A QUARTERLY FEEDER CATTLE PRICE FORECASTING MODEL
WITH APPLICATION TOWARDS THE DEVELOPMENT
OF A FUTURES MARKET STRATEGY

by

Paul K. Blakely

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APPROVED:

Dr. David E. Kenyon
Department of Agricultural Economics

Dr. M. C. Conner
Department of Agricultural Economics

Dr. Joseph Havlicek, Jr.
Department of Agricultural Economics

Dr. Robert B. Jensen
Department of Agricultural Economics

Mr. K. C. Williamson
Department of Animal Science

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

The sale of meat animals provides almost 30% of the income earned

by U.S. farmers.[1] However, while the number of hogs, sheep and lambs

on farms has decreased over the past 30 years, the number of cattle and

calves has increased dramatically (Table 1). The increased importance

of the beef producing sector has been in response to a significant up-

ward trent in the demand for beef product (Table 2). The pronounced

rise in production and consumption of beef during the last three dec-

ades has had a profound effect on the agricultural community. In

short, beef production is now the major agricultural enterprise in the

United States based on cash receipts from marketings of livestock and

crops.[2]

Because of its importance, the beef sector presented itself as

the most promising area in which significant marketing research contri-

butions could be made. These contributions took the form of facilita-

ting production decisions under uncertainty,[3] using futures markets for

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[1] Agricultural Outlook, USDA, ERS, AO-10, May, 1976.

[2] "Livestock and Meat Statistics", Agricultural Marketing Service, Statistical Reporting Service, ERS, USDA, Washington, D.C., Stat. Bull. No. 333 and Supplements, Washington, D.C.

[3] References include Bullock, J. B. and S. H. Logan, "An Applica- tion of Statistical Decision Theory to Cattle Feedlot Marketing", Ameri- can Journal of Agricultural Economics, Volume 52, No. 2, May, 1970;

TABLE 1-A

NUMBER OF CATTLE AND CALVES, SHEEP AND LAMBS, AND HOGS ON

FARMS, JANUARY 1, FOR U.S., 1943, 1953, 1963, 1973[a]

	1943	1953	1963	1973
	--------------- (1000 head) ----------------
Cattle and calves	81,204	94,241	104,488	121,534
Sheep and lambs	55,150	31,900	29,176	17,726
Hogs	73,881	51,755	58,695	61,106

[a]"Livestock and Meat Statistics", Agricultural Marketing
Service, Statistical Reporting Service, ERS, USDA, Washington, D.C.,
Stat. Bul. No. 333 and Supplements, Washington, D.C.

TABLE 1-B

PER CAPITA CONSUMPTION OF BEEF AND VEAL,

LAMB AND MUTTON, AND PORK IN POUNDS[a]

	1943	1953	1963	1973
Beef and veal	61.5	87.1	99.4	111.4
Lamb and mutton	6.4	4.7	4.9	2.7
Pork	78.9	63.5	65.4	61.6

[a]Agricultural Statistics.

hedging purposes in the live cattle and feeder cattle markets,[4] ana-

lyzing the optimal regional distribution patterns for producing and

slaughtering cattle,[5] as well as structuring models of the beef or

livestock sector.[6] Yet despite all the research that has been

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also Cattle Feedlot Marketing Decisions Under Uncertainty, Giannini
Foundation Monograph No. 28, April, 1972. See also Y. C. Chiang,
R. B. Jensen, D. E. Kenyon, and R. G. Kline, "Bayesian Decision Strat-
egies Applied to Production and Marketing Decisions for Cow-Calf Firms
in the Shenandoah Area of Virginia", Southern Journal of Agricultural
Economics, December, 1974; Elder, William A., "Risk, Uncertainty, and
Futures Trading; Implications for Hedging Decisions of Beef Cattle
Feeders", staff paper P69-20, University of Minnesota, Department of
Agriculture and Applied Economics, August, 1969.

