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**Volatility in Prices in Food Supply Chains:  
Evidence of the Invisible Hand?**

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*Robert D. Weaver and William Natcher*

*Pennsylvania State University*

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## Volatility in Prices in Food Supply Chains: Evidence of the Invisible Hand?

Weaver & Natcher IAMA 2000

Extensive literature over the past fifty years has considered the potential role of private sector arbitrage in stabilizing and managing economic life in a free market system. In the agricultural sector, a vast literature has accumulated concerning the relationship between inventory levels and price volatility. Early work in that area found a rationale for a role for public sector management of commodity price volatility and governments entered the business of intertemporal arbitrage trying to stabilize prices by managing stocks. However, the feasibility of such buffer schemes was later questioned when private sector intertemporal arbitrage was introduced into economic models that motivated a public sector role. This impossibility result was further strengthened as international trade and gaming among market coordinating intermediaries (grain traders) were added to models. During the same period, two other changes have influenced commodity markets: 1) expansion of the scope of forward contracting mechanisms such as futures and options markets as well as the use of forward contracting and 2) liberalization of international trade. During the past decade, reforms in trade policy as well as government budget constraints have led to reduction of government managed stocks. At the same time, private sector stocks have not expanded, and, in many cases, have substantially contracted resulting in significant decreases in stock-to-use ratios for many commodities. The evolution of this economic landscape has raised an important question that this paper takes on: what is the extent of price volatility and how has it been distributed through important food supply chains?

This paper will review evidence over the past decade based on monthly data to 1) establish the extent of price volatility at critical points in the beef, grains, and dairy supply chains, 2) evaluate evidence of pass-through of price volatility vertically through these chains, and 3) identify at what points in the supply chain the burden of exposure to price volatility is most significant.

Beef, key grain, and dairy food supply chains are considered to allow for a juxtaposition of chains that are differentially impacted by government intervention and regulation. State-of-the-art time series methods are used to derive estimates (natural, GARCH, and implied) volatility of prices along the vertical supply chains. The paper first presents an overview of what economic theory has to say about price volatility in a

Weaver & Natcher IAMA 2000

competitive supply chain. Opportunities for private sector led arbitrage and risk management to stabilize the economic implications of price volatility are noted, as are their implications for transmission of price volatility through the supply chain. The roles of storage, product substitution, and spatial diversification of sourcing are considered. Next, volatility measures are estimated based on various trading periods, e.g. for daily data, weekly, and monthly volatility. Estimates at farm, wholesale, processed, and retail levels are presented as appropriate.

### *How Can We Think about Vertical Chain Transmission of Price Volatility?*

The issue of vertical price structure or transmission of price volatility has had limited attention in the literature. From one perspective, papers have considered vertical price differentials as marketing margins and developed structural theories of their variation. In this paper, we introduce the notion that transmission of prices and their volatility follows from a type of “arbitrage”. The good at one market level or stage is arbitrated vertically into another market or stage, not by transportation, or storage, but by transformation. The relationships between price levels or volatility established by this type of vertical arbitrage are only subtly different than those established by other types of arbitrage.

An extensive literature has considered transmission from the perspective of market efficiency. 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

Weaver & Natcher IAMA 2000

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. 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

Weaver & Natcher IAMA 2000

(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 price 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.

### *A Brief Review of Theory and Empirical Implications*

Viewing vertical transmission as a form of arbitrage allows a direct derivation of implications of arbitrage for volatility. Consider a two-stage processing problem, the product available at stage  $i-1$  is transformed at stage  $i$  into a higher valued product. The profits for such arbitrage can be written:

$$1) \quad \mathbf{P}_i = P_{it} Y_{i,i-1} - P_{i-1t} Y_{i,i-1} - C(Y_{i,i-1})$$

Under competitive conditions, free entry would drive profits to zero, implying an arbitrage equilibrium condition as follows:

$$2) \quad P_{it} - P_{i-1t} - AC(Y_{i,i-1}) = 0$$

Relaxing this condition to suppose it holds in expectation conditionally on available information, we have

