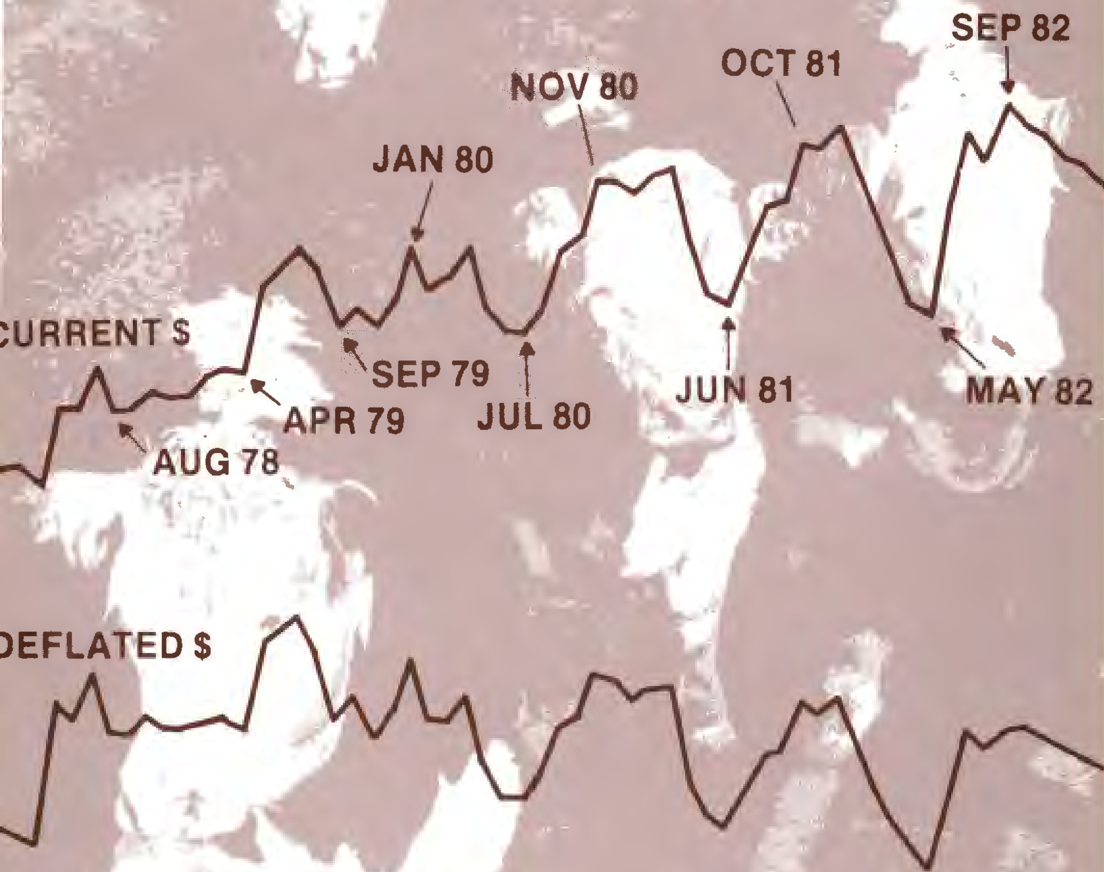
ANALYSIS OF FARM TO RETAIL BEEF PRICE SPREADS TO IMPROVE CATTLE PRICE FORECASTS



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Analysis of Farm to Retail Beef Price Spreads to Improve Cattle Price Forecasts

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The ultimate value of beef and consequently the value of cattle is determined at the retail market. Retailers price beef but consumers decide whether or not they will buy beef at those retail prices. Consumer purchase decisions cause retailers to raise prices when beef supplies are scarce relative to consumer demand. Likewise, lack of consumer purchases force lower prices whenever beef supplies are larger than can be sold at current prices. Thus, consumers decide the ultimate value of any given supply of beef.

Demand for live cattle is derived from consumer demand for beef at retail. Thus, consumer beef prices will be reflected in prices of live cattle. In the long run, packers and retailers must cover their costs plus a reasonable return on their investment. Thus, cattle prices cannot persist at levels above those allowing a competitive positive margin between retail beef and live cattle prices. Likewise, there is no evidence that packers and retailers earn more than competitive returns in the long run. So, general levels and trends in cattle prices reflect general levels and trends in retail beef prices and marketing costs.

