Consolidation in the Meat Sector

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Slaughter industries are consolidating, as the number of firms falls and plant sizes grow. Related changes are occurring in upstream livestock production sectors: large cattle feedlots and hog farms account for sharply growing shares of livestock sales. As in poultry, new contractual relationships have begun to replace spot market cash transactions for cattle and for hogs. Those sharp structural changes have raised concerns about market power, pollution control, and the reliability of traditional price reporting sources. This is a research conference, aimed at encouraging evaluation and discussion of research methods, data sources, and results.

Topics covered at the conference include the following:

* The existence, extent, and effects of market power in livestock and meat industries; Causal factors in consolidation, such as scale and scope economies, mergers, changes in product mix, innovation, and changes in contractual relations;

* Vertical coordination, as compared to spot markets for transferring livestock, including summaries of recent developments and implications for location, for product characteristics, and for price discovery;

* Externalities associated with consolidation, including the effects of larger animal production facilities on pollution and the effects of local control regulations on consolidation.

Efficiency and Competitiveness of Commodity Markets: Time Series Evidence

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Efficiency and Competitiveness of Commodity Markets: Time Series Evidence

Over the past twenty years the U.S. beef industry has experienced significant structural changes and increased market concentration in beef packing. This concentration has led researchers to ask whether market power is being exercised by industry participants to determine if the market is operating in a competitive manner. Although concentration alone in an industry does not imply noncompetitive behavior, it does raise concerns if natural barriers to entry exist. Feather and Sherrick (1992) note firms may choose to vertically integrate to reduce the risk of supply uncertainty and to increase the efficiency of the firm by reducing costs in the production process. Therefore, vertical integration may be chosen by firms as a means to reduce uncertainty as opposed to noncompetitive behavior.

Empirical examination of the efficiency of markets has most often involved evidence from estimated conditional means of prices. The definition of an efficient market suggests that it is impossible to make economic profits by trading on the full information set since all information will be instantaneously exploited by arbitrage and reflected by independent, identically distributed (iid) changes in prices. The implications of this for the first moment of price series has received considerable attention.

This paper will investigate market efficiency by estimating the conditional means and variance of price series. Estimation of the conditional means and variance jointly affords measurement of both the extent of and the intertemporal persistence of distortions in intertemporal arbitrage equilibrium. The paper is part of a stream of ongoing research by the authors that examines the implications for second moments, or price volatility, see e.g. Weaver, et al. (1989) and Loy and Weaver (1998). In this paper, our attention focuses on the persistence of price levels and volatility and implications for market efficiency. Persistence in levels may be considered using conventional VAR or error correction models. In the application reported here, stationarity of the series in differences along with the lack of cointegration allows the use of VAR models. Volatility persistence will be considered within the framework of a generalized autoregressive conditional heteroskedasticity (GARCH) model (see Engle (1982) and Engle and Bollerslev (1986)). The data used in this study consist of daily observations of prices for both live cattle and feeder cattle along with input prices of corn and soybeans. The frequency of observation allows the results to comment on the efficiency of multiple cattle markets over the sample period.

Alternative Approaches to Efficiency Analysis

Purely competitive or purely monopolistic markets are polar examples of market structures in which the actions of firms are either inconsequential or completely dominant in determining prices within the market. In the purely monopolistic market, a single seller of a product exists for which there exists no close substitutes and entry into the market is somehow constrained. When such a market condition exists, lack of competition results in the price of the product failing to contain all relevant information about the product. In particular, the adjustment of price will be managed strategically by the dominant firm rather than instantaneously adjusting to demand and supply changes, see Weaver et al. (1989). A similar result occurs when price is determined in a multiple firm game.

Although the pure monopoly market provides a foundation on which to study imperfect competition, many market structures display a combination of both competitive and noncompetitive behavior. In this scenario, evidence of exertion of market power to manage commodity prices is difficult to isolate from intertemporal price behavior.

Consider a generalized market clearing condition:

1)
$$z(p^e{}_t) + (1-\delta)S_{t-1} = D(p_t) - v_t + S_t$$

where z_t is the current harvest conditioned by $p^e{}_t$ the price expectation formed at time t-1, v_t is a random demand shock, S_t represents current storage at time t, and $D(p_t)$ is demand as a function of current prices. Muth considered the implications of the competitive case when $p^e{}_t$ is a homogeneous, rationale expectation. Helmberger et al. considered the implications of stock-outs, and a stream of literature has generalized the market situation to incorporate futures, options, forward contracts, and other forms of intertemporal arbitrage. Under competitive conditions, prices solve equation 1) and the associated arbitrage conditions. The implications for time series properties of the resulting prices will depend on the functional forms of the arbitrage conditions, the choice functions aggregated into a physical balance condition such as 1) and the exogenous stochastic processes impacting those choices and conditions.

Where price is not determined by a competitive process, an alternative theory of price determination through dominant firm strategic pricing, or gaming among firms, would lead to a theory of price evolution that differs from the competitive case. In particular, strategic pricing would imply inertia in price adjustment and perhaps asymmetry in adjustment.

It is commonly assumed that an efficient market is one where all information is reflected in current prices so

$$2)\ E[p_{t+1}|\Omega^c{}_t]=p_t.$$

In the price expectation, $\Omega^c{}_t$ represents all relevant information pertaining to the price p_{t+1}. If prices are determined by noncompetitive processes, this intertemporal arbitrage condition may be distorted in two ways. First, while dominant firms may continue to base decisions on a full information set $\Omega^c{}_t$ that reflects contemporaneous demand and supply conditions, their decisions would also reflect their conjectures concerning the current and possible future behavioral reaction of other firms to that information set. In other words, their decisions would also reflect a subjectively constructed strategic information set $\Omega^s{}_t$. Second, price would be determined by a mechanism that goes beyond the simple physical balance condition in 1). Here, an infinity of possible games and strategies could be specified, each leading to alternative specifications of a structural approach to the determination of price. In all cases, the level and evolution (dynamics) of equilibrium price could be represented simply by particular functions of the two information sets. Summarizing, under the competitive hypothesis 1) and 2) would imply

$$3)\ p_t = p^c(\Omega^c{}_t) \qquad dp_t = dp(d\Omega^c{}_t)$$

while a noncompetitive hypothesis would imply:

$$4)\ p_t = p^c(\Omega^c{}_t, \Omega^s{}_t) \qquad dp_t = dp(d\Omega^c{}_t, d\Omega^s{}_t).$$

Conventional structural models have been estimated with insertions of measures of firm concentration. This structural approach has been applied using parametric econometrics to the beef market to explicitly determine the impacts of concentration. For example, Schroeder (1988), Azzam and Pagoulatos (1990), and Schroeder and Azzam (1990) find evidence of periodic noncompetitive behavior in the input market for finished cattle. Schroeder (1988) and Schroeder and Azzam (1990) find evidence of market power in the output market for packed beef. Muth (1998) constructed a more general structural model of the beef packing industry to test for market power in both the input and output markets. Her results suggest both the finished cattle and the packed beef markets operate competitively.

