Analysis of Retail Beef to Live Cattle Price Spreads

by

John E. Ikerd

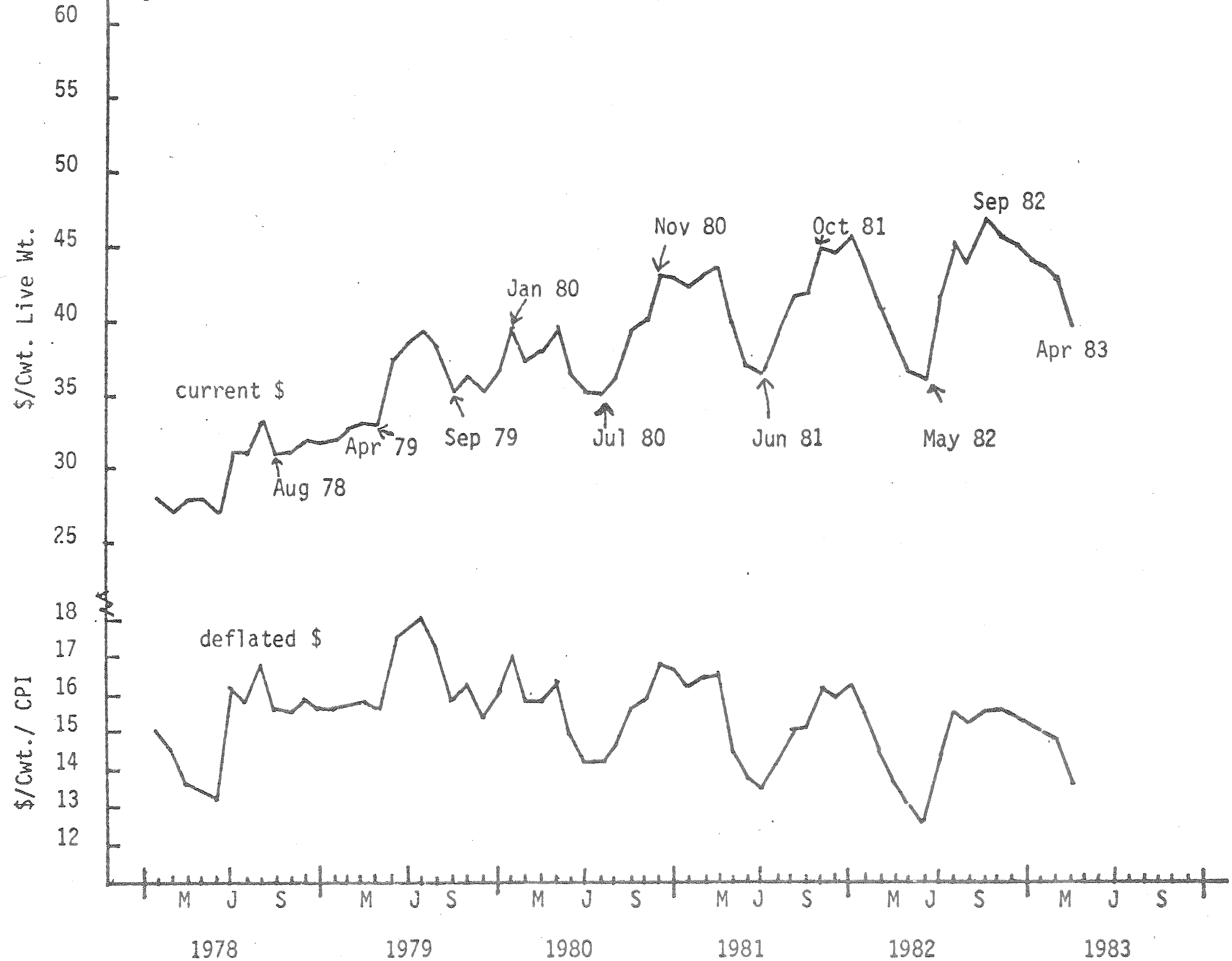
objective of the work reported here is to provide a solid research base for development of applied forecast models that will accurately project price spread changes for beef.