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Derived Demand--Implications for Forecasting

Since live cattle demand is derived from retail beef demand, it seems logical that forecasts of live cattle prices should be derived from retail market forecasts. However, spread between retail beef and live cattle prices may vary widely from month-to-month within any given year. And, these month-to-month variations in live-to-retail spreads often cannot be related directly to changes in packer or retail costs. Consequently, changes in live cattle prices within any given year may far exceed changes explainable by any corresponding change in retail beef prices.

Between August 1980 and February 1981 live cattle prices dropped from $72.31 to $61.50 at Omaha. During this same period, retail beef prices dropped from $2.42 to $2.38, a drop equivalent to less than $2 in live weight equivalent. Then, between February and June of 1981 live prices rose from $61.50 to $68.26 while retail prices rose only $0.01 per retail pound. Thus, very little of the variability in live cattle prices during this period was related to variability in the ultimate retail value of beef. Variability in live cattle prices during this period was related much more closely to variability in spreads between retail beef and live cattle prices.

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 equivalents to indicate the potential effect of changing spreads on live cattle prices. The general trend in spreads expressed in current dollars has been upward during this period. But, the general trend actually is slightly lower when spreads are deflated by the index of consumer prices. However, the dominant characteristics of these spread patterns is cyclical

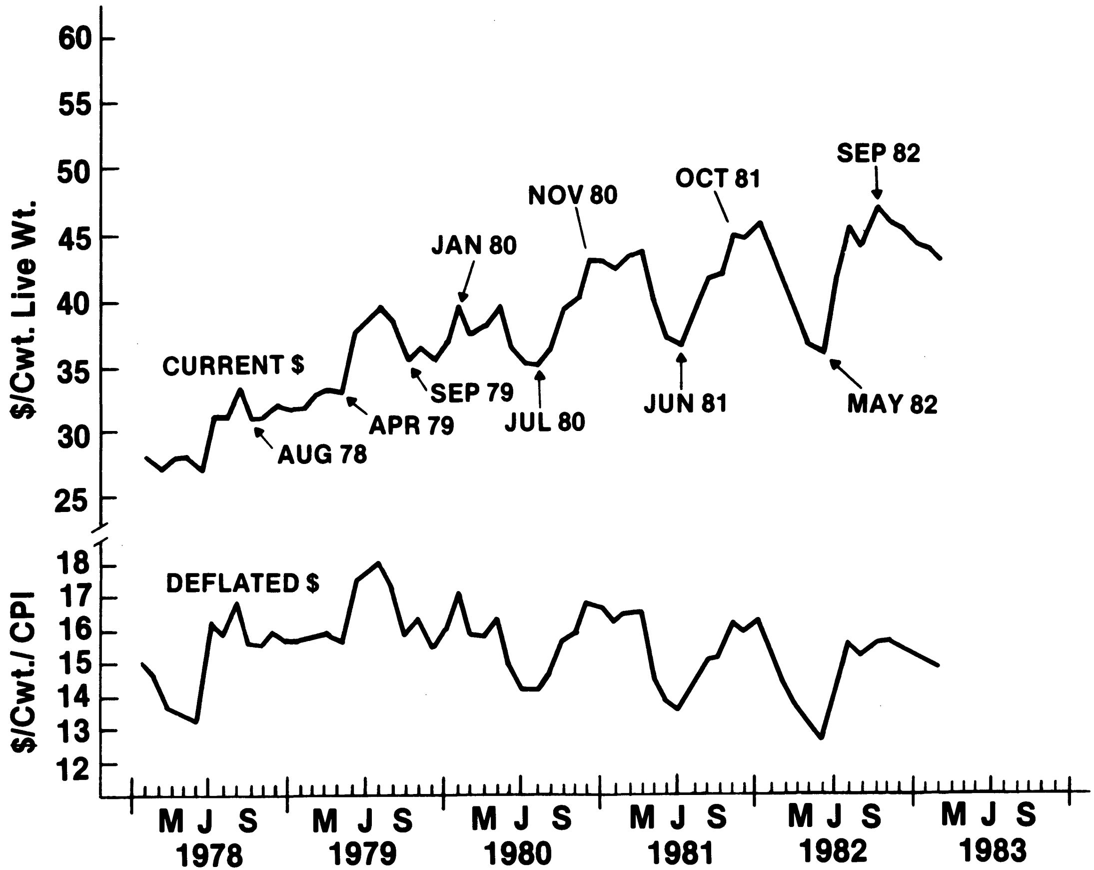

Figure 1. Retail Beef-Live Cattle Price Spread ($/cwt Live Weight).

variability with cycles ranging from 9-13 months in length.

Spreads between retail beef and live cattle prices in general have varied an equivalent of $8 to $10/cwt. live animal within most years since 1978. This means that live cattle prices have changed $8 to $10 relative to retail beef prices during each of these swings in price spreads. Thus, it is conceivable that market analysts could have forecast the ultimate value of beef, ie. retail beef price, with perfect accuracy while realizing errors of $8 to $10 in live cattle prices derived from those retail forecasts. There appears to be some seasonality in the cyclical spread patterns in Figure 1. However, cyclical low points, in particular, indicate that cycles have tended to be less than one year in length. Even if cycle lengths can be defined, questions remain as to whether such cycles are related to basic supply and demand fundamentals or whether the cycles are self generating lagged relationships.

Fundamental forecast models of live cattle prices would pick up spread variations to the extent that such variations are related to variables included in those models for other reasons. 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 magnitude of swings in price spreads seem to have increased in recent years. However, visual interpretations are inadequate bases for construction of reliable forecast models. The purpose of the work reported in this paper is to answer some of the questions related to determination of retail-beef-to-live-cattle price spreads. These answers provide a more solid conceptual basis for construction of forecast models for live cattle.

