feedlots that are not part of their normal market area. Alternatively, packers with few contract deliveries scheduled for a specific time period may find that most of the cattle ready for market are committed to others, resulting in "panic buying" to fill slaughter needs. The unevenness in the "matching up" process could affect cash price variability on a day to day basis.

Table 3. The Effect of Changes in the Number of Plant Owners on Annual Average Fed Beef Prices Using Restricted Seemingly Unrelated Regressions, 1973-1988

Dependent Variable	Variable	Coefficient	T Stat	R - Squared
	BeefQ[1/]	-1.23	-5.99**	
	PorkQ	.27	1.54	
	PoulQ	-.26	-0.80	
	Inc	.01	2.30*	
Colorado	# Colorado Owners	.09	0.24	.89
Price	% Col. Small Fdlt Mktgs	.59	1.64	
	% Col. Large Fdlt Mktgs	.07	.80	
	Constant	78.06	3.37**	
Kansas	# Kansas Owners	-.15	-.28	.87
Price	% Kan. Small Fdlt Mktgs	-.07	-.64	
	% Kan. Large Fdlt Mktgs	-.13	-1.36	
	Constant	89.20	3.93**	
Texas	# Texas Owners	.96	1.95	.96
Price	% Tex. Small Fdlt Mktgs	-1.91	-3.15*	
	% Tex. Large Fdlt Mktgs	-.30	-3.57**	
	Constant	94.93	4.33**	
Nebraska	# Nebraska Owners	.14	.36	.88
Price	% Neb. Small Fdlt Mktgs	.05	.35	
	% Neb. Large Fdlt Mktgs	.11	.40	
	Constant	79.88	3.45**	
Iowa	# Iowa Owners	.79	1.23	.87
Price	% Iowa Small Fdlt Mktgs	-.06	-1.36	
	Constant	83.97	3.70**	

* = 5% signif. level (2 tail)
** = 1% signif. level (2 tail)

[1/] The effects of BeefQ, PorkQ, PoulQ and Inc were restricted to be equal across the five state price equations.

To measure the effect of forward contracting on fed cattle prices, Cattle-Fax weekly state estimates of forward contract deliveries from October 1988 through December 1989 were transformed into percentages of state weekly slaughter for Colorado, Texas, Nebraska, and Kansas. The variable name is ___CONT, with the state prefix identifying the particular state involved. Correlation in weekly contract volumes between the four states was generally low. For example, the correlation between COLCONT and TEXCONT was .24, whereas correlation between KANCONT and NEBCONT was .56. Near-VAR (VARX) models were used to determine the effects of one and two weeks of lagged prices for each state and weekly contract variables for each of the four states on each state's current weekly fed cattle prices. Correlation in weekly contract volumes between the four states was generally low. Results for Colorado are reported in Table 4. (The results for other states were very similar.)

Table 4. Effect of Lagged Weekly Prices and Contract Deliveries as a Percent of Monthly Slaughter on Colorado Fed Cattle Prices.

Dependent Variable: COLORADO Prices

Variable	Coefficient	T value
COLORADO(-1)	-0.593	1.499
COLORADO(-2)	0.052	0.136
NEBRASKA(-1)	0.423	0.994
NEBRASKA(-2)	-0.606	-1.693
KANSAS(-1)	1.457	3.417**
KANSAS(-2)	0.547	1.454
TEXAS(-1)	-0.596	-0.012
TEXAS(-2)	-0.377	-1.976
COLCONT	-5.300	-0.976
KANCONT	59.078	2.744**
TEXCONT	-20.452	-2.545*
NEBCONT	-19.209	-0.880

R-Squared = .934

** - 1% significance level; * - 5% significance level

Kansas forward contracting had a significant positive effect on Colorado fed cattle prices, while Texas forward contracting had a significant negative effect. Colorado and Nebraska contract deliveries had no significant effects. In each other state equation (not shown), Kansas forward contracting was found to have the same significant positive effect on prices in Texas, Kansas and Nebraska. Texas contracting had a similar significant negative effect on Nebraska, Texas and Kansas prices. Colorado and Nebraska contract volumes had no significant effect. With the conflicting signs of the significant contract volume variables, and no effects of the other state contract volumes in this analysis, we cannot conclude that contract deliveries had any clear impact on price levels.