[4]References include Edwards, Roy V., "Some Observations Concern-
ing Livestock Futures Markets", Futures Trading in Livestock, Origins
and Concepts, Henry H. Bakken, ed., Mimis Publishers Inc., Madison,
Wisconsin, 1970; Gene A. Futrell, "Do Live Cattle Futures Differ From
Other Existing Futures Contracts", Futures Trading in Livestock, Ori-
gins and Concepts, Henry H. Bakken, ed., Mimis Publishers Inc., 1970;
Elder, op. cit.; Richard G. Heifner, "Optimal Hedging Levels and Hedg-
ing Effectiveness in Cattle Feeding", USDA, ERS, Agricultural Economics
Research, Volume 24, No. 2, April, 1972; Raymond M. Leuthhold, "The
Price Performance and the Futures Market of a Nonstorable Commodity:
Live Beef Cattle", American Journal of Agricultural Economics, Volume
56, No. 2, May, 1974.

[5]Aylor, F. I. and M. E. Juillerat, "Least-Cost Movement Analysis
of Slaughter Cattle and Calves With Emphasis on the Southeast", Bull.
No. 133, Southern Coop Series, January, 1968; J. D. Goodwin, "Optimum
Distribution Patterns of Feeder Cattle From the Southeast", Bull. No.
101, Southern Coop Series, October, 1965; Charles Y. Liu and Donald
West, "A Spatial Analysis of Beef Feeding and Slaughtering With Empha-
sis on the South", Bull. No. 177, Southern Coop Series, 1972; John E.
Trierweiler and Donald B. Erickson, "Structural Relationships for Na-
tional and Regional Beef Cattle Production", Economics Department,
Agricultural Experiment Station, South Dakota State University, Brook-
ings, South Dakota, Tech. Bull. 25, June, 1965.

[6]Myers, Lester H. and Joseph Havlicek, Jr., "Monthly Price Struc-
ture of the U.S. Beef, Pork and Broiler Markets", Chapter V, Quantita-
tive Models of Commodity Markets, edited by Walter C. Labys, Ballinger
Publishing Co., Cambridge, Mass., 1975, pp. 139-172. Clifford Hildreth
and F. G. Jarrett, A Statistical Study of Livestock Production and

conducted there exists a need for more information at the farm level. More specifically, the cow-calf operator wants the kind of data that will facilitate his production decisions.

According to Trierweiler and Erickson, cow-calf operators are slow to respond to market indicators such as changes in the price of feeder cattle.[7] They suggest that this is the result of two inherent characteristics of the cow-calf industry. These are the length of time necessary for the expansion of the industry's capacity and the length of time from the beginning of gestation to the marketing of the beef calves as feeders. During the planning period, producers must speculate on the price of feeders two years in advance.[8] One piece of data which would facilitate the cow-calf operator's production decisions would be a forecast of feeder cattle prices. Such a forecast would assist cow-calf operators and backgrounders in timing calf purchases and feeder sales.

Problem Statement

Cattle and calf sales constitute the largest single source of income to farmers in Virginia, accounting for approximately 18% of

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Marketing, Cowles Commission for Research in Economics, John Wiley and Sons Inc., New York, 1955; Marvin L. Hayenga and Duane Hacklander, "Monthly Supply-Demand Relationships for Fed Cattle and Hogs", American Journal of Agricultural Economics, Volume 52, No. 4, November, 1970.

[7] In this paper, calves are considered to be in the 300-500 lb. weight group, feeder cattle are in the 500-800 lb. weight group, and fed (fat) cattle are in the 800 lb. and over weight group. From birth, it generally takes an animal from one to one and a half years to achieve feeder cattle weight.

[8] Trierweiler and Erickson, p. 25.

the value of all farm commodities produced.[9] There are over 5,000 farm

operators engaged in the enterprise of backgrounding. Backgrounders

buy calves, usually in the fall, and feed them for up to one year.