Conceptual Models of Price Spread Determination

Several serious attempts have been made to define the structure underlying price spread determination. Gardner defines a set of simultaneous market relationships which recognizes the potential impacts of the elasticities of supply of and demand for marketing services on price spreads. Heien (1980) incorporates disequilibrium concepts into a model of price determination which deals explicitly with prices at retail, wholesale and farm levels. Myers and Havlicek incorporate the market for marketing services into a complex structural model of the total meat industry. Wohlgenant uses a similar approach but focuses more directly on changes in farm-to-retail spreads for beef. All of these studies provide valuable insights into the determination of price spreads as a part of overall price determination for beef. But, none of these studies deal specificially with determinants of supply of and demand for marketing services and consequently none deal directly 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 changes in prices at various levels within marketing systems as measures of pricing efficiency. The more quickly and accurately prices at one level are reflected at another, the more efficient the market adjustment to an outside shock. These studies have indirect implications for studies of price spreads.

Less than instantaneous adjustments in prices at different levels within a marketing system imply changes in price spreads between market levels. Heien (1976) concluded that changes in values of commodities at farm level, in most cases are fully passed on to retail levels within three months. Miller indicates that changes in live markets for cattle are fully reflected in changes in retail beef markets within one month. Lamm concluded that live cattle prices lead to changes in retail beef prices. He estimated that over half of the adjustment would be complete within one month. Another study by Lamm and Wescott drew similar conclusions. These and other similar studies indicate that adjustments at one level in the marketing system seem to be reflected at other levels within a matter of weeks. These studies also help identify the dynamics of price changes at various levels within marketing systems as the market in total responds to fundamental supply and demand changes. And, these studies provide valuable 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

The analytical approach used in this study builds on a conceptual framework utilizing knowledge gleaned from previously cited studies. But, emphasis 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 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 for derivation of demand for marketing services in the cattle-beef market. 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 beef stocks. Total retail beef supplies equal current production plus changes in market 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 beef demand ie. demand for beef in excess of that available from market stocks, at prices less than the retail market equilibrium. Excess demand, ED_r, is derived as the horizontal distance between D_r and S_r. Excess demand represents demand for beef from current period production.