SUR Analysis of Forward Contracting Effects

SUR analysis was also used to test the effect of forward contracting on state fed cattle prices for October 1988 through December 1989. Weekly fed cattle prices across the various states in the main fed cattle feeding region would likely be affected in a similar manner by conditions and resulting price movements in the wholesale beef market. The U.S. weekly average gross beef carcass cutout value in dollars per hundred weight, based on fabricated beef cuts for a Choice 1-3 550-700 lb. carcass, was used as a proxy for wholesale beef market prices. Weekly state level forward contracting as a proportion of state weekly federally inspected slaughter based on the Cattle-Fax forward contracting data was used as proxy for the overall proportion of forward contracting for Colorado, Kansas, Texas and Nebraska. SUR analysis allows one to restrict the effect of boxed beef price variation on state fed cattle prices to be equal across states, and to improve the efficiency of the estimate by allowing for contemporaneous correlation of the error terms across the system of equations. This is intuitively appealing because any errors in price prediction with respect to boxed beef prices and state level forward contracting amounts are likely to be related across states.

Table 5 reports the results of a SUR estimation of current week effects of boxed beef prices and forward contract deliveries on fed beef prices. From Table 5 it was found that forward contract deliveries in Kansas during the current week had a significant negative effect on Kansas fed cattle prices, while no other state showed a significant effect. The effect of boxed beef prices was positive and highly significant across the system of equations. The R-squared values were in the .56 to .73 range.

Table 6 gives the results of a SUR estimation of the effect of forward contract deliveries one week into the future and current week boxed beef prices on current week fed cattle prices. Intuitively, if beef packers have their slaughter needs for the coming week largely filled by forward contracted cattle, they may be less likely to bid aggressively for cattle in the current week.

Table 6 results indicate that one period ahead forward contract deliveries again had a significant negative effect only on Kansas fed cattle prices. The R-squared values for each state in Table 6 increased slightly relative to Table 5.

Table 5. SUR Analysis of Effect of Current Period Cattle Forward Contract Deliveries on Fed Cattle Price Levels (October 1988 to December 1989)

Dependent Variable	Variable	Coefficient	T Stat	R - Squared
	Weekly Boxed Beef Price[1/]	0.79	13.47**	
Colorado Price	Colorado Contracting / Fed. Insp. Slaughter	-0.30	-0.63	.62
	Constant	-16.75	-2.48*	
Kansas Price	Kansas Contracting / Fed. Insp. Slaughter	-6.62	-2.65*	.63
	Constant	-16.18	-2.40*	
Texas Price	Texas Contracting / Fed. Insp. Slaughter	-0.60	-0.58	.56
	Constant	-16.56	-2.45*	
Nebraska Price	Nebraska Contracting / Fed. Insp. Slaughter	-0.96	-0.32	.73
	Constant	-17.25	-2.56*	

** - 1% significance level; * - 5% significance level

[1/] The effect of Weekly Boxed Beef Price was set equal across the five state price equations.

The effect of forward contracting on the variation of daily prices within a week and the range of prices offered during a week was examined within a SUR framework similar to Tables 5 and 6 (not reported here). Price variability was measured as the standard deviation of the daily price range mid points within a week. An alternative weekly price variability measure was the range of lowest to highest reported prices offered within a week. This analysis found that forward contract deliveries had no significant effect on within-week price variability or the size of the price range reported for these states during the time period under examination.