They then sell the heavier feeder cattle to feedlots in the East and

Midwest.

There are also over 30,000 cow-calf operators in Virginia who

handle the preparation of calves to feeder cattle weight. Oftentimes

the cow-calf operations in the state will elect to feed their calves

to feeder cattle weight if the price of calves offered by background-

ers is considered too low.

Whether the enterprise of producing feeder cattle is undertaken

by backgrounders or cow-calf operators, at a certain point in time

their basic problem is the same -- price uncertainty. The cow-calf

operator has a longer planning and production period since it is he

who breeds the cows and has capital already invested during the gesta-

tion period. However, at the time those calves are weaned, approxi-

mately six to nine months after birth, he would like to know what price

he can reasonably ask for his weaned calves from the backgrounders. If

that price is not met he would like to know what price he can expect

if he were to hold the calves to feeder weight and instead sell to a

feedlot. At this same point in time, the backgrounder would like to

know what price he may offer for the weaned calves in order to make a

reasonable profit for bringing the calves to feeder weight. Both

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[9]Virginia Crops and Livestock, Volume 46, No. 9, September, 1974.

groups, in other words, want a reasonable estimate of what price they would be able to attain for feeder calves approximately two to four quarters later.

Traditionally, cattle producers have had little indication of what price their investment of capital and time will return. From the time the production decision is made (the decision of purchasing calves by backgrounders, or the decision to retain rather than sell the calves by cow-calf operators) until the time to sell the feeder cattle to feedlots, the price of their investment can change dramatically. Recent history provides an excellent example of an adverse price movement.

Using Winchester, Virginia prices, on October 1, 1973, a backgrounder who bought a choice or fancy calf in the 300-500 pound weight class would have paid an average of $42.50 per cwt. If he had sold that calf one year later as a 500-750 pound feeder, he would have received a market price of $28.50 per cwt. on the average.[10] Using an annual weight gain of 300 pounds, the backgrounder would have made an outlay of $191.25 (450 x $42.50) and would have received $213.75 (750 x $28.50) for selling the calf at feeder weight. This represents a substantial loss, since there is no doubt that the operator would not even have been able to cover feed costs. An indication of the price variability in feeder cattle is presented in the graph below.

One might ask whether the futures market for feeder cattle could be used as an accurate predictor of feeder cattle prices twelve months

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[10]Virginia Crop Reporting Service.