$$3) \quad P_{it} = P_{i-1t} + AC(Y_{i,i-1}) + \mathbf{e}_{i,j-1,t}$$

Weaver & Natcher IAMA 2000

Supposing that the information set available to each market stage is the same, we have the result that  $E_t(\mathbf{e}_{i,i-1,t} | \mathbf{P}_{i-1,t}) = 0$ . The results here are equivalent to conventional implications of efficient markets hypotheses. Where the prices are stationary, the hypothesis of efficient arbitrage could be examined by regression, though the conditional mean condition would best be enforced using GMM to ensure results do not reflect simultaneity bias. Where the price levels are nonstationary, long term co-movement in levels may be considered through an examination of cointegration. Differencing the arbitrage equilibrium condition results in a form that could be useful if the prices are I(1), i.e.

$$4) \quad dP_{it} - dP_{i-1t} - dAC(Y_{i,i-1}) = 0$$

or adding a stochastic term,

$$5) \quad dP_{it} = dP_{i-1t} + dAC(Y_{i,i-1}) + \mathbf{e}_{i,i-1,t}.$$

What are the implications of efficient arbitrage for the relationships across markets or stages of price volatility? This can be derived from a theory of arbitrage under risk aversion, see Weaver (1999).

The empirical implications of vertical arbitrage for prices and volatility can be explored directly using the GARCH model. Define  $\mathbf{R}_{it} = d\mathbf{p}_{it}$ , then the arbitrage equilibrium condition can be viewed as a restriction of the following relationship:

$$6) \quad \mathbf{R}_{it} = \mathbf{b} + \sum_{j=1}^p \mathbf{f}_j \mathbf{R}_{it-j} + \sum_{j=1}^p \mathbf{q}_j \mathbf{R}_{i-1t-j} + \mathbf{e}_{it} \quad \mathbf{e}_{it} \sim N(0, \mathbf{h}_{it}) \quad \forall i$$

Here,  $\mathbf{R}_{it}$  is the change in the price of commodity  $i$  in month  $t$ . The right hand side of this expression includes autoregressive processes in own stage and “previous stage” price differences. Given a vector of prices through a supply chain, it is clear that these relationships would define a vector autoregressive model, VAR.

The conditional variance of the error in this type of model of price often reflects heteroskedasticity that can be parsimoniously represented by some form of GARCH(p,q) process (see Engle (1982), and Engle and Bollerslev (1986)), e.g.

$$7) \quad h_{it} = \mathbf{a}_i + \mathbf{g}_i S_{it-1} + \sum_{j=1}^q \mathbf{r}_{ij} \mathbf{e}_{it-j}^2 + \sum_{j=1}^p \mathbf{r}_{ij} h_{it-j}^2 + \mathbf{m}_i \quad \mathbf{m}_i \sim i.i.d(0,1)$$

Weaver & Natcher IAMA 2000

where  $S_{it}$  is a vector of current stock levels and other structural determinants of the a time varying conditional variance. As in the case of the relationships across price differences defined above, it is likely that the conditional variances across different market stages are interdependent. As written, the GARCH(p,q) is univariate. To investigate the possibility of interdependence in volatility, we estimate a VAR in estimated conditional volatilities.

### **Price Volatility in Food Supply Chains: Empirical Evidence**

#### **Data**

In this paper, we explore time series evidence concerning transmission of prices and volatility in food markets based on data for monthly cash prices ranging from farm level to retail level for recent periods of time, see Table 1.

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 fo Texas/Oklahoma City. Soybean price is the #1 yellow cash price for Central Illinois. Corn price is the #2 yellow Chicago cash price.

#### *Graphic evidence of price variation over time*

Graphics for the prices analyzed are presented in Figure 1. These figures corroborate the claim that prices vary over time. These figures suggest several observations. First, farm level prices appear to have varied more than prices further upstream. This is notable for cattle and beef prices, as well as for dairy prices. Further, it is of interest to note specific types of price variation over time. In general, the prices do not reflect strong trends, though wholesale and retail beef prices seem to follow a series of three or so year trends. The farm level prices show dramatic spikes, while the

Weaver & Natcher IAMA 2000

upstream price spikes are smaller in percentage. Cattle prices show a substantial adjustment in late 1986 that persists through 1994. Following a downward spike, they revert to the range of 90 cents/lb. Grains show spikes, particularly in 1996, though prices revert. Dairy product prices appear to vary more substantially over time after 1996. The substantial spikes in butter prices are particularly dominant.