The right portion of Figure 2 represents the live market for cattle. Live demand, D_l, represents the reservation demand for cattle. As such, it represents quantities of cattle that will be kept in feedlots, on pastures and in breeding herds at various cattle price levels, P_{lc}. It is a demand based on expectations of future values of these cattle in their various possible future uses. Live supply, S_l, represents the quantity of cattle that will be sold rather than retained in feedlots, on pastures and in breeding herds at various price levels, P_{lc}. The more meaningful schedule in the live market segment is excess suppy, ES_l. Excess live supply represents the supply of cattle that will be offered for slaughter at various price levels, P_{lc}. ES_l is the difference between the reservation demand for live cattle and the live cattle supply function. The intersection of live supply and demand in Figure 2 is drawn only for purposes of conceptual illustration. By implications, at prices less than the

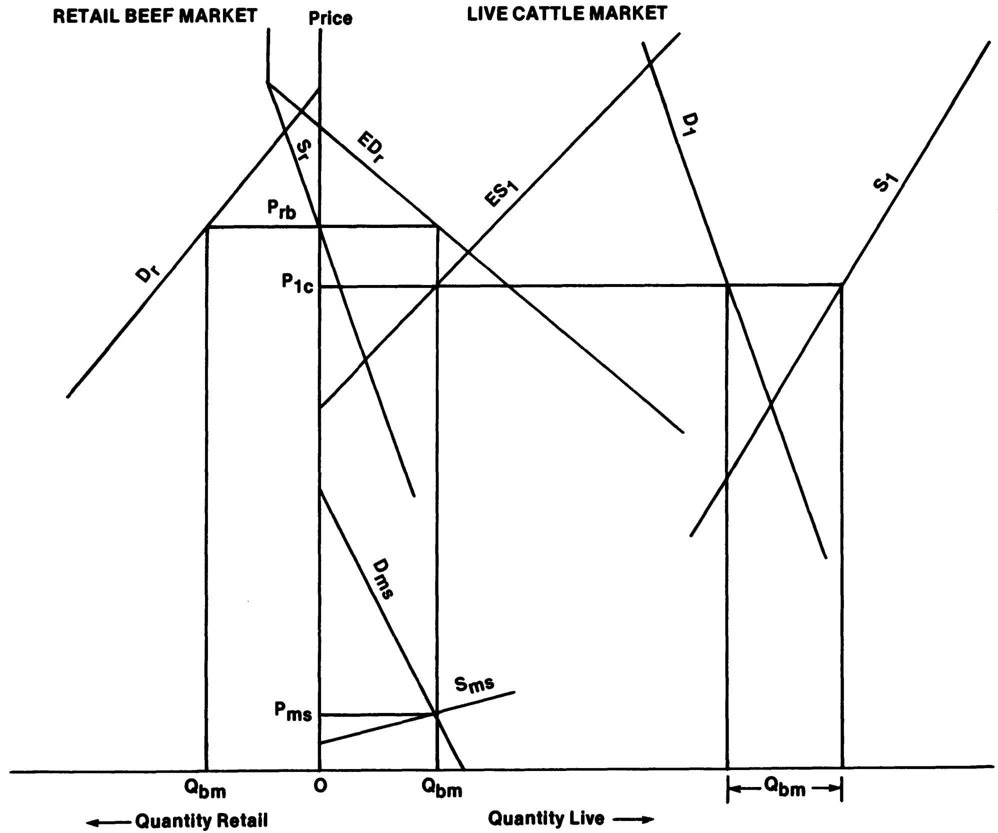

Figure 2. Intermarket Determination of Prices for Marketing Services.

live market equilibrium, cattle slaughter would go to zero. This is quite unlikely at any reasonable price level. Also, it should be noted that the intermarket interrelationships in Figure 2 are one way relationships. It is possible to supply an excess retail demand with transformed retail beef. But it is not possible to supply an excess live demand with processed beef.

The demand for composite slaughter, processing and retailing services can be derived from interrelationships between retail and live markets in Figure 2. Demand for marketing services in this case does not represent more services per animal but rather demand for more animals to which to apply services. The demand for marketing services 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.