Price Spread Trends and Patterns

Figure 1 shows trends and patterns in retail beef to live cattle price spreads for the 1978-1982 period. These spreads are expressed in terms of live cattle equivalent prices to indicate the potential effect of changing spreads on live cattle prices. Spreads between retail beef and live cattle prices have varied $8 to $10/cwt. within most years since 1978. That is, live cattle prices have changed $8 to $10 relative to retail beef prices during each of these swings in price spreads . Conceivably market analysts could have forecasted retail beef prices with perfect accuracy while obtaining errors of $8 to $10 in live cattle prices derived from those retail forecasts.

Models that forecast live cattle prices directly would pick up spread variations, to the extent that variations in price spreads are related to factors that determine supply of or demand for live cattle. But, existence of a unique fundamental and/or lagged structure for price spread determination would require that price spreads be given separate consideration in live cattle price forecasts. The purpose of the work reported in this paper was to examine the basic structure of markets which determine retail-beef-to-live-cattle price spreads. Knowledge of this structure provides a more solid conceptual basis for constructing forecast models for beef price spreads with an ultimate objective of more accurate cattle price forecasts.

Figure #1 Retail Beef - Live Cattle Price Spreads ($/cwt Live weight)



Conceptual Models of Price Spread Determination

Several serious attempts have been made to define the market structure underlying price spread determination. (see Gardner, Heien(1980), Myers and Havlicek, Wholgenant). These studies provide insights into the impacts of price spreads on cattle prices. But, none of these studies deals specifically with determinants of supply of and demand for marketing services nor with determinants of price spreads for beef. Neither do any of these studies result in promising approaches to forecasting spreads between retail beef and live cattle prices.

Several economic studies have focused on lags in prices changes among various levels within marketing systems as measures of pricing efficiency. Studies by Miller, Hein (1976), Lamm, Lamm and Wescott, Hall, et. al., and King indicate one to three month lags among price changes in retail, wholesale and live markets for beef. However, the largest proportion to such adjustments were found to occur within one month. These studies provide guidelines in selection of data and construction of fundamental forecast models. However, they shed little light on questions related to fundamental supply of and demand for marketing services for beef.

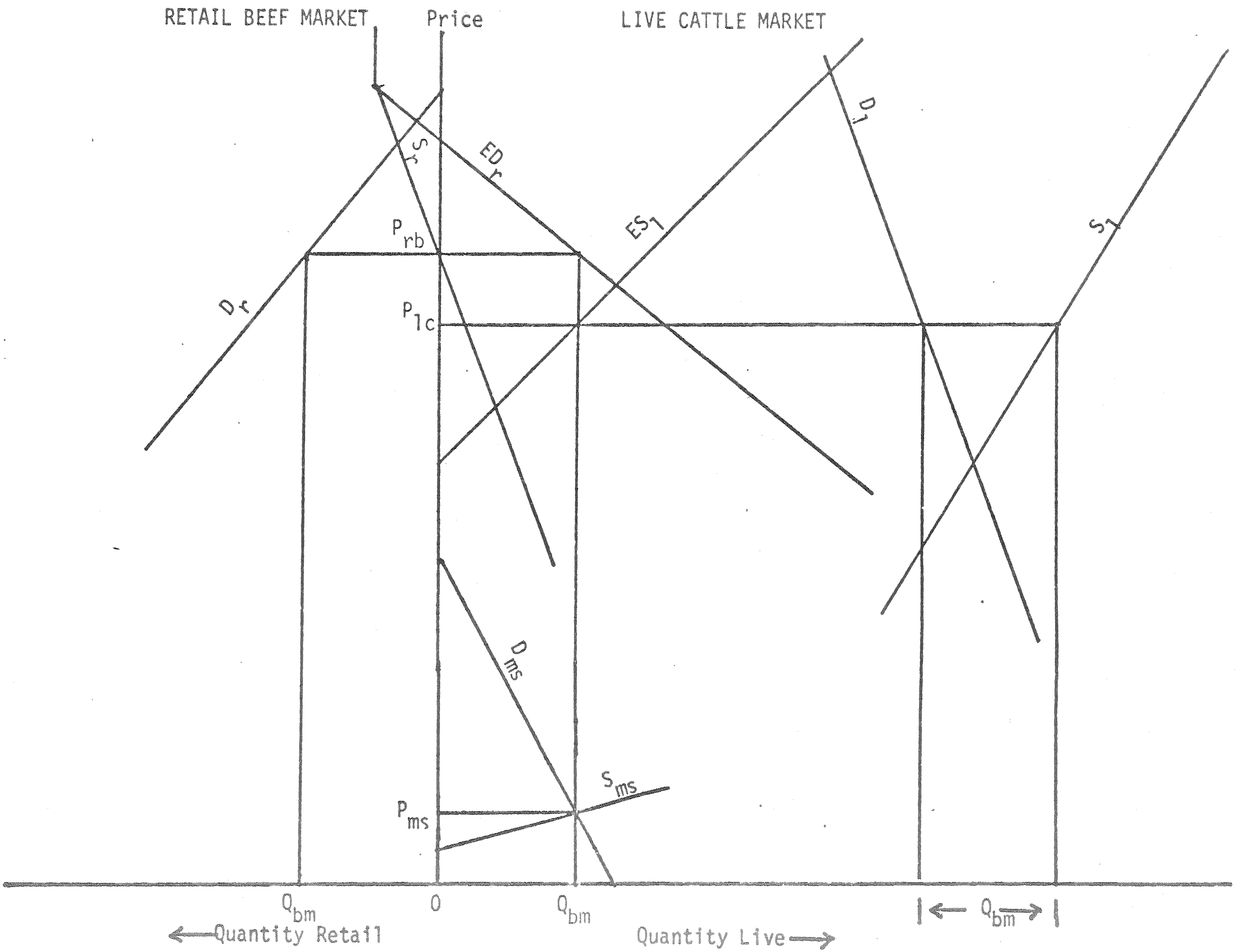
An Intermarket Approach to Price Spread Determination