While it is of interest to note these features of price variation over time, as the discussion above noted, it is not the wiggling of prices that is of concern when we think of price volatility. Instead, our interest is in an estimate of the range in which price might vary at specific future times.

#### *Nonstationarity of price levels*

Augmented Dickey-Fuller (1979) (ADF) tests indicate each series is non-stationary, though  $I(1)$ . A constant term and trend term were included in the estimated ADF equations. Further, the optimal lag length was determined by minimizing the AIC criteria. First differences of each series were found to be stationary,  $I(0)$ . Results are available from the authors.

#### *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 prices. For example, to examine the relationship between live and feeder cattle prices and between each of these and the feed input prices, Johansen (1988, 1991) cointegration tests were conducted on price levels for these four commodities. The results are available from the authors. No cointegration was found between pairs of these price level variables. This suggests that in the long-run the prices move according to their own fundamentals.

Weaver & Natcher IAMA 2000

These 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 notion that markets are efficient and arbitrage between markets is efficient. 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.

### **Multivariate Evidence of Transmission of Prices and Volatility**

#### *Multivariate structure of change in price series: VAR evidence*

The relationships among price differences in the beef and dairy supply chains are respectively considered. Recalling the price differences are interpretable as “surprises” or “shocks”, unanticipated based on past fundamentals, the price differences provide an important perspective on how such “news” is transmitted through the supply chain. First, the interrelationship across first differences of the price series in each chain are investigated based on 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 2 suggest the structure of the interrelationships among these series. Significant autocorrelation is found for corn, feeder cattle and live cattle prices in the beef chain,

Weaver & Natcher IAMA 2000

though not for wholesale and retail prices. Evidence of interrelatedness between corn and soybean prices confirm their joint determination in the feed complex. However, a significant role of wholesale and retail beef prices as determinants of corn prices suggests vertical feedback within the beef supply chain. As wholesale prices increase corn prices increase; as retail prices increase, corn prices decrease. Results suggest some feedback from wholesale and retail levels to feeder prices, though the relationships are weak. Live cattle prices are found to respond negatively to retail price increases. Wholesale prices respond positively to live cattle prices and negatively to retail prices, as would be predicted by theories of competitive prices in market chains.

The dairy chain results show no feedback from product levels to feed prices or the Federal Order farm price. Corn shocks appear transmitted to soybeans. Corn prices themselves appear to adjust instantaneously only its past shock plays a role. The latter is not explained by its shocks in its own or other prices. For dairy products, the unanticipated changes in prices are found to be negatively conditional on soybean prices and the farm price of milk and positively on corn prices. Across products, butter adjustments appear independent of other price adjustments, while cheddar barrel and block price shocks appear positively responsive to butter price shocks.

Together these results provide reasonable evidence that prices in these supply chains are consistent with the predictions of competitive price theory. Unanticipated shocks appear to be rapidly absorbed, no strong evidence of inertia in adjustment what found. Only limited feedback through the supply chain was found.

Weaver & Natcher IAMA 2000

*Univariate evidence of volatility variation*

We next turn to consider an alternative measure of price volatility, as provided by estimates of conditional variance based on GARCH models discussed above. GARCH models were estimated for each series of price differences based on specifications that optimized their fit. This approach involves simultaneously choosing lag lengths for both the elements of the conditional mean and conditional variance. Results are available from the authors.

Here we focus on VAR estimates of interrelatedness of those conditional variances across prices in the dairy and beef supply chains. Based on estimated GARCH models, estimated conditional variances were generated for each commodity price series except feeder cattle. GARCH results for this product were found to support a fixed variance over time. A VAR model for the conditional variances was estimated where the optimal lag was determined using the Sims modified likelihood ratio test starting with an initial lag length of 35.