Demand for marketing services thus is dependent on supply of and demand for beef at retail and supply of and demand for cattle in the live market. Shifts in factors affecting either market thus affects demand for marketing services. The demand for marketing services represents demand for and supply of beef from current production at alternative spreads between retail beef and live cattle prices. Supply of marketing services, S_{ms}, is exogeneous to the system. Supply of marketing services represents alternative levels of current beef supplies that packers and retailers are willing to move through the system at alternative spreads between retail beef and live cattle prices. The spread between retail beef and live cattle prices for any given price, P_{ms}, is determined by the intersection of the demand for and supply of marketing services. The price of marketing services, P_{ms}, is a function of both supply of and demand for those services.

At a spread greater than P_{ms}, higher retail prices relative to live cattle prices would result in quantities demanded and live cattle supplies smaller than profit maximizing levels for marketing firms. Potential for greater profits would result in competition for more cattle and greater beef sales which then would force live prices higher relative to retail prices. The spread would close back down to P_{ms}. At a spread smaller than P_{ms}, lower retail prices relative to live cattle prices would result in greater beef demand and greater live cattle supply than marketing firms would find profitable to move through the system. Retailers would have an incentive to raise retail prices while packers would reduce bid prices for live cattle. Reduced quantities of cattle supplied and reduced retail quantities demanded due to price changes would force the spread back up to P_{ms}.

"Shifts" in either supply or demand in either retail or live markets could cause "shifts" in demand for marketing services, D_{ms}. This would force the price spread, P_{ms}, to find a new equilibrium level. Shifts in costs of operation of marketing firms likewise would shift the supply of marketing services, S_{ms}, resulting in a new equilibrium level for the price spread, P_{ms}.

There are obvious difficulties in translating the concepts in Figure 2 into practical structural models of beef and cattle markets. Excess demand from the retail market for cattle is derived from "expected" retail supply and demand for beef. What is the appropriate lag period? How are expectations measured? Beef and cattle are not homogeneous. What prices should be used? How can live cattle be translated into beef supplies or vise versa? The same basic factors affect both reservation demand for and supply of live cattle. Exports and imports may affect the system from outside. Markets are rarely in long term equilibrium. Does Figure 2 represent a weekly, monthly, or quarterly relationship? These and other concerns are practical considerations that must be addressed in estimating structural parameters of any system representing markets for cattle and beef.

Estimation of Structural Model Parameters

A system of simultaneous equations representing a structural model of US markets for cattle and beef was estimated. Monthly data were chosen for analysis. It was assumed that most retail market effects would be reflected in live markets and vice versa within a one month 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. Changes in stocks held by packers and retailers, e.g. boxed beef, are not available for the data period. All quantities were divided by the number of slaughter or business days per month. Monthly data were used for 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 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)

$+ M2 + \ldots\ldots\ldots\ldots + M12$

(-.017 to -4.18)

4. $CBP = 78.512 + 0.596\ BPS - 0.194\ PPC\ M2 + \ldots\ldots\ldots\ldots + M12$

(3.98) (2.83) (0.01 to -2.31)

5. $BPS = RPB - GFV + BPA$

6. $EDR = RDB - RSB$

7. $ESL = GBP + BIM$

8. $EDR = ESL$

Values in parentheses below coefficients are t values.

Endogeneous Variables:

RSB = Quantity of beef supplies from retail stocks.

RDB = Quantity of beef purchased at retail.

ESL = Quantity of current supply.

CBP = Quantity of marketing services (commercial beef production)

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

RPB = Retail price of beef (composite choice price)

GFV = Gross farm or live value (choice steer)

EDR = Excess demand from retail market.

Exogeneous Variables:

BIM = Beef imports.

BPA = By-product allowance per retail pound equivalent.

BCS = Beef cold storage stocks at beginning of month.

SOM = Pork, chicken and turkey stocks at beginning of month.

EXF = Futures Prices for 4-6 months deferred delivery minus current live cattle prices.

IDC = Index of producer prices for intermediate goods (US Dept. of Commerce)

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

TPI = Total personal income for month, US.

ICS = Index of consumer sentiment (US Dept of Commerce)

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

CIE = Cattle inventory estimate -- 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 confirmed the hypothesized structural system of markets. Signs were consistent with expectations, with few exceptions which are discussed later. All individual model equations were highly statistically significant. All coefficients for independent variables had t values significant at the 0.05 level or lower with three exceptions noted in later discussion.