Table 6. SUR Analysis of Effect of Current Period Cattle Forward Contract Deliveries on Lagged Fed Cattle Price Levels (October, 1988 to December, 1989)

Dependent Variable	Variable	Coefficient	T Stat	R - Squared
	Weekly Boxed Beef Price (T-1)[1/]	0.80	14.05**	
Colorado Price (T-1)	Colorado Contracting / F.I.Slaughter (T)	-0.51	-1.12	.63
	Constant	-17.85	-2.72**	
Kansas Price (T-1)	Kansas Contracting / F.I.Slaughter (T)	-9.05	-3.34**	.66
	Constant	-17.15	-2.62*	
Texas Price (T-1)	Texas Contracting / F.I.Slaughter (T)	-0.59	-0.57	.57
	Constant	-17.71	-2.70**	
Nebraska Price (T-1)	Nebraska Contracting / F.I.Slaughter (T)	-3.96	-1.33	.75
	Constant	-18.30	-2.79**	

** - 1% significance level; * - 5% significance level

[1/] The effect of one period lagged boxed beef prices on lagged state prices was restricted to be equal across equations.

The weekly state level forward contracting amounts of cattle as reported in the Cattle-Fax data were on average highest in Texas, Kansas, and Colorado, followed by Nebraska. Assuming that the Cattle-Fax survey data is an adequate proxy for total forward contract deliveries in these four states, the inconsistency in the results among the three states where contracting volume (and Cattle-Fax coverage) were highest leads to the conclusion that any negative impact of contracting has not been clearly shown in these analyses.

Relevant Market

The relevant geographic market for industrial organization and antitrust analysis often is based on the trade areas of the firms dealing in closely related products, with some marginal attention

to the potential competitors who might fairly easily move into those trade areas if prices moved up (or down in the case of procurement markets) to make entry more attractive. Cross elasticity estimates are usually impractical due to data shortages, but market prices from various firms or geographic markets can often be obtained. Fairly simple correlation analysis is frequently relied on as one of the tools to characterize product, firm or geographic market interrelationships. However, simple analyses like that may mislead, especially in markets where many other common factors influencing general supply and demand conditions may be stronger influences on price behavior than the competitive arbitrage process, or lack thereof, among geographic areas.

How can the relevant geographic market for livestock be characterized? Long observation suggests that the procurement area of an individual livestock buyer can be viewed as having an amoeba or sometimes a tear drop shape around a slaughter plant. Each procurement area typically overlaps with others, with more significant influences from other buyers as you approach the fringe of the amoeba. Further, the fringe of the procurement area ebbs and flows in response to changing geographic cattle supply patterns, product demands, slaughter capacity utilization, cutting margins, and competitive pressures. As a shock occurs in the system (e.g. a new plant opens), one competitor begins taking more cattle from the fringe of another's procurement area, who in turn does the same thing to an adjacent competitor on another fringe of his/her procurement area, and the domino or ripple effect is transmitted well beyond those packers actively involved in the initial trade area where the shock occurred. Thus, the procurement or trade area may not be the appropriate focus of analysis. Rather, the area where the price reverberations from shocks to the system are sufficiently quick and strong would appear to be the best candidate as the relevant geographic market for subsequent structure-performance analysis, at least as a preliminary screening device. If the firms competing on the periphery of a target firm's procurement area were quickly and strongly affected by a third firm outside the target firm's area, the third firm would have to be included in the ideal collusive group for the group to be effective in exerting market power. The speed and strength of geographic market price arbitrage should be a good preliminary indicator of the relevant market geographic scope that would be appropriate. The absence of significant relationships among prices in different geographic locations should be a reasonable basis for excluding competitors in those areas from the same relevant market. Apparent arbitrage that was due to spurious correlation would have to be determined through further in-depth analysis of competitor interactions.

Since it seems likely that different statistical analysis and data selection choices could potentially lead to different results when analyzing the speed and strength of geographic market price interactions, we explore a few alternative types of price data including weekly, daily, regular and differenced price series. In addition, we examine the degree of correlation among prices in geographically dispersed markets, as well as the strength of lagged price interrelationships among these markets, with emphasis on Colorado as a focus of inquiry. Both simple econometric and vector autoregression techniques are used. The cointegrated nature of geographically dispersed daily prices are also examined using Dickey-Fuller unit root tests.