The results from the VAR model of conditional variances are presented in Table 2. The results support the conclusion that only weak relationships exist among the conditional variances with the most significant being the own conditional variance lag. Lag length is very short, indicating adjustment is rapid to changing market conditions. Corn price volatility adjusts rapidly and is found independent of price volatility in other products in the supply chain. Consistent with results based on price differences, soybean price volatility is found to be affected by last month's corn price volatility. Further, feedback is again found from wholesale beef price volatility to soybeans. Live cattle price volatility is found independent of other product price volatility though responsive to

Weaver & Natcher IAMA 2000

its own last month's volatility. This suggests some slowness in adjustment to price shocks. Similar results are found for wholesale beef.

Results for the dairy supply chain are consistent with those found for price differences. Volatility in soybeans and in cheese prices are found to be transmitted to butter prices. Volatility in the farm milk price is found independent of other product price volatility.

Figure 2 presents graphs of the estimated time varying price volatility for the products in the beef and dairy supply chain.

These graphs highlight the increased frequency of shocks to price volatility in cheese after 1995, and a persistently higher level of price volatility for butter and mailbox prices after 1995. Price volatility for grains appears no different, though some evidence of reduced frequency of spikes in volatility is apparent.

### **Conclusions**

The extent of price volatility at critical points along the supply chains is first assessed and evidence of shifts in regimes is summarized. Regime changes due to changes in government intervention are of particular interest and some evidence is found for butter and milk prices. Consistent conclusions are found for the transmission of volatility across the supply chain for two measures of price volatility, price differences over time and GARCH estimated conditional volatility. This paper considers whether shocks that occur at one point in the supply chain are transmitted to other points in the supply chain. Evidence suggests strongly that such transmission is instantaneous as one would expect in a competitive market chain. That is, although a shock might initially affect one point on the supply chain, it is instantaneously transmitted such that one could conclude the supply chain is affected by common shocks. Importantly, no evidence of strategic inertia in transmission is found. Such evidence would suggest that market power is exerted along the supply chain to inhibit rapid adjustment to shocks.

Evidence of transmission of price volatility within the supply chains is evaluated and compared across the dairy and beef supply chains. In both cases, results are consistent with the conclusion that the supply chain price formation is competitive.

Weaver & Natcher IAMA 2000

## 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
- Cotterill, 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

Weaver & Natcher IAMA 2000

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(1970) 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

Weaver & Natcher IAMA 2000

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. Yotopoulos. " " *American Journal of Agricultural Economics*. 76 (1974)

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.

Malliaropoulos, 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

Weaver & Natcher IAMA 2000

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.