Beginning beef stocks, beginning stocks of other meats which compete for cold storage with beef, and commercial input prices were all positively related to retail supplies of beef from stocks (see equation 1). Larger stocks at the beginning of the month and less availability of cold storage result in higher cost of holding stocks, and greater draw down in stocks from existing supplies. 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 reflected in futures prices, EXF, were negatively related to retail supplies. Expectations of higher future purchase costs caused marketing firms to add more current production to stocks and to reduce supplies from current stocks. The expected sign of retail beef price was positive but the observed sign was negative. This indicates that retail price picked up some undefined demand effects rather than supply effects hypothesized for the retail supply equation. However, the level of significance of the price coefficient 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 was a significant seasonal tendency to build beef stocks during October, November, and December and to supply the retail market from stocks during other periods, particularly March and September (See appendix A for monthly dummy coefficients.)

The retail demand equation included: supplies of other meats (which affect relative prices), consumer incomes and beef prices. (See equation 2.) Coefficients of these variables were highly significant with expected signs. The negative coefficient for the index of consumer sentiment variable caused some concern. A higher index value represents expectations among consumers that economic conditions are likely to improve in the future. The negative relationship could reflect a switch from perishable to durable goods purchases during periods of growing consumer confidence. The only significant seasonal patterns in retail beef demand were stronger demand periods in January, September, and October (See appendix A.)

The live supply equation includes only those variables that would be expected to influence the live market (see equation 3). Coefficients were highly significant and signs were as expected except for the expected price variable, EXF. Expectations of higher future price were thought to result in smaller current slaughter levels relative to inventories. There was a highly significant positive relationship between current prices, GFV, and quantities supplied indicating the expected supply-price relationship. Cattle on feed and cattle inventory variables both had highly significant, positive coefficients, as expected. These two variables might seem to represent the same basic factor, live cattle numbers. But on a monthly basis cattle on feed numbers vary more than inventories. The correlation between total inventories and on-feed numbers was only 0.25. The only significant seasonal factors were smaller supplies relative to prices and inventories for September and October (See appendix A.)

The final equation estimated 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, i.e. slaughter more cattle, CBP, - at higher prices for services, ie. higher beef price spreads, BPS. Estimated costs of slaughter, processing and retailing, PPC, had a significant negative relationship with supply of marketing services, CBP. This indicates that as costs of marketing rise, marketing firms will be willing to market less beef at any given price spread or price of service. Seasonal patterns were similar to those for live supply with smaller supplies of services in the August-September-October period. (See appendix A.) The data indicate that packers and retailers have flexibility in plant capacity to absorb variability in slaughter and processing.

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. Equation 8 represents equilbrium quantity relationships between retail beef and live cattle markets.

Statistical results in general confirm hypothesized relationships among the retail beef market, the live cattle market and the market for slaughter, processing and retailing services. Some of the unexplained error in model estimates likely is due to measurement errors and the use of proxy variables such as change in cold storage stocks for retail beef supplies. Future research may be able to build on and refine the basic concepts verified by the results presented here. The results presented are sufficient to provide research based direction in constructing future applied beef cattle price forecast models.

Further Analysis of Beef Price Spreads

A single equation model for price spreads was estimated using the variables identified with the simultaneous equation model. Single equation results were as follows:

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

The estimated coefficient for commercial beef production was smaller and less significant in the single equation model than in the simultaneous equation system. This implies that single equation models of price spreads may underestimate the effect of slaughter levels or other marketing service demand measures on beef price spreads.

Individual forecasted values and residual errors were calculated for the single equation model of price spreads. 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 time span from 1979 to 1981. Forecast errors as large as 13.00 extend back to 1973. These errors amount to $5 to $7 per hundredweight of live cattle. And, they are observed within the same data period used to estimate the parameters of the forecast model.