$/Cwt.
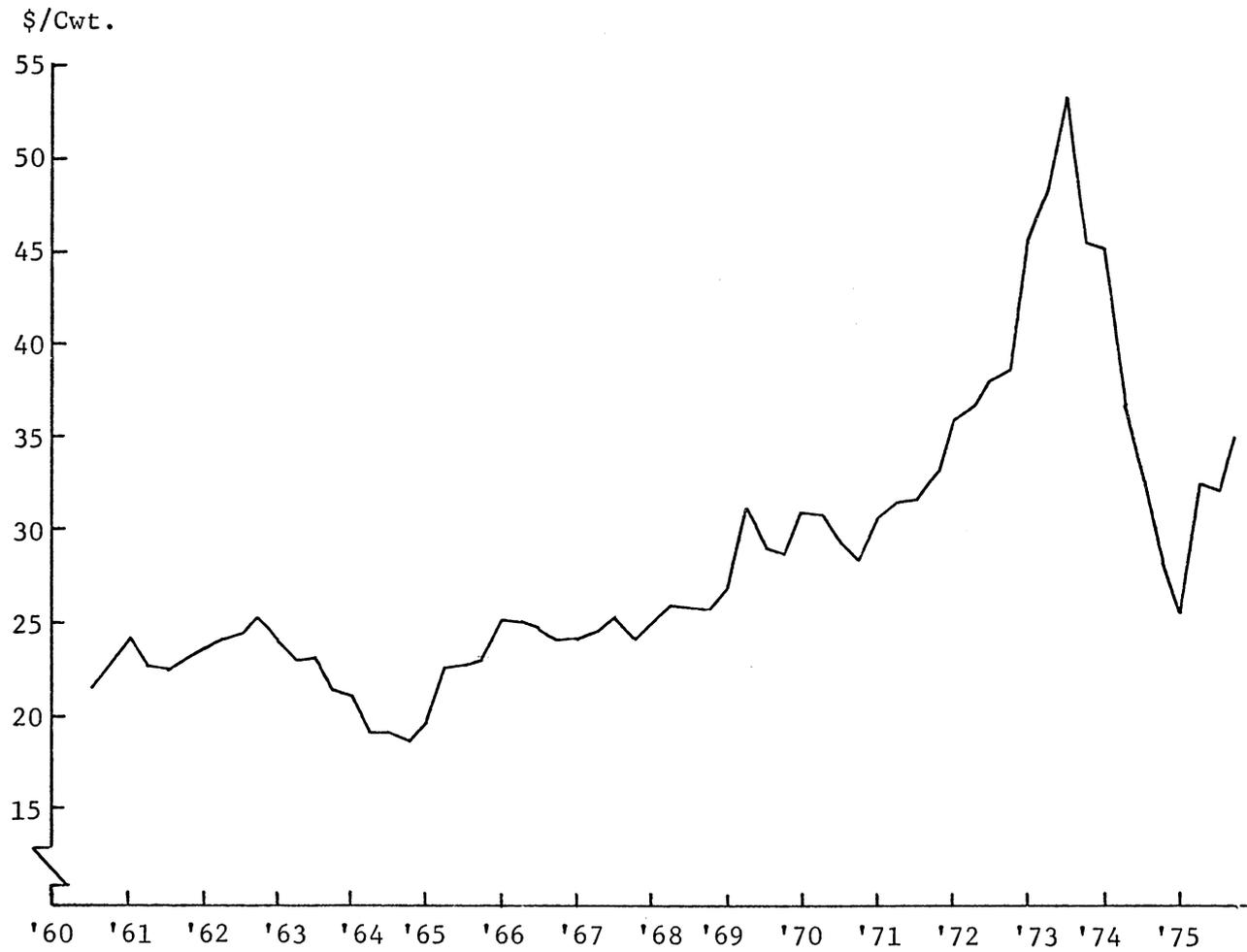
Figure 1-A.   Average Price per cwt. Received in 10 National Markets for Feeder
Steers, All Weights Combined, 1960-1975.

hence. In fact, this particular possibility has not been examined

although a very closely related study indicates that the futures mar-

ket is not a very accurate predictor of distant prices when a nonstor-

able commodity is involved. Leuthhold found that beef cattle futures

prices at time t_1 offered a poor indicator of distant cash prices rela-

tive to cash prices at time t_1.

> "Further evaluation of live beef cattle price relationships
> revealed that for distant futures, the cash price is a more
> accurate indicator of future cash price conditions than is
> the futures price ... The producer who looks at the futures
> price routinely to establish a feeding margin so that he
> can decide whether or not to purchase and feed cattle may
> receive false signals and be misled into a costly decision,
> either a money loss or foregone profits."[11]

Evidently there is a need for a forecast which would predict bet-

ter than either the cash or futures price. The example presented above

demonstrated that relying on the cash quotations could produce poor

estimates of future prices due to the volatile nature of prices in the

feeder calf business. The agricultural community in Virginia could

benefit from a price forecasting model for feeders which is more accu-

rate than using either the futures market quotations or current cash

prices as a predictor of future feeder prices.

Objectives and General Approach

The specific objectives of this study are:

(1) To develop a price forecasting equation(s) for feeder cattle.

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[11]Leuthhold, Raymond M., "The Price Performance on the Futures
Market of a Nonstorable Commodity: Live Beef Cattle", _American Jour-
nal of Agricultural Economics_, Volume 56, No. 2, May, 1974.