While highly restrictive parameterizations of 4) could be articulated as did Applebaum (1982) following Bresnahan (1982), Lau (1982), these parameterizations could be complicated by dynamic behavioral hypotheses as did Steen and Salvanes, among others. However, both the logic and power of this approach, is brought to question by the simple fact that it nests the competitive specification within a specific articulation of a noncompetitive alternative hypothesis, leaving inference conditioned by the particular noncompetitive specification adopted.

Lau and Yotopoulos (1974) parametrically estimated the distance between price and marginal cost opening up the notion that parametrically (e.g. Atkinson and Halvorsen, 1980) or nonparametrically (e.g. Love and Shumway, 1994) allocative efficiency could be examined. However, once again, both parametric and nonparametric results may be questioned given the specification uncertainty from which they emerged. Nonparametric results are especially sensitive to specification error in functional properties, inclusion of variables, as well as in dimension of the model (number of variables), and sample.

As an alternative to structural, parametric or nonparametric approaches, researchers have employed various time series techniques to study competitiveness in markets including the livestock industry. Weaver et al. (1989) considered the impact of local market structure on the speed of transmission of price change within retail grocery markets. Loy and Weaver (1998) considered transmission of volatility in food prices across space in Russia. Recent literature considering livestock includes Khan and Helmers (1997) who investigated the relationship between the input price of corn and livestock prices over three regimes within a VAR framework. They hypothesize that the increased volatility in corn prices led to the structural changes in the livestock industry and they conclude that beef is more susceptible to changes in corn prices than is pork. Schroeder (1996) used a VAR model to investigate spatial price integration among 28 beef packing plants. Results suggest that daily prices are generally cointegrated but distance between plants weakens the spatial price linkages. Moreover, plants that purchased a large percentage of cattle through noncash instruments tended to have weaker long-run relationships suggesting that non-geographic factors impact price relationships.

Reconsideration of Time Series Approaches

Time series approaches to analyzing the competitive structure of markets over intertemporal dimensions are founded on the efficient market hypothesis and have test hypotheses that restrict the conditional mean of price level. The conventional efficient market hypothesis (EMH) has three forms; weak, semi-strong, and strong. The weak form of the EMH states simply that intertemporal change in price (e.g. in 4)) will be an IID process, or equivalently, price level in equation 3) will follow a random walk. Current prices, fully reflect the historic sequence of prices implying that changes in price are independent and identically distributed (IID).

Considering that the assumption of IID is one of the foundations of statistical inference a myriad of tests have been devised to test the assumption. These tests include, parametric, nonparametric, and semiparametric approaches. A considerable amount of research has employed these techniques to support and challenge the EMH. For example, research by Roberts, Canarella and Pollard (1986) find evidence supporting the random walk hypothesis while the work of Pindyck and Rotenmburg (1990), and Peterson, Ma and Ritchie (1992) challenges the EMH with findings that commodity cash prices demonstrate mean reversion. Evidence of mean reversion is also found by Bessembinder, Coughenour, Seguin,and Smoller (1995) for futures prices of certain agricultural commodities.

Spatial efficiency in markets implies convergence of prices in separated markets to one price (law of one price, LOP). In this case, spatial arbitrage with free entry and atomistic traders will result in uniform prices for homogeneous commodities in spatially separated markets once prices are adjusted for transportation costs and exchange rates. Explanations of incomplete spatial arbitrage (see e.g. Sexton et al., 1991) may include technological infeasibility, regulatory constraints, or the existence of noncompetitive entry barriers. Like those for the EMH, tests of the LOP hypothesis have examined evidence of randomness in price difference.[1] Although simple to conduct, results of this approach are biased and inconsistent if price series are nonstationary, Chowdury (1991). In this case, cointegration can be examined to establish evidence of long-run co-movement.[2] Cointegration has direct implications for market efficiency since if the prices for two homogeneous assets in distinct markets are not cointegrated, then they will

[1] e.g. by estimation of the regression, $p_{1,t}=\alpha_0+\beta_1 p_{2,t}+\varepsilon_t$ where $p_{1,t}$ represents a price series generated in one market while $p_{2,t}$ are prices in another market and testing whether the parameter estimate β_1 is significantly different from unity.

[2] In a bivariate case, market prices would be cointegrated if $[p_1 \quad p_2]\eta = p_1 - \eta_2 p_2 = 0$ where η is called the cointegrating vector.

tend to drift apart without bound a property that is inconsistent with the EMH that proposes that arbitrage will bind prices into a long-run relationship. Chowdhury used the cointegration approach to reject the EMH in the cash and futures markets of four nonferrous metals. Fanchon and Wendel looked at cointegration of corn and feeder cattle prices finding that 1) both price levels were I(1), 2) monthly average, CPI deflated feeder cattle prices across weight classes (K.C. 400-500lb, 600-700lb. and Omaha 1000lb. steers) are co-integrated, and 3) these cattle prices are co-integrated with corn price (Omaha Y#2). Goodwin (1992) found supporting evidence for the LOP in the international wheat markets by employing a multivariate cointegration test.

The notion that firm concentration (say, R_{ti}) may affect the price level or its adjustment in some i^{th} market has been considered by e.g. Cotterill (1986) and Weaver et al. (1989), respectively. In general, a reduced form price function such as 3) or 4) could be generalized to incorporate such measures, e.g. $\mathbf{p}_t = X\beta + \omega_1 R + \varepsilon_t$ where $\mathbf{p}_t$ is a Nx1 vector of commodity prices, X a Nxk matrix of explanatory variables, and R is a concentration index. If X could be defined to include elements of $\Omega^c{}_t$, then failure to reject the hypothesis $\omega_1=0$ would leave the researcher with a form such as 3) that might be viewed as consistent with competitive equilibrium. However, such an approach would be useful only after the relevance of elements in $\Omega^s{}_t$ were also explored. Alternative, rejection of the hypothesis $\omega_1=0$ would suggest market concentration impacts prices, however, in the absence of a specification that is consistent with 4), the interpretation of these results would be difficult. For example, in a study of price levels, Cotterill (1986) concluded Vermont retail food prices were higher in concentrated markets. Several earlier studies also found concentration measures to be statistically significant in explaining price differentials in markets (see for example Hall et al. (1979), and Lamm (1982)). The importance of specification (e.g. exclusion of relevant variables) was highlighted by Newmark (1990) who found when local consumer income was included concentration measures were no longer found significant determinants of retail grocery prices.