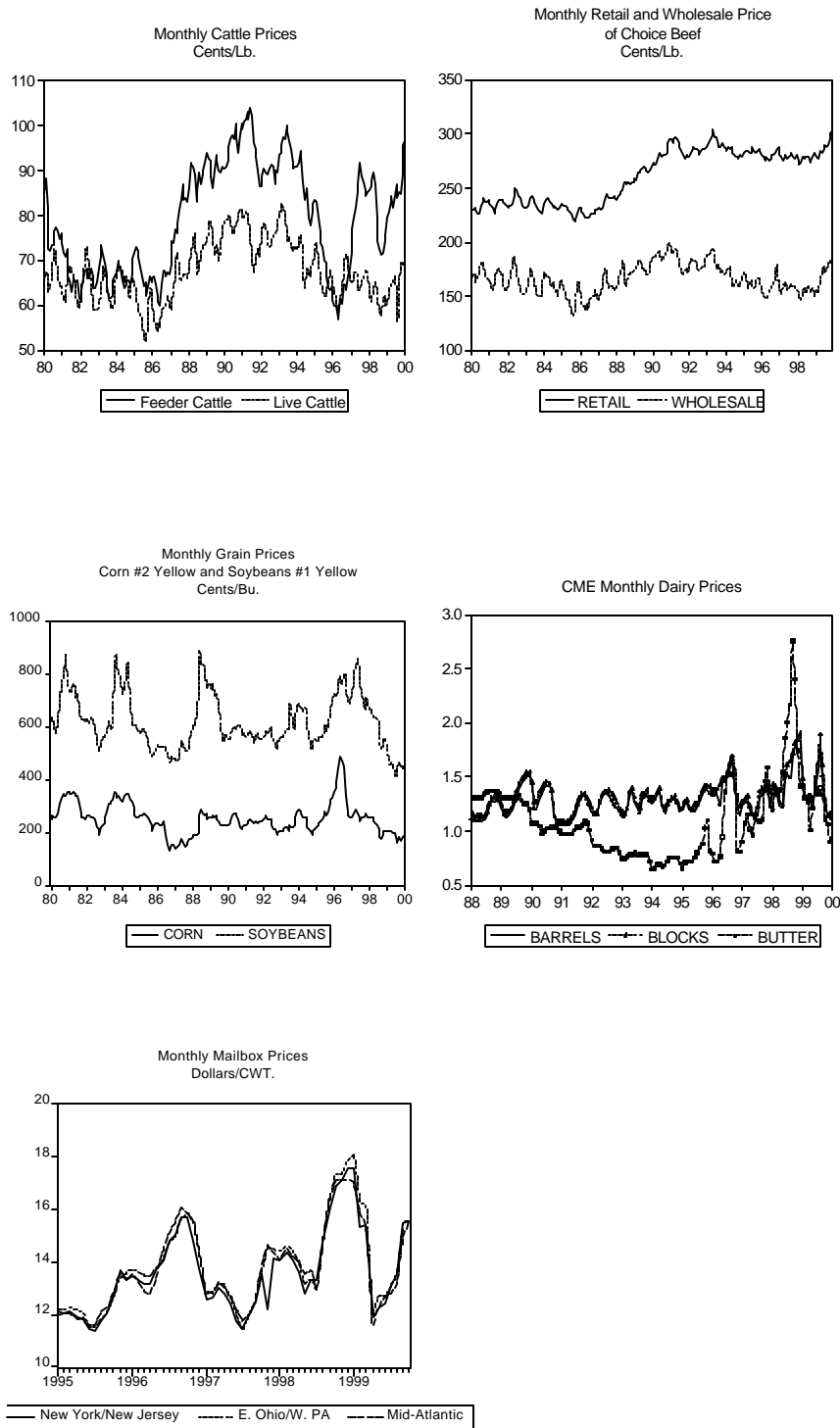
Weaver, R.D., P. Chattin, and A. Banerjee. "Market Structure and the Dynamics of Retail Food Prices." *Northeastern Journal of Agricultural and Resource Economics* 18(2) 1989: 160-170.

Weaver, R.D. and W.C. Natcher. "Efficiency and Competitiveness of Commodity Markets: Time Series Evidence for the Beef Sector." Paper presented at the conference Consolidation in the Meat Sector, February 25-26, 1999. Washington, D.C. Sponsored by Packers and Stockyards Administration. (reprint available from authors).

Weaver, R.D and W.C. Natcher. "Transmission of Price Volatility in the Beef Markets." *American Journal of Agricultural Economics*. December, 1999.

Weaver & Natcher IAMA 2000

**Figure 1 Graph of Price Levels**



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**Table 1. VAR Results for Price Differences in Beef and Dairy Supply Chains  
Beef Complex Vector Autoregression Based on Price Differences (1980-1999)**