Emphasis in this study is placed on derivation of supply and demand functions for a composite of slaughter, processing and retailing services for beef. The demand for these marketing services is derived from analysis of the retail market for beef and the live market for cattle as related, but separate entities within a marketing system. The approach follows that of Bressler and King in dealing with interregional markets. Derivation of demand for a marketing service is the same conceptually regardless of whether the service is one of transportation, storage, exchange or in this case; slaughter, processing and retailing.

Figure 2 shows the conceptual framework. The left portion of figure 2 represents the retail beef market. D_r represents retail beef demand and S_r represents supplies of beef from retail or market stocks. Q_{bm} represents the quantity of beef supplied from current production rather than from market stocks. Total retail beef supplies equal current production plus changes in stocks. Figure 2 shows an equilibrium stock situation with net supplies from stocks, equal to zero. However, higher retail prices, P_{rb}, would result in retail supplies being drawn from stocks, and a lower retail price would result in an addition to existing stocks. ED_r represents excess retail demand.

The right portion of figure 2 represents the market for live cattle. D_l represents the reservation demand for cattle. This schedule represents quantities of cattle that will be kept in feed lots, on pastures and in breeding herds at various cattle prices, P_{lc}. It is a demand based on expectations of future values of these cattle in their various possible future uses. The live supply schedule, S_l, represents the quantity of cattle that will be sold rather than retained in feed lots, on pastures and in breeding herds at various price levels, P_{lc}.

Figure 2. Intermarket Determination of Prices for Marketing Services



Excess live supply, ES_l, represents the supply of cattle that will be offered for slaughter at various price levels, P_{lc}. Excess supply is the difference between reservation demand for live cattle and live cattle supply functions. The intersection of live supply and demand is drawn for illustration purposes only. Prices below the live market equilibrium would imply zero slaughter and incentives to transform retail beef into live cattle rather than vice versa. Neither of these occurances is logical at reasonable price levels.

The demand for marketing (slaughter, processing and retailing) services can be derived from relationships shown in figure 2. The demand function, D_{ms}, equals excess retail beef demand, ED_r, minus excess live cattle supply, ES_l, with respect to the vertical or price axis.