Does Price Volatility Reflect Market Performance?

The possibility that price dynamics are different under competitive vs. noncompetitive pricing was explored by Weaver et al. (1989) and, more recently, by Loy and Weaver (1998). Both the regression and the cointegration approaches used to examine market efficiency rely on the behavior of the conditional mean of the series to provide insight into the structure of the markets. However, the EMH has implications for both the level and transmission of volatility. The latter implication provides a further basis for empirical examination of market efficiency.

Shiller (1981) noted the potential usefulness of estimated volatility levels for the assessment of market efficiency in financial markets with results that focused on the magnitude of price movements. That persistence of volatility as an indicator of competitiveness holds promise is suggested by several past studies. Lock and Sayers, Poterba and Summers, and Chou have examined the arrival of information and the persistence of volatility in financial markets. For example, Lock and Sayers consider the S&P 500 index futures market and examine the flow of information using contract volume, floor transactions levels, the number of price changes, and executed order imbalance. They conclude that the variables explain a significant portion of return variance, though do not fully explain persistence in volatility. Poterba and Summers (P-S) examine the relationship between price volatility and price levels for the S&P 500 index for the period 1928-1984 and the results suggest shocks to the market appear not to persist. Chou utilized a GARCH model to investigate volatility persistence and changing risk premium in equity markets and finds a high degree of volatility persistence in stock returns, concluding that the discrepancy between his finding and P-S's is the result data frequency. P-S utilized monthly observations while Chou utilized weekly data.

Evidence of time varying volatility in commodity markets is extensive, see e.g. Baillie and Myers, and Holt and Aradhyula (1998). Loy and Weaver (1998) and Weaver and Banerjee (1990) have examined the volatility implications of market performance.

Time Series Evidence Concerning Market Efficiency in Cattle Markets

Data

In this paper, we explore time series evidence concerning market efficiency in cattle markets based on a limited set of data of daily cash prices for the period of 6/18/93 to 6/2/97 for livestock input prices (corn and soybeans) and output prices (live and feeder cattle). Feeder cattle (FCATTLE) price is the average daily Oklahoma City cash price. Live cattle (LCATTLE) is the average choice cash price for Texas/Oklahoma City. Soybean price is the #1 yellow cash price for Central Illinois. Corn price is the #2 yellow Chicago cash price. In this application, our concern is whether cattle prices are determined competitively. Concentration in meat packing has been interpreted by some as a signal that packers may be able to control procurement prices to their advantage. In the notation of equations 3) and 4), we hypothesize that input prices would be elements of Ω^c_t. If cattle prices are noncompetitively determined, then elements of Ω^s_t would also determine the cattle price. Further we maintain that competitive processes would result in the change in cattle prices quickly adjusting to changes in input prices or changes in prices of particular product forms.

Figure 1 provides graphs of the four price series along with first differences. Descriptive statistics for each series are presented in table 1. Results from a Jarque-Bera test suggest corn, soybeans, feeder cattle, and live cattle prices are each characterized by a non-normal distributions.[3]

Nonstationarity of price levels

Augmented Dickey-Fuller (1979) (ADF) tests indicate each series are non-stationary I(1). Given the absence of an *a priori* hypothesis concerning the data generating process and the absence of apparent trend, a constant term but no trend term was included in the estimated ADF equations. The optimal lag length was determined by minimizing the AIC criteria. First differences of each series were found to be stationary, I(0).

Nonstationary price levels are not co-integrated

The results from the ADF tests motivated the use of cointegration tests to determine if a long run relationship exists between pairs of the commodities. To examine the relationship between live and feeder cattle prices and between each of these and the

[3] This test provides an approach to determine if $Y_t \sim N(.)$. The test is based on measuring the skewness (third moment) and the kurtosis (fourth moment) of the data.

$$Skewness=S=1/T \sum(y_t-\mu)^3/\sigma^3$$

$$Kurtosis=K=1/T \sum(y_t-\mu)^4/\sigma^4$$

$$\text{Test:} \quad (T-K)/6\,[S^2 + 1/4(K-3)^2] \sim \chi^2_2$$

Implementing the above test statistic, the null hypothesis is

$$H_o: y_t \sim N(.)$$

Therefore, if the test statistic exceeds the critical value from a χ^2_2 distribution then there is evidence for non-normal prices feed input prices, Johansen (1988, 1991) cointegration tests were conducted on price levels for all four commodities. The results are presented in table 2. The table provides the outcomes from various functional forms of the test based on 10 lags in each case. No cointegration was found between pairs of the price level variables.

These results suggest these cattle markets are operating efficiently with regard to input prices and across the two product forms considered. As Goodwin noted for the case of spatial markets, cointegration implies arbitrage opportunities have been driven to on-average zero, the profits from arbitrage are stationary. In the case considered here, results are consistent with the interpretation that price adjustment is instantaneous, shocks to feed prices are transmitted rapidly into cattle prices, leaving no long-term relationship. In other words, if corn and live cattle prices were cointegrated, then this would imply information in either market could be used to forecast prices in the other markets. This would imply persistence in the transmission of the shock from one product market to the other, contradicting the EMH. The lack of evidence supporting cointegration between live cattle and feeder cattle similarly supports market efficiency. As previously mentioned, although these commodities share common fundamentals, their adjustment to those fundamentals appears to rapid, leaving their relationship a contemporaneous short-term one, rather than a long-term one.

Short-run causal structure in price changes

While cointegration tests suggest there is no long-run relationships between pairs of the price levels, short-run relationships may exist. In the absence of stationarity in levels, we explore short-run bivariate relationships among price changes (first differences were found stationary) based on Granger causality. Optimal lag length was found to be very short by all criteria, lag length for the Granger tests was set to 10. The results presented in table 3 are consistent with the existence of a causal relationship from soybean price differences to feeder cattle price differences, from soybean to live cattle, from corn to soybean. Feedback from output to input prices is found from live cattle to corn. Causality between output prices is found in both directions, from feeder cattle to live cattle price changes and from feeder cattle to live cattle price changes suggesting these prices may be jointly determined.