Included observations: 240						
Standard errors & t-statistics in parentheses (Critical Value=1.65 at a test size of .05)						
	<b>SOYBEANS</b>	<b>CORN</b>	<b>FEEDER</b>	<b>LIVE</b>	<b>WHOLESALE</b>	<b>RETAIL</b>
<b>SOYBEANS(-1)</b>	0.108181 (0.07659) (1.41256)	-0.036443 (0.03357) (-1.08562)	0.003235 (0.00562) (0.57527)	-0.000617 (0.00523) (-0.11805)	-0.008056 (0.01141) (-0.70632)	-0.000454 (0.00529) (-0.08594)
<b>CORN(-1)</b>	0.412692 (0.15962) (2.58551)	0.505333 (0.06996) (7.22287)	0.002938 (0.01172) (0.25064)	0.008736 (0.01090) (0.80135)	-0.019408 (0.02377) (-0.81648)	0.006329 (0.01102) (0.57437)
<b>FEEDER(-1)</b>	0.723317 (0.92673) (0.78050)	-0.353183 (0.40620) (-0.86948)	0.286612 (0.06805) (4.21205)	0.051702 (0.06329) (0.81687)	0.020930 (0.13801) (0.15165)	0.054048 (0.06397) (0.84484)
<b>LIVE(-1)</b>	0.252220 (1.52432) (0.16546)	-0.630735 (0.66814) (-0.94402)	-0.008953 (0.11192) (-0.08000)	0.212707 (0.10411) (2.04317)	0.874506 (0.22700) (3.85242)	0.300122 (0.10523) (2.85213)
<b>WHOLESALE(-1)</b>	0.358761 (0.67632) (0.53046)	0.611833 (0.29644) (2.06391)	-0.052263 (0.04966) (-1.05243)	0.070142 (0.04619) (1.51855)	0.022018 (0.10072) (0.21861)	0.247815 (0.04669) (5.30789)
<b>RETAIL(-1)</b>	-1.116025 (0.76664) (-1.45574)	-0.696265 (0.33603) (-2.07204)	0.096572 (0.05629) (1.71559)	-0.196193 (0.05236) (-3.74709)	-0.395771 (0.11417) (-3.46659)	0.031299 (0.05292) (0.59141)
R-squared	0.076586	0.233510	0.090394	0.133972	0.178389	0.443703
Adj. R-squared	0.056855	0.217132	0.070958	0.115467	0.160833	0.431817
Sum sq. resids	260909.8	50126.29	1406.651	1216.996	5786.220	1243.353
F-statistic	3.881515	14.25755	4.650858	7.239832	10.16126	37.32776
Log likelihood	-1179.500	-981.5447	-552.7446	-535.3655	-722.4567	-537.9366
Akaike AIC	9.879168	8.229539	4.656205	4.511379	6.070473	4.532805
Schwarz SC	9.966184	8.316555	4.743221	4.598395	6.157489	4.619821
Mean dependent	-0.803596	-0.355908	0.047583	0.006750	0.043333	0.305000
S.D. dependent	34.38334	16.54172	2.543710	2.424821	5.428319	3.058053
Log Likelihood	-4319.655					
Akaike Information Criteria	36.29712					
Schwarz Criteria	36.81922					

\*Optimal lag chosen by minimizing the SIC

Weaver &amp; Natcher IAMA 2000

**Table 1. VAR Results for Price Differences in Beef and Dairy Supply Chains  
Dairy Complex Vector Autoregression Based on Price Differences (1995-1999)**

Included observations: 56 after adjusting endpoints Standard errors & t-statistics in parentheses (Critical Value=1.68 at a test size of .05)						
	(SOYBEANS)	(CORN)	(OHIO)	(BUTTER)	(BARRELS)	(BLOCKS)
(SOYBEANS(-1))	0.029077 (0.15138) (0.19208)	-0.166692 (0.09531) (-1.74888)	0.000483 (0.00409) (0.11796)	-0.000641 (0.00099) (-0.64627)	-0.001029 (0.00058) (-1.78041)	-0.001033 (0.00057) (-1.80374)
(CORN(-1))	0.593670 (0.20944) (2.83460)	0.677691 (0.13187) (5.13904)	-0.001076 (0.00566) (-0.18996)	0.001445 (0.00137) (1.05315)	0.001529 (0.00080) (1.91180)	0.000936 (0.00079) (1.18134)
(OHIO(-1))	1.344596 (4.75910) (0.28253)	-0.742742 (2.99654) (-0.24787)	0.105004 (0.12870) (0.81587)	-0.074389 (0.03119) (-2.38539)	-0.022882 (0.01817) (-1.25917)	-0.031297 (0.01800) (-1.73826)
(BUTTER(-1))	-3.910927 (22.0666) (-0.17723)	-5.448498 (13.8941) (-0.39214)	0.472906 (0.59676) (0.79246)	0.389070 (0.14460) (2.69074)	0.152649 (0.08426) (1.81163)	0.116955 (0.08348) (1.40095)
(BARRELS(-1))	-33.64262 (93.0314) (-0.36163)	-21.68759 (58.5767) (-0.37024)	-0.695628 (2.51588) (-0.27649)	-0.600247 (0.60961) (-0.98464)	-0.042084 (0.35524) (-0.11847)	0.430779 (0.35196) (1.22395)
(BLOCKS(-1))	64.91096 (90.4295) (0.71781)	24.99265 (56.9385) (0.43894)	3.741907 (2.44552) (1.53011)	0.680099 (0.59256) (1.14773)	0.275625 (0.34530) (0.79821)	-0.089306 (0.34212) (-0.26104)
R-squared	0.199762	0.356230	0.228172	0.206755	0.209329	0.238811
Adj. R-squared	0.119738	0.291853	0.150990	0.127431	0.130262	0.162692
Sum sq. resids	46904.96	18595.58	34.30365	2.014011	0.683908	0.671341
F-statistic	2.496283	5.533502	2.956260	2.606450	2.647486	3.137346
Log likelihood	-267.9153	-242.0097	-65.73776	13.64570	43.88740	44.40668
Akaike AIC	9.782690	8.857490	2.562063	-0.273061	-1.353121	-1.371667
Schwarz SC	9.999692	9.074492	2.779065	-0.056059	-1.136119	-1.154665
Mean dependent	-1.670732	-0.970821	0.059821	0.007221	0.000196	0.000448
S.D. dependent	32.64513	22.91702	0.898936	0.214855	0.125406	0.126632
Log Likelihood	-405.2890					
Akaike Information Criteria	15.76032					
Schwarz Criteria	17.06233					