Shifts in factors affecting supply of or demand for beef at retail and supply of and demand for cattle in the live market thus affect demand for marketing services. Supply of marketing services, S_{ms}, is exogenous to the system. The spread between retail beef and live cattle prices for any given period, P_{ms}, is determined by the intersection of the demand for and supply of marketing services.

Estimation of Structural Model Parameters

A system of simultaneous equations representing the foregoing structural model of US markets for cattle and beef was specified. It was assumed that most retail market effects would be reflected in live markets and vice versa within the one-month data time frame. Imports were added to domestic supplies and stock changes in estimating total retail supplies. Changes in cold storage stocks were used to approximate changes in total stocks. All quantities were divided by the number of slaughter or business days per month. Monthly data were used from January 1964 through December 1981. This period includes times of generally stable price spreads as well as more volatile spreads of recent years.

Intermarket relationships are represented by a model including four simultaneous equations and four identities. The same general variables likely determine both supply and demand relationships at the live level. Thus, a single excess supply equation represents the live market.

The model, estimated by two stage least squares, with quantity dependent coefficients is shown below:

1. RSB = -1.435+0.002 BCS +0.001 SOM -0.076EXF +0.007 IDC
   (2.35) (2.37) (4.40) (1.74)

   -0.007 RPB + M2 + ...+ M12
   (1.56) (0.35 to -4.13)

2. RDB = 59.964 -0.309 RSO + 0.500 TPI -0.294 RPB -0.053 ICS
   (8.41) (28.57) (17.59) (2.06)

   + M2 + ... + M12
   (-0.21 to -8.29)

3. ESL = 0.942 +0.242 EXF +1.428 CFM +0.584 CIE +0.081 GFV
   (1.83) (3.68) (9.76) (6.12)

   + M2 +...............+M12
   (-.017 to -4.18)

4. CBP = 78.512 +0.596 BPS -0.194 PPC M2 +..........+ M12
   (3.98) (2.83) (0.01 to -2.31)

5. BPS = RPB - GFV + PBA

6. EDR = RDB - RSB

7. ESL = CBP + BIM

8. EDR = ESL

Values in parentheses below coefficients are t values.

RSB = Quantity of beef supplies from retail stocks.

RDB = Quantity of beef purchased at retail.

ESL = Quantity of current beef supply.

CBP = Quantity of marketing services.(commercial beef production)

BPS = Beef Price Spread per retail pound.(choice beef)

RPB = Retail price of beef.(choice composite price)

GFV = Gross farm or live value (choice steer).

BPA = By-product allowance per retail pound equivalent.

EDR = Excess demand from retail market.

BIM = Beef imports.

BCS = Beef cold storage stocks at beginning of month.

SOM = Pork, chicken and turkey--cold storage stocks first of month.

EXF = Futures prices for 4-6 month deferred delivery, minus current live cattle prices.

IDC = Index of producer prices for intermediate goods (Business Conditions Digest)

ROS = Pork, chicken and turkey--change in cold storage stocks during month.

TPI = Total personal income for month, US.

ICS = Index of consumer sentiment (Business Conditions Digest)

CFM = Cattle on-Feed--monthly, from 7 state reports.

CIE = Cattle inventory -- monthly estimate from annual and mid-year reports.

PPC = Processing and marketing cost estimate--average of labor costs index plus IDC.

M2....M12 = Monthly dummy variables (0,1), January base.

The statistical results in general confirm the hypothesized structural system of markets. Signs were consistent with expectations, with few exceptions. All independent variables had acceptable t values.

Beef stocks, stocks of other meats and commercial input prices were all positively related to retail supplies of beef from stocks(see equation 1). The intermediate producers goods cost, IDC, was accepted at the 0.08 significance level because of the logical relationship between costs of holding stocks and stock levels.

Live cattle price expectations (EXF) were negatively related to retail supplies. Expectations of higher future purchase costs caused a building of stocks from current production and a reduction in supplies from current stocks. Retail price picked up some undefined demand effects rather than supply effects hypothesized for the retail supply equation resulting in a negative sign. However, the level of significance of price was relatively low, t value significance at 0.12. The price variable was included because of its obvious logical significance. Questions of specification error in the retail supply equation could not be resolved. There were significant seasonal tendencies to build beef stocks in early winter and draw down stocks in early spring and fall.