Contemporaneous Price Correlations

In the following tables, the simple correlation matrices are reported for weekly average USDA direct price reports from the states indicated during 1973-1989 (Table 7) and daily USDA price reports during 1987-89 (Table 8). There were fewer states with frequent daily reports than with frequent weekly reports for use in our analysis. The states are denoted by their abbreviation. OM is the Omaha terminal market price.

Table 7. Correlation Matrix of Weekly Prices, 1973-1989

	NB	TX	KS	CO	IA	IL	CA
NB	1.00	0.97	0.98	0.98	0.97	0.97	0.92
TX		1.00	0.98	0.98	0.97	0.96	0.89
KS			1.00	0.99	0.98	0.98	0.93
CO				1.00	0.98	0.97	0.95
IA					1.00	0.99	0.91
IL						1.00	0.91
CA							1.00

Table 8. Correlation Matrix of Daily Prices, 1987-1989

	NB	TX	KS	CO	IA	IL	AZ	OM
NB	1.00	0.97	0.97	0.98	0.98	0.82	0.90	0.98
TX		1.00	0.996	0.99	0.97	0.82	0.95	0.97
KS			1.00	0.99	0.97	0.81	0.94	0.97
CO				1.00	0.98	0.82	0.95	0.97
IA					1.00	0.83	0.90	0.99
IL						1.00	0.77	0.83
AZ							1.00	0.90
OM								1.00

The weekly average price correlations are quite high for all states included in the analysis, ranging from .89 to .99. However, part of that high correlation was associated with a strong upward trend in prices during 1973-89. A separate examination of first differenced weekly prices (not shown here) exhibited lower, but still fairly high correlations between all markets studied (.76 to .93).

Daily price patterns were also highly correlated (.77 to .996). The lowest correlations occurred for those states most spatially separated such as Illinois and most other states, especially Arizona, and also between Arizona and both Nebraska and Iowa. While the prices were relatively highly correlated for both the differenced and the undifferenced series, potentially different conclusions could arise due to the choice of either raw or differenced daily or weekly data in other cases where geographic markets had slightly weaker price linkages.

Lagged Price Relationships

Contemporaneous price response measured by the simple correlation of prices may not be a sufficient test of price interrelationships in some situations. Even if contemporaneous correlation were low, a strong price response within a reasonably short time period to a shock in another area may be sufficient to consider those areas all part of the relevant market. Thus, the strength of same-time period price linkages and the speed and strength of lagged price linkages need to be considered in making a judgement regarding the appropriate relevant market.

One statistical procedure which may be useful in evaluating lagged price interaction speed and strength among several geographic areas is vector autoregression. VAR models were estimated for each of the weekly, daily, and differenced price series described earlier. Due to space constraints, we will illustrate the results from one model focusing on Colorado prices as the selected endogenous price variable.

Vector autoregression analysis was used to determine the effect of lagged weekly average fed steer prices in Colorado and other states on prices in Colorado during 1973-89. First differences effectively eliminated the upward trend in prices during this time period and provided a stationary series. Only the significant coefficients of a VAR analysis of the effect of lagged price changes in Colorado and other geographically dispersed states on price changes in Colorado are shown in Table 9. Colorado weekly price changes were significantly related to one and three week lagged price changes of Colorado prices, one week lagged values of Kansas, Nebraska, Arizona, Iowa and Illinois prices, and one and two week lagged values of Washington prices.

Similar analyses were carried out for each state. Those lagged first differenced weekly prices which had a significance level of at least 5% are summarized in Table 10.