<sup>c</sup>Optimal lag chosen by minimizing the SIC

Weaver &amp; Natcher IAMA 2000

**Table 2. Summary of VAR results for Conditional Variances  
Beef Complex Vector Autoregression Based on Conditional Variance Estimates  
(1980-1999)<sup>c\*</sup>**

Included observations: 229					
Standard errors & t-statistics in parentheses (Critical Value=1.65 at a test size of .05)					
	SOYBEANS	CORN	FEEDER	LIVE	WHOLESALE
<b>SOYBEANS(-1)</b>	0.110571 (0.06891) (1.60460)	0.003410 (0.02663) (0.12806)	4.85E-05 (0.00018) (0.26501)	0.002214 (0.00199) (1.11534)	0.004149 (0.00260) (1.59474)
<b>CORN(-1)</b>	0.439012 (0.18540) (2.36786)	0.020205 (0.07165) (0.28199)	-0.000423 (0.00049) (-0.85799)	-0.006542 (0.00534) (-1.22478)	0.000670 (0.00700) (0.09564)
<b>FEEDER(-1)</b>	-3.596869 (25.9953) (-0.13837)	13.95471 (10.0459) (1.38909)	0.018932 (0.06909) (0.27404)	0.445644 (0.74885) (0.59510)	-0.268707 (0.98147) (-0.27378)
<b>LIVE(-1)</b>	-2.324843 (2.22777) (-1.04358)	-0.155526 (0.86093) (-0.18065)	-0.004840 (0.00592) (-0.81749)	0.126791 (0.06418) (1.97569)	-0.046942 (0.08411) (-0.55809)
<b>WHOLESALE(-1)</b>	3.514526 (1.84064) (1.90941)	0.992187 (0.71132) (1.39486)	0.003144 (0.00489) (0.64281)	0.009646 (0.05302) (0.18192)	0.144179 (0.06949) (2.07467)
<b>INTERCEPT</b>	18.29614 (60.5314) (0.30226)	-23.19677 (23.3925) (-0.99163)	2.316625 (0.16087) (14.4005)	0.775257 (1.74374) (0.44459)	4.998518 (2.28541) (2.18714)
R-squared	0.068113	0.021154	0.008050	0.030309	0.033885
Adj. R-squared	0.047219	-0.000793	-0.014191	0.008568	0.012224
Sum sq. resids	23212.89	3466.735	0.163954	19.26328	33.09004
F-statistic	3.259896	0.963876	0.361964	1.394055	1.564296
Log likelihood	-853.7828	-636.0616	504.2598	-41.48974	-103.4378
Akaike AIC	7.509020	5.607525	-4.351614	0.414758	0.955789
Schwarz SC	7.598986	5.697492	-4.261648	0.504724	1.045756
Mean dependent	33.25124	14.97082	2.362622	2.121367	5.155824
S.D. dependent	10.45239	3.941267	0.026925	0.295176	0.387585
Log Likelihood	-1094.870				
Akaike Information Criteria	9.824192				
Schwarz Criteria	10.27402				

<sup>c</sup>Optimal lag chosen by minimizing the SIC

\*Monthly retail prices were found to have a constant variance and consequently were not included in the VAR model.