Granger causality tests provide limited insight into market efficiency. Following the argument presented above, if markets are efficient then the change in price will be an IID random variable. If each product market involves distinct fundamentals, i.e. their information sets (e.g. $\Omega^c{}_{t,i}$, $\Omega^c{}_{t,j}$ for two commodities *i* and *j*) are independent, then the changes in price will be independent. Granger causality tests provide evidence concerning intertemporal dependence. However, application of this thinking to commodities is disrupted by the existence of common fundamentals such a macroeconomic variables or due to cross trading (substitution or complementarily across commodities either on the supply or demand side). Given such possibilities, prices will be Granger causally related even in noncompetitive situations. Pindyck and Rotemberg (1990) considered these issues within the context of examining co-movement of raw commodity prices for cases where the commodities might be otherwise thought to be unrelated. After taking out macroeconomic variation, they found considerable co-movement remained. Banerjee and Weaver (1982, 1990) consider such co-movement as evidence of market efficiency for cash - future arbitrage for livestock to determine whether volatility of cash prices could be changed with the introduction of futures trading.

Here, we find that price changes for soybeans induce changes in the change in live cattle prices, a result that would be inconsistent with the efficient market hypothesis were it not that soybeans are an input to cattle production. Changes in soybean prices are similarly reflected in feeder cattle prices, again as a result of input transformation linkage of their markets. If these markets were instantaneously efficient, then such relationships would be only contemporaneous. We find some inertia in adjustment. However, such inertia could be a result of either adjustment costs or market powerful agents strategically adjusting prices. Under the latter condition, output prices might be strategically adjusted, e.g. to maintain market share. Our results are interesting in that no relationship is found for corn price changes and livestock price changes. This tends to confirm competitiveness in these markets that leads to instantaneous adjustment of corn and livestock prices.

Multivariate structure of change in price series: VAR evidence

The relationships among past input prices and current livestock prices is explored for the first differences of the price series using a vector autoregressive (VAR) model. The Sims (1980) modified likelihood ratio test was used to determine the optimal lag length and was found to be seven lags. AIC and SIC criteria generated similar results. VAR results presented in table 4 suggest the structure of the interrelationships among these series. Significant autocorrelation is found for both feeder cattle and live cattle along with a few significant relationships between these cattle prices and lagged input prices. For example, a one period lag of corn and a two period lag of soybean price is significant for feeder cattle price. Alternatively, the only significant input relationship for live cattle is a three period lag of soybean price. These results appear to support the previous findings that price changes in the input market are not in a statistically significant sense being transmitted into the live and feeder cattle livestock markets.

Univariate evidence of volatility variation

Finally, another approach used to investigate relationships across input and output prices for livestock was to estimate a GARCH(1,1) model on price differences for each commodity.[4] Estimated GARCH models are reported in Table 5. Corn and soybeans are found to be IGARCH with a significant, positive constant in the GARCH process. This indicates these processes are strictly stationary. Feeder cattle price changes are found not to follow either ARCH or GARCH processes, while live cattle conditional variance is found to follow a covariance stationary process. Based on estimated GARCH(1,1) models, estimated conditional variances were generated for each commodity price series except feeder cattle. VAR models were estimated for the conditional variances to explore the interaction between the conditional second moments of the series. Intuitively, this approach accounts for the interaction of price volatility across markets. Loy and Weaver motivate this possibility for food markets.

The results from the VAR model of conditional variances are presented in Figure 2. The optimal lag for the model was once again determined using the Sims modified likelihood ratio test starting with an initial lag length of 35. The figure reveals only weak relationships exist among the conditional variances with the most significant being the own conditional variance lag. However, in general, lag length is very short, indicating adjustment is rapid to changing market conditions. Corn price volatility adjusts almost fully in two days, soybeans and live cattle in less than six days, to past own price volatility. The lag structure illustrates day of week autocorrelation, e.g. Monday's price volatility is found to be affected by last Monday's, though this dies out rapidly and is not substantial in magnitude, see e.g. Live Cattle. Cross-commodity transmission of volatility is also rapid. Soybean and live cattle price volatility impact on corn price volatility appears nearly contemporaneous, similar results are found for impacts of corn and live cattle price volatility on soybean price volatility and for corn and soybean price volatility on live cattle. While transmission is not found instantaneous, results suggest very rapid adjustment. If prices for cattle were manipulated by packers, such a rapid adjustment would not be expected.

[4] Feeder cattle prices were found to have a constant conditional variance and thus the following results were conducted on corn, soybeans and live cattle.

Table 1: Descriptive Statistics: Price Levels

	Corn	Soybeans	Feeder Cattle	Live Cattle
Mean	3028.179	6666.991	76.90382	6787.865
Median	2840.000	6700.000	78.00000	6750.000
Maximum	5584.000	8824.000	102.5000	7875.000
Minimum	2046.000	5000.000	54.25000	5450.000
Std. Dev.	743.4180	900.6262	12.36212	470.7142
Skewness	1.388373	0.261584	0.070597	-0.002178
Kurtosis	4.269823	2.216294	1.802440	2.199834
Jarque-Bera	388.4489	36.99582	60.58695	26.67855
Probability	0.000000	0.000000	0.000000	0.000002
OBS	1000	1000	1000	1000

Table 2: Johansen Cointegration Test Summary

	Description of Model Specification				
Form	None	None	Linear	Linear	Quadratic
Intercept	No Intercept	Intercept	Intercept	Intercept	Intercept
Trend	No Trend	No Trend	No Trend	Trend	Trend
Rank	*Log Likelihood*				
0	-17735.41	-17735.41	-17734.77	-17734.77	-17727.17
1	-17727.44	-17726.01	-17725.37	-17720.20	-17715.82
2	-17724.22	-17720.48	-17720.11	-17713.48	-17709.64
3	-17723.43	-17717.88	-17717.53	-17708.59	-17707.47
4	-17723.41	-17717.20	-17717.20	-17706.65	-17706.65
	Akaike Information Criteria				
0	24.83740	24.83740	24.84418	24.84418	24.83691
1	24.83745	24.83657	24.84135	24.83292	24.83013
2	24.84712	24.84361	24.84690	24.83753	24.83382
3	24.86169	24.85654	24.85786	24.84585	24.84560
4	24.87784	24.87337	24.87337	24.86011	24.86011
	Schwarz Criteria				
0	25.62958	25.62958	25.65617	25.65617	25.66870
1	25.66924	25.67332	25.69295	25.68948	25.70154
2	25.71852	25.72491	25.73811	25.73864	25.74483
3	25.77271	25.78241	25.78868	25.79152	25.79622
4	25.82846	25.84380	25.84380	25.85034	25.85034
L.R. Test:	*Rank = 0*	*Rank = 0*	*Rank = 0*	*Rank = 0*	*Rank = 0*