(2) To examine the possibility of reducing the mean square
error of income and raising the level of revenue to the
feeder producer relative to that which would be achieved
under the common practice of consistently selling feeder
cattle in the cash market. A selected strategy incor-
porating forecasted prices and the use of the futures
market would be developed to this end.

A structural model of the feeder cattle market was derived from
a block recursive theoretical framework. The theoretical derivation
served to indicate the more important variables which then would form
the basis for statistical analysis. Rather than concentrating on a
statistical derivation of the structure of the feeder cattle industry,
most of the effort was devoted to refining the predictive equation
through the use of statistical techniques developed expressly for fore-
casting purposes.

The forecast assumed that the backgrounder or cow-calf operator
would be marketing a beef animal weighing approximately 750 pounds
after having purchased (or having withheld from sale) a calf weighing
approximately 450 pounds.

Feeder producers should benefit from knowledge of a strategy
which could reduce the variability of their year-to-year income on
sales of feeders, especially if the reduction in variability accompa-
nied a rise in mean income. To this end, the futures market was em-
ployed in conjunction with the forecast of feeder prices in order to
form a strategy to stabilize producers' income and perhaps raise the
mean income from feeder sales. Even if mean income were not higher

under the strategy, the producer should be aware of the tradeoff involved between a higher income and a stable income, assuming the latter could be obtained.

The general approach employed in addressing these objectives is as follows: Chapter II is a presentation of the review of literature which includes a discussion of some background on the beef industry, hedging in the futures market and evaluation of forecasting methods. Chapter III is a presentation of the theoretical development of the structural model. Chapter IV presents the results of the empirical estimation of the structural equations for the feeder cattle market and a computation of the analytically reduced form for the price of feeders. It was the intent initially to use the reduced form as an input in the transfer function forecasting method developed later. Ultimately the reduced form series was abandoned as a candidate for the input series in favor of the first stage of a two stage least squares estimation of the feeder cattle market.

The development of the forecasting theory is given in Chapter IV, wherein the Box-Jenkins forecasting methods are outlined. An explanation of how the input series is employed in the more sophisticated transfer function forecasting model is presented. In Chapter V, the empirical results of the forecasting models are displayed.

The development of three strategies which have as their goal the reduction of income variance to feeder cattle producers, is presented in Chapter VI. One of the strategies incorporates the transfer function forecasts presented in Chapter V. Chapter VII offers the summary and conclusions of the study.

CHAPTER II

REVIEW OF LITERATURE

Most of the studies pertaining to the beef cattle sector report-
ed in journals and technical bulletins have been directed toward the

enhancement of cattle producers' economic position. In a review of

such literature, it might facilitate discussion to impose a categori-

zation on the material. Accordingly, the studies have been separated

into three overlapping groups: interregional competition in the beef

industry, the facilitating of production decisions, and hedging in

the futures markets. Each will be discussed in turn.

Interregional Competition in Beef Industry

Regional Distribution Patterns

Beef cattle are produced in virtually every state in the union.

Because of geographic differences there has developed a natural gravi-

tation towards specialization. For example, "... the Southeastern

states increased farm production of beef cattle 81% from the 1947-49

average to the 1960-62 average ... The Corn Belt still ranks first in

the production of fed cattle".[1] More recent data indicates that for

1975, almost two-thirds of projected U.S. fed cattle would be finished

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[1]Goodwin, T. D., "Optimum Distribution Patterns of Feeder Cattle
From the Southeast", Bull. No. 101, Southern Cooperative Series,
October, 1965.

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in the Texas-Oklahoma Panhandle, Kansas and Nebraska, with Iowa and Illinois accounting for another one-sixth of the total.[2] These projections are borne out by figures from the 1975 supplement of Live-stock and Meat Statistics.