Weaver &amp; Natcher IAMA 2000

**Table 2. Summary of VAR results for Conditional Variances  
Dairy Complex Vector Autoregression Based on Conditional Variance Estimates  
(1995-1999)**

Included observations: 52 after adjusting endpoints Standard errors & t-statistics in parentheses (Critical Value=1.68 for a test size of .05)						
	SOYBEANS	CORN	OHIO	BUTTER	BARREL	BLOCKS
<b>SOYBEANS(-1)</b>	-0.222773 (0.11661) (-1.91043)	-0.097177 (0.11263) (-0.86283)	-0.001910 (0.00339) (-0.56371)	0.002289 (0.00050) (4.57996)	0.000844 (0.00035) (2.38087)	0.001080 (0.00075) (1.43266)
<b>CORN(-1)</b>	0.786133 (0.15323) (5.13039)	0.016865 (0.14800) (0.11396)	-0.002788 (0.00445) (-0.62625)	-0.000252 (0.00066) (-0.38318)	0.000946 (0.00047) (2.03072)	0.000299 (0.00099) (0.30157)
<b>OHIO(-1)</b>	-0.126771 (2.32446) (-0.05454)	-0.193854 (2.24506) (-0.08635)	0.927787 (0.06753) (13.7385)	0.011744 (0.00996) (1.17895)	0.010534 (0.00706) (1.49118)	0.024951 (0.01503) (1.66029)
<b>BUTTER(-1)</b>	-0.832176 (14.1149) (-0.05896)	-8.084276 (13.6328) (-0.59300)	0.161135 (0.41008) (0.39294)	0.835226 (0.06049) (13.8083)	0.033930 (0.04290) (0.79094)	0.062836 (0.09126) (0.68857)
<b>BARREL(-1)</b>	16.18193 (77.5926) (0.20855)	54.44077 (74.9420) (0.72644)	1.377103 (2.25427) (0.61089)	0.986337 (0.33251) (2.96633)	-0.085940 (0.23582) (-0.36443)	-0.433664 (0.50165) (-0.86447)
<b>BLOCKS(-1)</b>	-15.19891 (38.2574) (-0.39728)	-31.53715 (36.9505) (-0.85350)	-0.142974 (1.11148) (-0.12863)	-0.398778 (0.16395) (-2.43237)	0.025176 (0.11627) (0.21653)	0.279370 (0.24734) (1.12949)
<b>C</b>	28.79282 (6.70182) (4.29627)	18.37679 (6.47289) (2.83904)	0.051513 (0.19471) (0.26457)	-0.102773 (0.02872) (-3.57848)	0.040565 (0.02037) (1.99156)	0.036244 (0.04333) (0.83648)
R-squared	0.404707	0.042562	0.864551	0.882359	0.242360	0.182643
Adj. R-squared	0.325335	-0.085096	0.846491	0.866673	0.141342	0.073662
Sum sq. resids	2021.489	1885.739	1.706254	0.037123	0.018672	0.084496
F-statistic	5.098843	0.333406	47.87144	56.25314	2.399164	1.675920
Log likelihood	-168.9538	-167.1464	15.05573	114.5790	132.4463	93.19496
Akaike AIC	6.767454	6.697939	-0.309836	-4.137654	-4.824858	-3.315191
Schwarz SC	7.030121	6.960606	-0.047168	-3.874986	-4.562191	-3.052523
Mean dependent	33.58195	15.88642	0.806679	0.181733	0.092531	0.093687
S.D. dependent	8.159909	6.214417	0.496992	0.078661	0.021983	0.045022
Log Likelihood	53.04189					
Akaike Information Criteria	-0.424688					
Schwarz Criteria	1.151316					

<sup>c</sup>Optimal lag chosen by minimizing the SIC

Weaver & Natcher IAMA 2000

Figure 2. Conditional Volatility Estimates of Price Volatility