Table 3. Pairwise Granger Causality Test Summary*

Null Hypothesis:	*Obs*	*F-Statistic*	*Probability*
DFCATTLE does not Granger Cause DCORN	989	0.72266	0.70362
DCORN does not Granger Cause DFCATTLE		0.70839	0.71718
DLCATTLE does not Granger Cause DCORN	989	**2.60452**	**0.00401**
DCORN does not Granger Cause DLCATTLE		1.28660	0.23310
DSOYBEAN does not Granger Cause DCORN	989	1.39869	0.17556
DCORN does not Granger Cause DSOYBEAN		**3.03561**	**0.00085**
DLCATTLE does not Granger Cause DFCATTLE	989	1.08422	0.37120
DFCATTLE does not Granger Cause DLCATTLE		**2.41690**	**0.00768**
DSOYBEAN does not Granger Cause DFCATTLE	989	**1.85900**	**0.04725**
DFCATTLE does not Granger Cause DSOYBEAN		0.99942	0.44190
DSOYBEAN does not Granger Cause DLCATTLE	989	**1.76411**	**0.06296**
DLCATTLE does not Granger Cause DSOYBEAN		1.54625	0.11803

**Lag length = 10 Results in bold support rejection of the null.*

Table 4: VAR. Results on Price Differences

	DCORN	DSOYBEAN	DFCATTLE	DLCATTLE
DCORN(-1)	0.119153	0.193106	-0.017603	-0.001105
Std. Err.	(0.03473)	(0.05616)	(0.04158)	(0.00054)
T-Stat	(3.43065)	(3.43826)	(-0.42337)	(-2.04623)
DCORN(-2)	0.093116	0.096392	0.018247	-0.000633
	(0.03506)	(0.05669)	(0.04197)	(0.00054)
	(2.65602)	(1.70028)	(0.43478)	(-1.16168)
DCORN(-3)	0.000638	0.099455	-0.004057	0.000818
	(0.03521)	(0.05694)	(0.04216)	(0.00055)
	(0.01812)	(1.74655)	(-0.09625)	(1.49395)
DCORN(-4)	0.009159	0.021152	-0.017557	0.000286
	(0.03529)	(0.05707)	(0.04225)	(0.00055)
	(0.25951)	(0.37062)	(-0.41554)	(0.52147)
DCORN(-5)	-0.024090	-0.029121	0.081246	-0.000424
	(0.03519)	(0.05691)	(0.04213)	(0.00055)
	(-0.68453)	(-0.51172)	(1.92850)	(-0.77604)
DCORN(-6)	-0.029162	0.002775	-0.012380	-0.000195
	(0.03521)	(0.05693)	(0.04215)	(0.00055)
	(-0.82832)	(0.04874)	(-0.29374)	(-0.35610)
DCORN(-7)	0.010549	0.058443	0.009606	0.000107
	(0.03479)	(0.05625)	(0.04164)	(0.00054)
	(0.30325)	(1.03896)	(0.23068)	(0.19729)
DSOYBEAN(-1)	0.025686	-0.081884	0.063767	-7.25E-05
	(0.02152)	(0.03480)	(0.02576)	(0.00033)
	(1.19361)	(-2.35310)	(2.47527)	(-0.21686)
DSOYBEAN(-2)	-0.029185	-0.035119	-0.024632	0.000874
	(0.02171)	(0.03511)	(0.02599)	(0.00034)
	(-1.34405)	(-1.00018)	(-0.94756)	(2.58902)
DSOYBEAN(-3)	-0.027382	-0.033781	-0.053258	-0.000474
	(0.02186)	(0.03535)	(0.02617)	(0.00034)
	(-1.25259)	(-0.95564)	(-2.03513)	(-1.39454)

Table 4: continued VAR. Results on Price Differences

	DCORN	DSOYBEAN	DFCATTLE	DLCATTLE
DSOYBEAN(-4)	-0.040117	-0.075815	-0.012086	-0.000166
	(0.02192)	(0.03545)	(0.02625)	(0.00034)
	(-1.82980)	(-2.13844)	(-0.46048)	(-0.48724)
DSOYBEAN(-5)	-0.021826	-0.024386	-0.001260	-0.000890
	(0.02193)	(0.03546)	(0.02625)	(0.00034)
	(-0.99521)	(-0.68762)	(-0.04799)	(-2.61001)
DSOYBEAN(-6)	0.007849	0.014547	0.026766	0.000396
	(0.02192)	(0.03544)	(0.02624)	(0.00034)
	(0.35813)	(0.41044)	(1.02011)	(1.16206)
DSOYBEAN(-7)	-0.010524	-0.006046	-0.038133	-0.000141
	(0.02176)	(0.03519)	(0.02606)	(0.00034)
	(-0.48355)	(-0.17177)	(-1.46356)	(-0.41550)
DFCATTLE(-1)	-0.010169	-0.035931	0.120144	0.000744
	(0.02694)	(0.04356)	(0.03225)	(0.00042)
	(-0.37751)	(-0.82490)	(3.72580)	(1.77709)
DFCATTLE(-2)	-0.020457	-0.064052	0.034269	0.000256
	(0.02704)	(0.04372)	(0.03237)	(0.00042)
	(-0.75666)	(-1.46506)	(1.05880)	(0.60920)
DFCATTLE(-3)	-0.003837	-0.022689	0.020149	0.001052
	(0.02701)	(0.04368)	(0.03233)	(0.00042)
	(-0.14207)	(-0.51947)	(0.62314)	(2.50479)
DFCATTLE(-4)	0.020464	0.098218	0.057973	0.000915
	(0.02709)	(0.04381)	(0.03243)	(0.00042)
	(0.75534)	(2.24189)	(1.78746)	(2.17387)
DFCATTLE(-5)	0.004659	-1.97E-05	-0.006335	0.000439
	(0.02719)	(0.04397)	(0.03255)	(0.00042)
	(0.17133)	(-0.00045)	(-0.19462)	(1.03862)
DFCATTLE(-6)	0.011282	-0.023857	-0.087678	-0.000129
	(0.02715)	(0.04390)	(0.03250)	(0.00042)
	(0.41554)	(-0.54340)	(-2.69758)	(-0.30474)
DFCATTLE(-7)	-0.041730	-0.027587	-0.033916	0.000431
	(0.02676)	(0.04327)	(0.03203)	(0.00042)
	(-1.55967)	(-0.63762)	(-1.05890)	(1.03663)
DLCATTLE(-1)	-3.125598	2.272343	6.153784	-0.081503
	(2.08553)	(3.37244)	(2.49664)	(0.03242)
	(-1.49871)	(0.67380)	(2.46483)	(-2.51431)
DLCATTLE(-2)	1.128208	-2.663133	1.616408	-0.032728
	(2.10121)	(3.39779)	(2.51541)	(0.03266)
	(0.53693)	(-0.78378)	(0.64260)	(-1.00210)
DLCATTLE(-3)	4.782415	-0.436521	1.099245	-0.035227
	(2.07200)	(3.35056)	(2.48044)	(0.03221)
	(2.30812)	(-0.13028)	(0.44316)	(-1.09381)
DLCATTLE(-4)	1.299036	6.215211	-0.894238	-0.022946
	(2.07689)	(3.35847)	(2.48630)	(0.03228)
	(0.62547)	(1.85061)	(-0.35967)	(-0.71081)
DLCATTLE(-5)	-1.994761	-4.234696	-0.264733	-0.135791
	(2.07262)	(3.35157)	(2.48119)	(0.03222)