The retail demand equation included supplies of other meats, consumer incomes and beef prices (see equation 2). All these coefficients were highly significant with expected signs. The negative sign for consumer sentiment might reflect a switch from perishable to durable goods purchases during periods of growing consumer confidence.

Retail demand showed seasonal strength in January, September and October.

The live supply equation includes only those variables that would be expected to influence the live market (see equation 3). All variables were highly significant and signs were as expected except for the expected price variable, EXF. Expectations of higher future prices were thought to result in smaller current slaughter levels relative to inventories. However, current live price (GFV) has a highly significant positive relationship with quantities supplied, as expected. Cattle on feed and cattle inventory variables both had highly significant, positive coefficients. Correlation between cattle inventories and cattle-on-feed numbers was only 0.25. Significant negative seasonal supplies were shown for August, September and October.

The final model equation represents supply of beef marketing services(see equation 4). Demand for marketing services is derived from previous model equations representing retail and live markets. Beef price spreads had a highly significant positive coefficient as expected. Packers and retailers were willing to supply larger quantities of services, CBP, at higher prices for services, ie. higher beef price spreads, BPS. Estimated costs of slaughter, processing and retailing, PPC, were significantly, negatively related to beef production or supply of marketing services. This indicates that as costs of marketing rise, marketing firms are willing to market less beef at any given price spread or price of service. Seasonal coeficiants were significantly smaller for August, September and October.

The model identities represent equilibrium conditions among markets. Equation 5 represents equilibrium conditions for prices among various levels within the beef marketing system. Equations 6 and 7 define excess demand and supply in relation to other data set variables. Equation 8 represents equilibrium quantity relationships between retail beef and live cattle markets.

Statistical results in general confirm the hypothesized relationships among the retail beef market, the live cattle market and the market for slaughter, processing and retailing services.

Further Analysis of Beef Price Spreads

A single equation model for price spreads was estimated using the variables identified with the simultaneous equation model. Statistical results were quite similar for the single equation and for a price dependent form of the simultaneous equation system. Single equation results were as follows:

$$\underset{}{BPS} = .19.589 + \underset{(1.98)}{0.101\ CBP} + \underset{(54.79)}{0.444\ PPC} \underset{(1.02 \text{ to } -1.64)}{+M2 + \ldots\ldots + M12} \quad R^2=0.95$$

The estimated coefficient for commercial beef production was smaller and less significant in the single equation model than in a price spread dependent equation in the simultaneous equation system. This implies that single equation models of price spreads may underestimate the effect of slaughter levels on beef price spreads.

Individual forecasted values and residual errors were calculated for the single equation model. Analysis of those forecast errors confirm the misleading nature of R^2 values in forecasting models. Forecast errors as large as 15.96 and -13.16 were observed within the

1979 to 1981 data period. Forecast errors as large as 13.00 extend back to 1973. These errors amount to $5 to $7 per hundredweight of live cattle. It is highly likely that the structural equation derived from the simultaneous system would show little improvement over the single equation forecasting results.

The residual forecast error exhibited a pattern of cyclical variation similar to that observed in price spread values in figure 1. Residuals were analyzed for serial correlation, resulting in a first order autocorrelation of 0.73 and a Durbin-Watson D statistic of 0.54. These results cast further doubts on the adequacy of structural model estimates alone in forecasting price spreads for beef.

Time Series Analysis of Forecast Errors

Serial correlation in forecast errors suggest that autoregressive techniques such as ARIMA might be used to define autoregressive characteristics of residuals. Forecast models might then be developed to combine structural and time series forecasts of price spreads. Residual data from the single equation structural model were analyzed using a statistical ARIMA routine.

Initial analysis of residual data indicated that the series was unstable and thus had to be transformed before time series coefficients could be estimated. The usual procedure in such cases is to take first differences of the data and proceed. However, price spread relationships, as shown in figure 1, indicate cycles of increasing amplitude in current prices but cycles of constant amplitude in deflated terms. The residual series was deflated by the consumer price index and a stable, analyzable series resulted.