Most analysts would agree that the structural model of beef price spreads represented by the single equation is inadequate as a practical forecasting model. And, 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 anlyzed for serial correlation, resulting in a first order autocorrelation of 0.73 and a Durgin-Watson D statistic of 0.54. These results confirm a high degree of serial correlation of error which casts 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 (Autoregressive Integrated Moving Averages) might be used to augment structural models in analysis of variation in beef price spreads. Definable autoregressive characteristics of residuals could lead to development of forecast models that would 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 showed the series to be unstable, indicating that autocorrelation coefficients did not decrease as lags were increased. Thus, the data 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. To the extent that forecast errors were proportional to spread values, deflating the residual errors would stabilize the series. The residual series was deflated by the consumer price index and a stable, analyzable series resulted.

Autocorrelations among thirty lag periods indicated an irregular pattern of correlation decay. There was a fairly abrupt decay through the fourth period lag. But, autocorrelation was higher again in the fifth and sixth periods. Autocorrelation dropped again through the ninth period but moved higher in the tenth and eleventh before finally dropping sharply to zero after the twelfth period. Partial autocorrelations declined or "died down" to zero after the first period but recovered and produced a sine-wave like pattern with alternate positive and negative values at three to five month lag intervals through the thirty month period.

Autocorrelations and partial autocorrelations were anlayzed using guidelines of Bowermann and O'Connell. Existence of one period autoregression was obvious but existence of cycles or sine-wave patterns indicated that second order or higher autoregression was present also. Given a two period autoregression assumption, based on partial autoregression patterns, the total autoregression 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:

$$E_t = -0.142 + 1.451\ E_{t-1} - 0.914\ E_{t-2} + 0.744\ e_{t-1} - 0.361\ e_{t-2}$$
(23.72) (15.73) (8.04) (3.80)

$$-0.342\ e_{t-3}\ -0.037\ e_{t-4}\ -0.400\ e_{t-5}\ -0.025\ e_{t-6}$$
(3/70) (0.39) (4.27) (0.25)

$$-0.156\ e_{t-7}\ -0.018\ e_{t-8}\ +0.001\ e_{t-9}\ -0.275\ e_{t-10}$$
(1.62) (0.19) (0.07) (3.00)

$+0.003\ e_{t-11}\ -0.045\ e_{t-12}$ Chi Squares =5.64 at 18 lag
(0.03) (0.59) Probability level=0.13

Where: E_t = Residual error from beef price spread model for time period t.

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

Values in parenthesese are t ratio values.

A probability level of 0.05 or less generally is considered adequate to insure validity of ARIMA models. Other characteristics of the model seemed to offset the higher than desirable Chi Square statistic. The model did generate cyclical forecast patterns, as seen in recent years. For example, 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. The pattern indicated a downward trend for January, February, and March. The lowest projected point of the year came in April and May. An uptrend was projected for June through September with a leveling out in October and a decline in November and December. Examination of Figure 1 indicates a very similar pattern in 1982 spreads. 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 basic shortcomings of the time series model seems to be with magnitudes of cyclical patterns and in forecasting data turning points. Examination of single period model forecasts for the last ten years of data indicated that the model forecasts in general lagged major changes in actual spreads. This could reflect the fact that the amplitude of cycles generated by the model were less than the amplitude of cyclical forecast residual patterns in recent years. Thus the model, in a sense, was continually trying to catch up with more dynamic changes in the observed data. This result may indicate that the total data period should be divided into the more stable period of the sixties and a more volatile period of the seventies rather than trying to fit a single model to the total period.

The ARIMA analysis identified a 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.

<u>Summary and Conclusions</u>

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, in such 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 identities representing market equilibrium conditions.

Results of the analysis supported the basic price spread determination hypothesis. All factors that affect supply of or demand for live cattle may have an indirect effect 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.

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. A single equation price dependent form of the quantity dependent structural model indicated that about 95% of the variation in beef price spreads can be explained by changes in supply of or demand for marketing services, as reflected in commercial beef production, and an index of costs of slaughter, processing and retailing. The single equation form of the spread determination model indicated that the impact of 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 the 0.95 R^2 values. Observed errors were equal to $5 to $7 per cwt. in live cattle equivalent. 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 was a two period autoregression and twelve period moving average pattern in the residual data. Test statistics suggested a marginally acceptable fit for this model. However, the autoregression 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 that of observed cycle lengths. The basic problems of the model seemed to relate to inability of a model based on the total data period to capture a more volatile pattern of spreads and residuals for the later data periods. But, the time series model did provide valuable insights into the dynamic nature of price spreads over time.