	(-0.96243)	(-1.26349)	(-0.10670)	(-4.21515)
DLCATTLE(-6)	-3.385778	-2.927602	-1.185659	-0.028156
	(2.08636)	(3.37378)	(2.49763)	(0.03243)
	(-1.62282)	(-0.86775)	(-0.47471)	(-0.86824)
DLCATTLE(-7)	-1.169885	0.819495	-0.603036	-0.004696
	(2.06631)	(3.34136)	(2.47364)	(0.03212)
	(-0.56617)	(0.24526)	(-0.24379)	(-0.14622)
Constant	0.615966	2.888540	-0.857107	-0.012544
	(1.71505)	(2.77335)	(2.05313)	(0.02666)
	(0.35915)	(1.04153)	(-0.41746)	(-0.47056)
R-squared	0.055304	0.044869	0.060895	0.067367
Adj. R-squared	0.027836	0.017098	0.033590	0.040250
Sum sq. resids	2780836.	7271634.	3985250.	671.8184
S.E. equation	53.73714	86.89662	64.33016	0.835243
Log likelihood	-5345.102	-5821.872	-5523.587	-1214.278
Akaike AIC	7.997007	8.958236	8.356855	-0.331267
Schwarz SC	8.140245	9.101474	8.500093	-0.188029
Mean dependent	0.574597	2.635081	-1.108871	-0.012722
S.D. dependent	54.50104	87.64914	65.43860	0.852577
Determinant Residual Covariance		4.78E+10		
Log Likelihood		-17826.94		
Akaike Information Criteria		24.82377		
Schwarz Criteria		25.39672		

Table 5. Univariate GARCH(1,1) Parameter Estimates (January 1, 1986 – June 2, 1997)

	Corn	Soybeans	Feeder Cattle	Live Cattle
AR(1) dP_{t-1}	1.85	2.85	-.013	-1.87
	1.68	1.33	-.52	-0.67
ARCH(0)	27.21	161.23	.72	1071.35
	2.81	2.51	22.15	3.65
ARCH(1)	**.09**	**.122**	0.00	.08
	6.39	**4.22**	0.00	3.78
GARCH(1)	**.89**	**.866**	.0018	.66
	54.27	**28.31**	.33	8.62

*T-statistics Estimates in bold imply I-GARCH form.