Table 9. The Significant Lagged Weekly First Differenced Fed Steer Price Relationships With Fed Steer Prices in Colorado

Dependent Variable: COLORADO Price

Lagged Independent Variables: Prices in COLORADO, KANSAS, NEBRASKA, TEXAS, ARIZONA, CALIFORNIA, WASHINGTON, IOWA, ILLINOIS

Variable	Lag	Coefficient	T Value
COLORADO	1	-0.830	-6.715**
COLORADO	3	-0.339	-2.757**
KANSAS	1	0.365	2.994**
NEBRASKA	1	0.671	6.649**
ARIZONA	1	-0.131	-2.056*
WASHINGTON	1	10.280	3.348**
WASHINGTON	2	0.209	2.423*
IOWA	1	0.258	1.954*
ILLINOIS	1	-0.450	-3.741**

R-Squared = 0.296, Durbin-Watson statistic = 1.948

**1% significance level; *5% significance level.

The significant weekly lagged price effects were primarily in the first two weeks among the centrally located cattle feeding states. California prices exhibited no lagged linkages to the Midwest, but Arizona and Washington prices did. Lagged daily price relationships also were estimated by VAR analysis. A trend variable was added to the equation to induce stationarity. Table 11 shows the results of VAR analysis using, in turn, each state's daily steer price as the dependent variable and 10 daily lags of the same state and other major cattle feeding state's daily prices as dependent variables. Only lagged daily prices that had a significance level of at least .05 are reported.

These results show relatively short term significant lagged price relationships among daily prices in the major cattle feeding states. Many significant lagged price relationships occurred within 10 business days, with a high proportion within 1 to 3 business days. This is consistent with the weekly VAR price analysis in Tables 9 and 10.

Table 10. Significant Weekly Lags in Price Relationships in Weekly First Differenced VAR Analysis.

Dependent Variables	Independent Variables								
	CO	KS	NB	TX	AZ	CA	WA	IA	IL
CO	1,3	1	1		1		1,2	1	1
KS	1	1	1	1			1,2	1	1
NB	1	1	1				1,2	1,2	1
TX	1	1	1	2	1		1,2	1	1
AZ	3		1		1	1	1		1
CA	1		1				1,2	1	1
WA	1		1		1			1	1
IA	1		1		1		1,2		1
IL	1		1		1		2	1	

Cointegration Tests of Daily Prices

The linked nature of spatially related fed cattle marketing regions can be analyzed through the use of pairwise cointegration tests. Engle and Granger (1987) presented seven such tests which were later applied to weekly state level fed cattle prices by Goodwin and Schroeder (1990). Engle and Granger identified an augmented Dickey-Fuller test as the recommended approach, closely followed by a basic unaugmented Dickey-Fuller test. The basic Dickey-Fuller test and the augmented Dickey-Fuller test are used here to determine whether daily fed cattle prices reported in eight states for 1987-1989 are highly integrated.

These tests are applied in this case to pairs of nonstationary state fed cattle price series (P1 and P2) which become stationary after taking their first differences. The first step in such pairwise tests is to run a "cointegrating regression" of the form $\{ P1_t = A + BP2_t + U_t \}$, where t represents time period, "$P1_t$" and "$P2_t$" represent the natural logs of prices, "A" represents a constant, "B" is the regression coefficient for P2, and "U_t" represents the residuals. This

Table 11. Significant Daily Lags in VAR Price Analyses (1987-89).

Dependent Variables	Independent Variables							
	CO	KS	NB	TX	AZ	IA	IL	OM
CO	1,2,5,10		1,4		3	8		7
KS			1			1		1
NB	4	5	1	5	4	4		
TX	1	1	1,8	1		1	2	1,2
AZ		9	1,2,6				2	3,4,8
IA		10	1			1	7	1,4,6
IL	1						1	
OM	1	4	1	8	10	3,4,8,10	2	3,4,8

equation can then be restated as $\{ P1_t - A - BP2_t = U_t \}$. The second step is to run regressions on these residuals to develop Dickey-Fuller unit root tests. The basic Dickey-Fuller unit root test comes from the regression:

$$DU_t = -(Phi)*U_{t-1} + E_t$$

where DU_t represents the first difference of the cointegrating equation residuals, U_{t-1} is the one time period lagged error of the cointegrating equation, the (Phi) is the regression coefficient on U_{t-1}, and E_t is the time period t error for this regression. To test for market cointegration, a t-test is done on Phi (i.e., comparing the ratio of Phi divided by its standard error to the appropriate t distribution critical value). If Phi is significantly different from zero, the null hypothesis that there is no cointegration between the two markets is rejected.