In the last few decades there have been extensive changes in the distribution patterns of these functions partly as a result of the increasing degree of specialization and partly due to institutional constraints such as the existing transportation network. Goodwin examined the optimum distribution patterns of feeder cattle from production areas to consumption areas in 1962. He used reactive programming analysis, using as inputs quarterly demand functions for feeder cattle, fixed supplies at 1962 production levels plus imports, and existing truck transportation rates. In general, Goodwin's study suggested that more feeder cattle be shipped to the North Central Region at the expense of the Western region under the optimum distribution. He estimated that returns for the industry could have been increased by 6.4% over the actual pattern of distribution for 1962.

Aylor and Juillerat, using 1962 data, sought to obtain the least cost movements of cattle to slaughter, calves to slaughter, and beef and veal from slaughter to consumption areas.[3] The analytical tool employed was a linear programming transportation model. The solution

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[2]Dietrich, Raymond A., Interregional Competition in the Cattle Feeding Economy, Texas A & M University, B-1115, September, 1971.

[3]Aylor, F. I. and M. E. Juillerat, "Least-Cost Movement Analysis of Slaughter Cattle and Calves With Emphasis on the Southeast", Bull. No. 133, Southern Cooperative Series, January, 1968.

suggested that the level of slaughtering cattle be increased by 2/3 in the Southeast Region. The reasons for urging this dramatic shift were primarily due to the lower estimated slaughter costs in the Southeast and the fact that the Southeast was a low beef production region relative to their consumption. Another interesting conclusion for purposes of the present analysis was that the Southeast produced 27% more live calves than it had capacity to handle. Consumption of veal in the region was low, leaving open the speculation that the Southeast region and Virginia in particular already had the facility for producing feeder calves in substantial numbers.

The two above studies indicate that the Southeast Region's major role in cattle production is to raise calves to feeder weight, and then to ship them to the feedlots in the East and Midwest. The potential for developing the Southeast into a feedlot region as well was researched by Liu and West.[4] They developed a multidimensional transhipment model to obtain the location of beef feeding and slaughtering which would minimize aggregate industry costs, given the areas of feeder cattle production, beef consumption, area differences in slaughter and feed costs and transportation charges. They concluded that Virginia and three other Southern states were in a good position in 1965 to expand their feedlot operations. However, they also noted that feeder cattle production would continue to be the most important function for the cattle-beef enterprises in the South.

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[4]Liu, Charles Y. and Donald A. West, "A Spatial Analysis of Beef Feeding and Slaughtering With Emphasis on the South", Bull. No. 177, Southern Cooperative Series, 1972.

A more recent work indicates that there has in fact been even a greater degree of specialization in cattle marketing. Van Arsdall and Skold[5] present a primarily descriptive report on the changing cattle industry from 1960 to 1970. They also present extensions of trends forward to 1980. One important finding which is germane to the present study was that the placement of cattle on feed is now more evenly distributed throughout the year. In 1960 the percentage of cattle placed on feed by quarters was 21-16-21-42 with the bulk of feeders being placed during the fourth quarter. In 1970 the percentage distribution by quarters was 21-22-25-32. The change indicates that the demand for feeders is becoming more evenly distributed throughout the year. This is most likely due to the increased specialization in the industry and the resultant expanded feedlot capacity.

Structural Supply and Demand Models

Identifying the sources of variation in the price and quantity of a commodity is often an important goal in itself. Such structural models perform this function and serve to give advance notice of the effects on price and quantity of taxes, foreign grain deals and other public policy decisions. In addition, the structural models provide the individual farmer with a basis from which more efficient allocation decisions can be made.

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[5]Van Arsdall, Roy N. and Melvin D. Skold, "Cattle Raising in the United States", ERS, USDA, Economic Report No. 235, Washington, D.C., January, 1973.