Figure 1: Price Levels and Price Differences

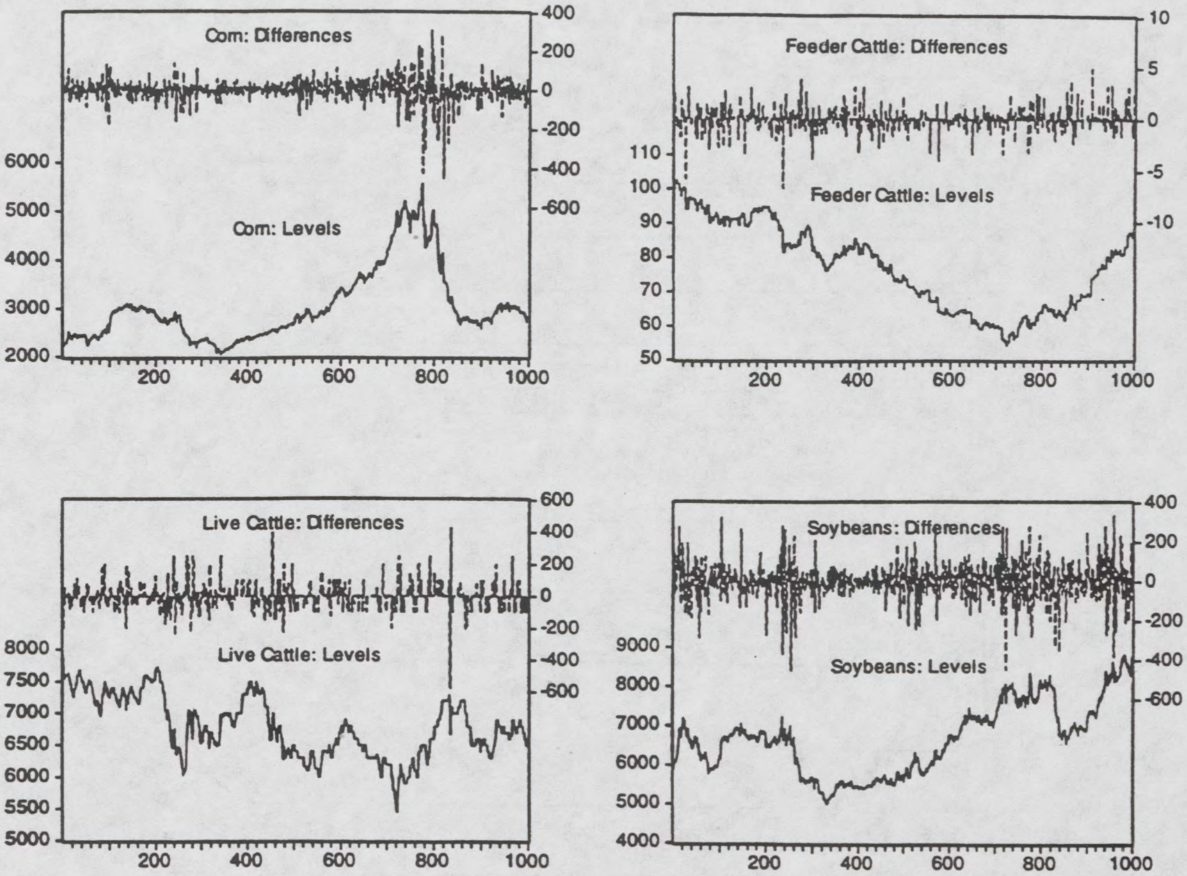


Figure 2a: VAR(17) Parameter Estimates
Estimated Lag Distribution for Corn

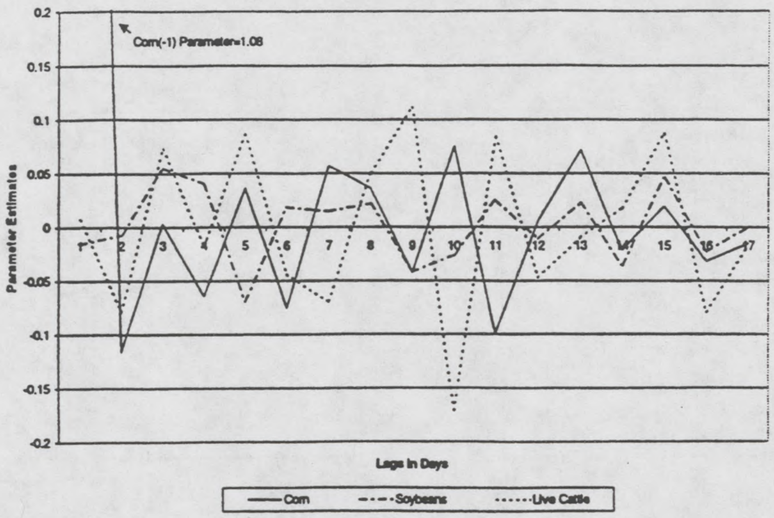


Figure 2b: VAR(17) Parameter Estimates
Estimated Lag Distribution for Soybeans

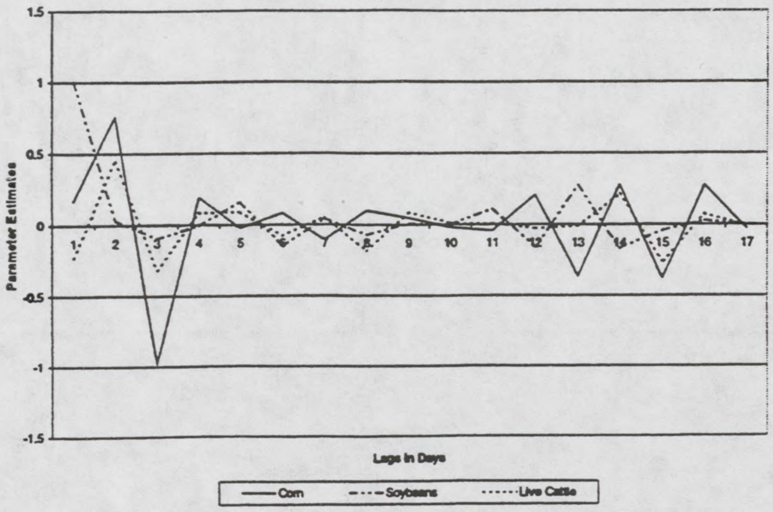
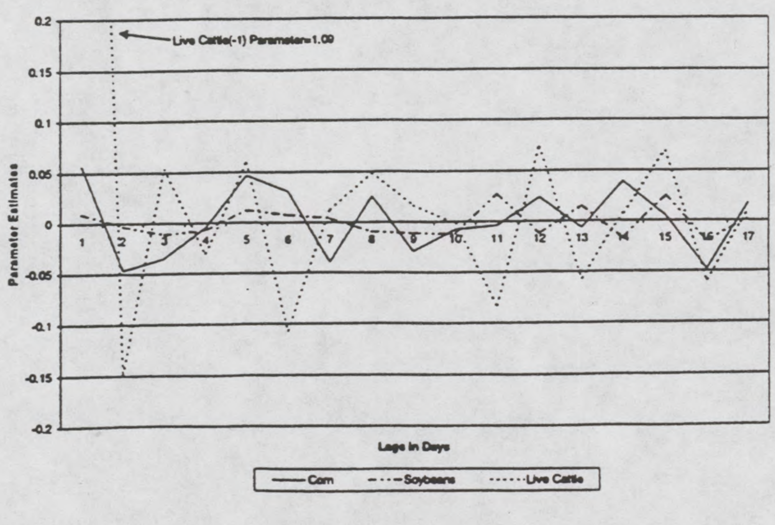


Figure 2c: VAR(17) Parameter Estimates
Estimated Lag Distribution for Live Cattle



References

Applebaum, E. "The Estimation of the Degree of Oligopoly Power." *Journal of Econometrics,* 19 (1982) 287-299.

Atkinson, S.E. and R. Halvorsen. "A Test of Relative and Absolute Price Efficiency in Regulated Utilities." *Review of Economics and Statistics.* 62 (1980) 81-88.

Azzam, A.M. and E. Pagoulatos "Testing Oligopolistic and Oligopsonistic Behavior: An Application to the U.S. Meat-Packing Industry." *Journal of Agricultural Economics*. 41(1990) 362-370.

Baillie, R.T. and R.J. Myers "Bivariate Garch estimation of the Optimal Commodity Futures Hedge." *Journal of Applied Econometrics* 6(1991): 109-124

Bessembinder, H. J. Coughenour, P. Seguin, and M. Smooler. "Mean Reversion in Equilibrium Asset Prices" *Journal of Finance* L(1) 1995: 361-375.

Breshahan, T.F. "The Oligopoly Solution Concept is Identified." *Economic Letters.* 10(1982) 87-92.