Autocorrelations and partial autocorrelations were analyzed using guidelines from Bowermann and O'Connell. Existence of one period autoregression was obvious but existence of cycles or sine-wave partial autocorrelation patterns indicated that second order or higher autoregression was present also. The total autocorrelation pattern could have indicated third order, seventh order, eighth order, eleventh order or twelfth order moving average relationships. All of these options were analyzed. Only the eleventh and twelfth order moving averages produced convergent solutions. The two period autoregression, twelve period moving average model produced superior statistical results.

The ARIMA model with estimated coefficients from deflated residual beef price spreads is as follows:

$$
\begin{aligned}
E_t = & -0.142 + \underset{(23.72)}{1.451}\, E_{t-1} \underset{(15.73)}{-0.914}\, E_{t-2} \underset{(8.04)}{+0.744}\, e_{t-1} \underset{(3.80)}{-0.361}\, e_{t-2} \\
& \underset{(3.70)}{-0.342}\, e_{t-3} \underset{(0.39)}{-0.037}\, e_{t-4} \underset{(4.27)}{-0.400}\, e_{t-5} \underset{(0.25)}{-0.025}\, e_{t-6} \\
& \underset{(1.62)}{-0.156}\, e_{t-7} \underset{(0.19)}{-0.018}\, e_{t-8} \underset{(0.07)}{+0.001}\, e_{t-9} \underset{(3.00)}{-0.275}\, e_{t-10} \\
& \underset{(0.03)}{+0.003}\, e_{t-11} \underset{(0.59)}{-0.045}\, e_{t-12}
\end{aligned}
$$

Chi Square =5.64 at 18 lag
Probability level=0.13

Where:

E_t = Residual error from structural model for time period t.

e_t=Residual error of time series model for time period t.

Values in parenthesese are t ratio values.

The ARIMA model results indicated a marginal fit of the model. But, other characteristics of the model seemed to offset the higher than desirable chi square statistic. The model generated cyclical forecast patterns, as seen in price spreads in recent years. For example, a 12 month forward forecasts from the end of the data period in December 1981 projected a pattern quite closely related to observed spread patterns for 1982(see figure 1). The structural model would have accounted for some of the 1982 variation. But, the structural model for the most part would have indicated a general upward trend in spreads with minor deviations associated with slaughter levels.

The ARIMA analysis provided valuable information concerning an identifiable pattern of serial correlation of structural forecast errors. The fact that such a pattern is statistically definable indicates that time series analysis may be an important element in construction of practical, applied models for beef price spread forecasting.

Summary and Conclusions

The objective of this study was to identify the factors that affect spreads between retail beef and live cattle prices by validating a conceptual model of the spreads determination process. It was hypothesized that beef price spreads represent market prices for composite slaughter, processing and retailing services for beef. The demand for these services is derived from the retail market for beef and the live market for cattle. Parameters of an intermarket model were estimated by two stage least squares analysis of a system of four equations and four identities. The equations represent retail supply and demand, live market excess supply and supply of marketing services with indentities representing market equilibrium conditions.

Results of the analysis supported the basic price spread determination hypothesis. All factors that affect supply of or demand for retail beef or the supply of or demand for live cattle may have indirect effects on beef price spreads through the demand for marketing services. The primary factors affecting supply of those marketing services by packers and retailers are their costs of operation and quantity of marketing service demanded, ie. cattle available for slaughter.

All parts of the model, in spite of a questionable retail supply function, supported the basic hypothesis of a unique identifiable market for slaughter, processing and retailing services. About 95% of the short-run variation in beef price spreads can be explained by changes in demand for marketing services, as reflected in commercial beef production, and an index of costs of slaughter, processing and retailing. A single equation form of the spread determination model indicated that the impact of beef production levels on price spreads may be underestimated by a single equation approach.

Analysis of residual errors of forecasts from the single equation model indicated that substantial forecast error exists in structural model forecasts in spite of 0.95 R^2 values. Observed errors were equal to $5 to $7 per cwt. in live cattle equivalent prices. Analysis of those residuals by time series statistical procedures indicated highly significant serial correlation. Examination of error patterns suggested a cyclical pattern of serially correlated error.