Implications

The basic purpose for the study reported here was to provide a research based, conceptual framework for development of applied forecasting 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 inclusions 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.
- Results of this study leave some unanswered questions regarding determination, explanation and forecasting of beef price spreads. But, results presented here provide a conceptual basis for development of models designed to forecast rather than identify the structure and nature of beef price spread determination.

Further refinement is possible. However, 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.

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Appendix A. Coefficients of Monthly Dummy Variables (t values in parentheses)

Equation	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No.1 - Retail Supply	0.47	0.09	0.40	0.36	0.46	0.52	0.45	0.14	−0.54	−0.98	−1.07
	(1.86)	(0.35)	(1.59)	(1.41)	(1.80)	(1.99)	(1.76)	(0.52)	(−2.05)	(−3.54)	(−4.13)
No.2 - Retail Demand	−5.56	−7.93	−8.56	−6.00	−3.09	−5.83	−4.82	−0.21	−0.83	−3.50	−3.72
	(−5.53)	(−7.43)	(−8.29)	(−5.77)	(−2.99)	(−5.67)	(−4.52)	(−0.21)	(−0.83)	(−3.41)	(−3.46)
No.3 - Excess Live	−4.88	−5.77	−8.69	−7.08	−5.38	−9.00	−5.12	−0.51	−0.36	−2.89	−5.02
Supply	(−2.41)	(−2.84)	(−4.22)	(−3.37)	(−2.53)	(−4.18)	(−2.39)	(−0.24)	(−0.17)	(−1.41)	(−2.46)
No.4 - Market	−3.79	−4.74	−5.57	−2.89	−1.69	−4.94	−3.09	−0.51	0.01	−2.25	−4.41
Supply	(−1.58)	(−1.99)	(−2.31)	(−1.19)	(−0.07)	(−2.07)	(−1.80)	(−0.21)	(0.01)	(−0.93)	(−1.83)

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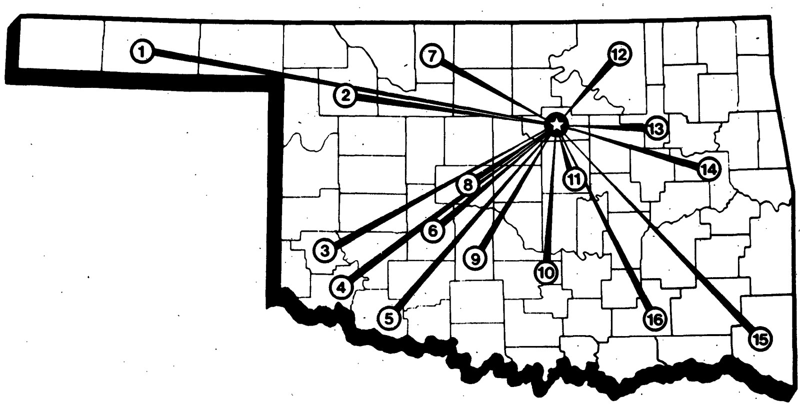

Main Station—*Stillwater, Perkins and Lake Carl Blackwell*

1. **Panhandle Research Station — *Goodwell***
2. **Southern Great Plains Field Station — *Woodward***
3. **Sandyland Research Station — *Mangum***
4. **Irrigation Research Station — *Altus***
5. **Southwest Agronomy Research Station — *Tipton***
6. **Caddo Research Station — *Ft. Cobb***
7. **North Central Research Station — *Lahoma***
8. **Southwestern Livestock and Forage Research Station — *El Reno***
9. **South Central Research Station — *Chickasha***
10. **Agronomy Research Station — *Stratford***
11. **Pecan Research Station — *Sparks***
12. **Veterinary Research Station — *Pawhuska***
13. **Vegetable Research Station — *Bixby***
14. **Eastern Research Station — *Haskell***
15. **Kiamichi Field Station — *Idabel***
16. **Southeastern Oklahoma Agricultural Research and Extension Center — *Atoka***