Canarella, G., and Pollard S.K. "The Efficiency of the London Metal Exchange: A Test with Overlapping and Non-overlapping Data," *Journal of Banking and Finance*, 10, (1986) 575-593

Chou, R.Y. (1988) "Volatility Persistence and Stock Valuations: Some Empirical Evidence Using GARCH." *Journal of Applied Econometrics* 3: 279-294

Chowdhury, A.R., "Futures Market Efficiency: Evidence from Cointegration Tests" *Journal of Futures Markets* , (1991) 577-589

Cottterill. R.W. "Market Power in the Retail Food Industry: Evidence from Vermont." *The Review of Economics and Statistics*, (1986): 379-386

Davidson R. and J.G. MacKinnon (1993) "Estimation and Inference in Econometric." Oxford University Press, New York NY

Dickey, D.A. and W.A. Fuller (1979) Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74:427-31

Dyckman, T.R., D.H. Downes, R.P. Magee, *Efficient Capital Markets and Accounting*, Prentice-Hall., Englewood Cliffs, NJ 1975

Engle, R.F. "Autoregressive Conditional Heteroskedasticity with Estimates of Variance of the United Kingdom Inflation." *Econometrica* 50(1982) 987-1007

Engle, Robert F. and Tim Bollerslev (1986) "Modelling the Persistence of Conditional Variances." *Econometric Reviews* 5:1-50

Engle.R.F. and T. Bollerslev "Modelling the Persistence of Conditional Variances." *Econometric Reviews* 5(1986) 1-50

Fama, E.F. "Efficient Capital Markets: A Review of Theory and Empirical Work", *The Journal of Finance*, 25, 1(970) 383-417.

Featherstone, A.M. and B.J. Sherrick "Financing Vertically Coordinated Agricultural Firms." American Journal of Agricultural Economics (1992) 1232-1237

Fanchon, P. and J. Wendel. "Estimating VAR Models under Non-stationarity and Co-integration: alternative approaches for forecasting cattle prices." *Applied Economics.* 24 (1992) 207-217.

Granger, C.W.J. (1969) "Investigating Causal Relationships by Econometric Models and Cross-Spectral Methods." *Econometrica* 52:681-700

Goodwin B.K. "Multivariate Cointegration Tests and the Law of One Price in the International Wheat Market." *Review of Agricultural Economics*, Vol. 14 No. 1, January, 1992 117-124

Hall, Lana, Schmitz, and Cithern "Beef Wholesale-Retail Marketing Margins and Concentration." *Economica* 46(1979): 295-300

Holloway, G. and A Bayaner "Conduct and Volatility in Food-Price Determination: VAR Evidence from Turkish Agriculture." Proceedings from the Annual Meeting of the American Agricultural Economics Association, Salt Lake City, Utah, August 2-5, 1998

Holt, M.T. and S.V. Aradhyula "Endogenous Risk in Rational-Expectation Commodity Models: A Multivariate Generalized ARM-M Approach." *Journal of Empirical Finance* 5(1998) 99-129

Johansen, S. (1988) "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 12:231-54

--------. (1991) "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Model." *Econometrica* 59:1551-80

Khan, M.A., and G. A. Helmers "Causality, Input Price Variability, and Structural Changes in the U.S. Livestock-Meat Industry." Western Agricultural Economics

Association Meeting, Reno Nevada July 13-16, 1997.

Lamm, R.M. "Unionism and Prices in the Food Retailing Industry." *Journal of Labor Research* 3(1982); 69-79

Lau, L.J. "On Identifying the Degree of Competitiveness from Industry Price and Output Data" *Economic Letters.* 10 (1982) 93-99.

Lau, L.J. and P.A. Yotopoulos. "A Test for Relative Efficiency and Application to Indian Agriculture" *American Economic Review. 61* (1971): 94-109

Locke, P.R. and C.L. Sayers (1993) "Intra-Day Futures Price Volatility: Information Effects and Variance Persistence." *Journal of Applied Econometrics* 8: 15-30

Love, H.A. and C.R. Shumway. "Nonparametric Tests for Monopsonistic Market Power Exertion." *American Journal of Agricultural Economics.* 76 (1994) 1156-1162.

Loy, J.P. and R.D. Weaver. "Inflation and Relative Price Volatility in Russian Food Markets." *European Review of Agricultural Economics*, 1998.

Malliaropulos, D. "A Multivariate GARCH Model of Risk Premia in Foreign Exchange Markets." *Economic Modelling* 14(1997) 61-79

Newmark, C.M. "A New Test of the Price-Concentration Relationship in Grocery Retailing." *Economics Letters*, 33(1990): 369-373.

Noelke, C.M. and K.C. Raper "Parametric and Nonparametric Market Power Tests: An Empirical Investigation." Proceedings from the Annual Meeting of the American Agricultural Economics Association, Salt Lake City, Utah, August 2-5, 1998

Peterson, R.L., C.K. Ma, and R.J. Ritchey. "Dependency in Commodity Prices." *J. Futures Markets*, (1992) 429-46

Pindyck, R.S., and J.J. Rotemberg, "The Excess Co-movement of Commodity Prices." *Econ. J.* (1990) 1173-89

Poterba, J.M. and L.H. Summers (1986) "The Persistence of Volatility and Stock Market Fluctuations." *The American Economic Review* 76(5): 1142-1151

Roberts, H. "Stock Market "Pattern" and Financial Analysis: Methodological Suggestions." *Journal of Finance*, Vol. 39(1959) 1127-1139

Schroeder, T.C. "Spatial Fed Cattle Transaction Price Relationship." *Definition of Regional Cattle Procurement Markets* Prepared for the Grain Inspection, Packers, and Stockyards Administrations, U.S. Department of Agriculture May 1996,69-

92.

Schroeter J.R. and A. Azzam "Measuring Market Power in the Multi-Product Oligopolies: the U.S. Meat Industry." *Applied Economics* 22(1990) 1365-1376

Schroeter, J.R. "Estimating the Degree of Market Power in the Beef Packing Industry." *The Review of Economics and Statistics*. 70(1988) 158-162

Sexton, R.J., C.L. Kling, and H.F. Carman "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." *American Journal of Agricultural Economics* August (1991):568-580.

Shiller, R.J. "The Use of Volatility Measures in Assessing Market Efficiency." *Journal of Finance* 36(1981): 291-304 Reprinted in *Market Volatility*. MIT Press, Cambridge, Massachusetts 1993.

Sims, C. (1980) "Macroeconomics and Reality." *Econometrica* 1:1-49

Steen, F. and K.G. Salvanes. "Testing for Market Power using a Dynamic Oligopoly Model" *Working paper. Institute of Economics. Norwegian School of Economics and Business Administration.* 1996.

Weaver, R.D. and A. Banerjee "Cash Price Variation in the Live Beef Cattle Market: The Causal Role of Futures Trade." *Journal of Futures Markets* 2 (4)1982: 367-389.

Weaver, R.D. and A. Banerjee "Does Futures Trading Destabilize Cash Prices? Evidence for U.S. Live Beef Cattle." *Journal of Futures Markets* 10 (1)1990: 41-60.

Weaver, R.D., P. Chattin, and A. Banerjee. "Market Structure and the Dynamics of Retail Food Prices." *Northeastern Journal of Agricultural and Resource Economics* 18(2) 1989: 160-170.