Residual errors from the structural equation were analyzed by ARIMA statistical procedures. It was concluded that there were two period autoregression and twelve period moving average patterns in the residual data. Test statistics suggested a marginally acceptable fit for this model. However, the autoregressive model did generate cyclical forecast patterns quite similar to those observed in actual price spread and residual data. The moving average lag length corresponded to observed cycle lengths.

Implications

The basic purpose for the study reported here was to provide a research based, conceptual framework for development of applied forecast models. The ultimate objective is to improve forecasting accuracy for cattle prices through better forecasts of spreads between retail beef and live cattle prices.

Results of this study lead to the following conclusions:

- Structural forecast models which include measures of demand for marketing services, such as projected beef production and costs of marketing services, are needed to forecast general trends in beef price spreads over time.
- Neither structural models of supply and demand for marketing services nor inclusion of general variables affecting markets at other levels within the system are likely to explain cyclical patterns in spreads observed in recent years.
- Time series models, such as ARIMA models, are capable of quantifying cyclical patterns of residual error from structural model estimates. Residule error analysis may be superior, conceptually, to inclusion of questionable lag structures in single equation forecast models.

Further refinement of any study is always possible. And, results of this study leave some unanswered structural questions. But, at some point questions must be raised as to trade-offs between further refinement of an existing study and using current results as a basis for a next step toward an ultimate objective. Results from this analysis of farm-to-retail beef price spreads seem sufficiently conclusive to justify the next step toward building practical, applied models that will more accurately forecast beef price spreads and ultimately will provide more accurate forecasts of live cattle prices.

References

Bowerman Bruce L., and Richard T. O"Connell, Time Series and Forecasting, Duxbury Press, North Scituate, Mass, 1979.

Bressler, Raymond G. and Richard A. King. Markets, Prices and Interregional Trade, John Wiley & Sons Inc., New York, NY, 1970.

Gardner, Bruce L. "The Farm-Retail Price Spread in a Competitive Food Industry, " American Journal of Agricultural Economics, 57:3, August 1975, pp. 399-409.

Hall, L.L., W. G. Tomek, N. L. Ruther and S.S. Kyeveme, Case Studies in Transmission of Farm Prices, A.E. Research 81-12, Dept. of Agricultrual Economics, Cornell, University, Ithica, N.Y. August, 1981.

Hein, Dale. A Study of the Relationship Between Farm-Level Prices and Retail Food Prices, Unpublished paper prepared for the Council of Wage and Price Stability, Washington, D.C., September 1976.

Hein, Dale M. "Markup Pricing in a Dynamic Model of the Food Industry," American Journal of Agricultural Economics, 62:1, February 1980, pp. 10-18.

King, R.A., "Transmission of week-to-week changes in choices beef prices between farm, carcass, and retail levels", Contributed paper, AAEA, August 1976.

Lamm, R. McFall. "Dynamics of Food Price Inflation," Western Journal of Agricultural Economics, 4:2, December 1979, pp. 121-134.

Lamm, R. McFall and Paul C. Westcott. "The Effects of Changing Input Costs on Food Prices, " American Journal of Agricultural Economics, 63:2, May 1981, pp. 187-196.

Miler, Stephen E. "Univariate Residual Cross Correlation Analysis: An Application to Beef Prices, " North Central Journal of Agricultural Economics, 1:2, July 1979, pp. 141-146.

Myers, L.H. and J. Havice K, Jr. "Monthly Price Structure of the U.S. Beef, Pork and Broiler Markets, " pp. 139-172 in W. C. Labys, Quantitative Models of Commodity Markets, Cambridge, MA, Publishing Co., 1975.

United States Department of Commerce, Business Conditions Digest, Monthly, US Gov. printing office.

Wohlgenant, Micheal K. An Analysis of Short-Run Changes in the Farm-Retail Price Spread for Beef, Unpublished paper, Department of Economics and Business, North Carolina State University, Raleigh, NC, March 1980.