The augmented Dickey-Fuller test involves a regression on lagged differenced values of the cointegrating regression errors:

$$DU_t = -(Phi)U_{t-1} + B_1*DU_{t-1} + B_2*DU_{t-2} + B_3*DU_{t-3} + B_4*DU_{t-4} + E_t$$

where the B_i are the regression coefficients on the lagged differenced cointegrating equation errors and the other variables are as before. The t-test on Phi is carried out as before with the same null hypothesis as in the basic Dickey-Fuller test. Four lags were used in order to be consistent with the critical values presented in Engle and Granger for these tests.

The results for 1987-1989 daily state average fed cattle prices are given in Table 12. Only the calculated t-ratios of Phi are presented. Since the tests are not symmetric, both results for the regression of P_{1t} on P_{2t} and P_{2t} on P_{1t} are presented. The basic Dickey-Fuller tests (not shown) indicated a high degree of price integration among almost all states. Colorado fed cattle prices are closely integrated (1% significance level) with Kansas, Texas, Iowa and Illinois, and are less closely linked to Nebraska (5% significance level). The Arizona and Omaha prices are the exceptions. They are not as closely integrated with each other or with other states. Arizona is highly integrated with Illinois (1% level), and less so to Kansas and Texas (10% level). Omaha is highly integrated (1%) or nearly so with Nebraska, Iowa, and Illinois. Illinois is highly integrated with all other states according to the basic Dickey-Fuller test.

Table 12. Augmented Dickey-Fuller Unit Root Test Results. Daily State Average Prices, 1987-89.

	IA	TX	KS	CO	NB	IL
IA	-	4.04[a/]	2.91[c/]	3.33[b/]	3.78[a/]	4.26[a/]
TX	3.99[a/]	-	7.85[a/]	4.96[a/]	4.01[a/]	3.48[b/]
KS	2.94[c/]	7.89[a/]	-	5.12[a/]	3.36[b/]	3.25[b/]
CO	3.19[b/]	4.96[a/]	5.17[a/]	-	2.11	2.96[c/]
NB	4.07[a/]	3.93[a/]	3.39[b/]	2.42	-	3.79[a/]
IL	8.14[a/]	5.63[a/]	5.44[a/]	5.08[a/]	5.97[a/]	-

Significance levels: [a/] = 1% level, Critical Value = 3.77
[b/] = 5% level, Critical Value = 3.17
[c/] = 10% level, Critical Value = 2.84

Test statistics are presented in absolute values.

The results of the augmented Dickey-Fuller tests reported in Table 12 do not include the Arizona or Omaha prices since prices were not reported as many days per week as for other markets. Arizona tended to have prices reported 1 to 2 days per week, with periods of time where it was active 4 days a week. Omaha was consistently active 3 days per week. By this more stringent test, Colorado is highly integrated with Texas, Kansas and Illinois (1% significance level), Iowa (5%), and not integrated with Nebraska. Nebraska is highly integrated (1% significance level) with Iowa, Texas, and Illinois, and also with Kansas (5% level). Overall, price behavior in these primary cattle feeding states still shows a significant amount of integration.

Summary and Conclusions

Several different models were employed to test the impact of the changing number of competing packers on feedlot prices in Colorado and other major cattle feeding states. Our results suggest that fed cattle prices in Colorado have not declined relative to other cattle feeding states during 1973-89 when the number of resident larger slaughter firms declined from eight to two. The results were generally similar for other large cattle feeding states where less dramatic changes occurred in the number of large packers. The impact of changing feedlot concentration was generally insignificant or had unexpected impacts.

The impact of forward contracted cattle deliveries on weekly price levels was usually insignificant or had mixed signs, though the higher levels of contracting were associated with lower fed cattle prices in a small number of situations. The same basic conclusion applies to the impact of higher contract deliveries on spot price volatility, usually an insignificant or unclear effect, though a few cases had higher price volatility associated with higher contract volumes. One potential contributor to these insignificant results may be the use of state price indices when the state may not be the appropriate geographic relevant market.

In examining price behavior among geographically dispersed states to determine whether the state is the appropriate relevant market, several tests of price linkages were performed. The contemporaneous correlation among weekly and daily prices among the widely dispersed cattle feeding states was high, as was the correlation of weekly first differenced price series.

The vector autoregression analysis of weekly and daily lagged prices suggests that many of these state prices are also significantly affected by recent price changes in other states. These relationships were especially strong within the first two weeks for weekly data. The daily VAR results are consistent with the weekly results, with many strong lagged price relationships within a two week period. Tests for cointegration of daily state prices reveal that these price series are highly linked together in their price movements. These results give support to the idea that relevant geographic market for structural and competitive analysis is much larger than any state, and is much larger than the trade areas of individual firms due to the indirect competitive effects on and through the behavior of "third-party" firms in the dynamic arbitrage process in fed cattle markets, and perhaps in other commodity markets as well. The combination of correlation and vector autoregression approaches may be useful preliminary tests which could suggest geographic

areas or products with weak contemporaneous or lagged price linkages which should be excluded from a relevant market, and which ones deserve more in-depth analysis in the process of delineating a relevant market in antitrust cases or structural analysis.

References

Engle, R. F. and C. W. J. Granger. "Cointegration and Error Correction: Representation, Estimation, and Testing." Econometrica, Vol. 55, No. 2, March, 1987, pp. 251-276.

Goodwin, B. K., and T. C. Schroeder. "Testing Perfect Spatial Market Integration: An Application to Regional U.S. Cattle Markets." North Central Journal of Agricultural Economics, Vol. 12, No. 2, 1990, pp. 173-186.

Hayenga, M., R. Deiter, and C. Montoya. "Price Impacts Associated with the Closings of Hog Slaughter Plants." North Central Journal of Agricultural Economics, July, 1986, pp. 237-242.

Jones, Rodney, Ted Schroeder, James Mintert, and Frank Brazle. "The Impact of Captive Supplies on Cash Fed Cattle Markets." in Applied Commodity Price Analysis, Forecasting, and Market Risk Management, (M. Hayenga, editor), NCR-134 Conference Proceedings, April, 1991, pp. 239-253.

Marion, Bruce, Fredrick Geithman, and Gwen Quail. Monopsony Power in an Industry in Disequilibrium: Beef Packing, 1971-1986, Food System Organization-Performance and Public Policies Working Paper WP-96, Dept. of Agricultural Economics, University of Wisconsin, December, 1990.

Miller, S. E., and H. M. Harris. Monopsony Power in Commodity Procurement: the Case of Slaughter Hogs. Working Paper 012281, Dept of Agr Econ and Rural Soc, Clemson Univ., 1981.

Quail, G., B. Marion, F. Geithman, and J. Marquardt. The Impact of Packer Buyer Concentration on Live Cattle Prices. NC Project 117 Working Paper WP-89, May, 1986.

Schroeder, Ted C. and B. K. Goodwin. An Examination of Regional Fed Cattle Price Dynamics. Working Paper No. 90-3, Department of Agricultural Economics, Kansas State University, 1988.

Schulz, Margaret M., The Relevant Geographic Market Area for Fed Cattle and the Changing Structure of the Beef Packing Industry. Unpublished Ph.D. dissertation, Iowa State University, 1988.

Slade, Margaret E. "Tests of Market Boundaries Applied to Petroleum." Journal of Industrial Economics, Vol. 34, No. 3, March, 1986, pp.291-304.

Stigler, G. J., and R. A. Sherwin. "The Extent of the Market." Journal of Law and Economics, Vol. 28, October, 1985, pp. 555-585.