Hildreth and Jarrett[6] worked with livestock aggregates in attempting to estimate a number of relations at the farm level. The livestock aggregate quantity included hogs, cattle, calves, milk, sheep, chickens, eggs, and turkeys. A simultaneous system was estimated using both least squares and limited information maximum likelihood. The system included a production relation, demand functions for feed grain, protein feed, and livestock products. Supply functions included those for the corresponding demands. There were a number of arguments mentioned in the Hildreth and Jarrett study that could be used to forecast feeder prices. The authors included time as a variable to account for important unobserved factors which had increased fairly smoothly over time. As had been mentioned previously, the cattle industry has expanded dramatically between 1950 and 1970. Whether this expansion has been fairly smooth in order to make use of an explicit time variable will be investigated. They also noted that current price may also serve as an indicator of expectation of future price movements, in accordance with a cobweb theorem. "It has often been asserted that, in the absence of offsetting factors, an increase in price (particularly of cattle) leads to favorable anticipations, to an attempt to build up inventories and lower current sales and to a strengthening of the tendency for current price to rise".[7] This serves to indicate that a forecast of feeder prices may have to include lag operators.

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[6]Hildreth, Clifford, and F. G. Jarrett, A Statistical Study of Livestock Production and Marketing, Cowles Commission for Research in Economics, John Wiley and Sons Inc., New York, 1955.

[7]Hildreth and Jarrett, p. 106.

Havlicek and Myers[8] developed a simultaneous system to describe
the livestock-meat sector of the United States. The monthly model
determined the interrelationships between pork, broilers, and beef at
the retail level as well as specified the relationship between retail
and farm levels in the hog and cattle sectors. Myers and Havlicek in-
cluded an expectational element in the supply response functions of
hogs and cattle. This was especially important when predictions were
made. Despite the expectational formulations the authors found that
"the cattle-beef component of the model exhibited the greatest devia-
tions between predicted and observed values".[9] The model, however,
was tested for the months in 1971-72 when cattlemen were holding back
their cattle from market despite record prices, anticipating a lift of
the price freeze. Their research leaves unanswered to what extent
supply responds to current rather than expected prices in the beef-
cattle sector.

Myers and Havlicek reported that marketing margins for beef and
pork have been studies by a number of researchers but no general con-
clusions have been reached as to how they respond to changes in other
variables. By and large those studies which have specified marketing
margins include most of the same types of variables as would have been
explicitly formulated for each market in the system under consideration.

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[8]Myers, Lester H., and Joseph Havlicek, Jr., "Monthly Price
Structure of the U.S. Beef, Pork, and Broiler Markets", Chapter V,
Quantitative Models of Commodity Markets, edited by Walter C. Labys,
Ballinger Publishing Co., Cambridge, Massachusetts, 1975.

[9]Myers and Havlicek, p. 44.

Oftentimes marketing margins were employed because this specification
leads to shortcuts in estimation. Since the present study uses eco-
nomic theory rather than statistical estimation to derive the final
form to be estimated, it was considered that the marketing margin
specification would be unnecessary.

Hayenga and Hacklander[10] developed a monthly supply and demand
relationship for cattle and hogs using two-stage least squares. They
hypothesized that farmers react more to the direction of the monthly
price change rather than the current level of prices. The writers
considered the overall fit of the demand, supply and storage equations
to be quite good. The only major flaw in the article was that the
cross-flexibilities of demand for beef and pork had opposite signs.
In the live cattle demand equation the quantity of hogs coefficient
was negative, indicating substitutability. In the live hog demand
equation, however, the coefficient of quantity of cattle was positive,
indicating complementarity. The authors concede that there was per-
haps a spurious statistical result. Bullock, in a criticism of the
article, opined that their use of ratios as independent variables in
regression analysis can sometimes lead to biased results. Ratios are
inappropriate when the relationships between other variables and the
numerator of the ratio is the relationship of interest. The problem

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[10]Hayenga, Marvin L., and Duane Hacklander, "Monthly Supply-
Demand Relationships for Fed Cattle and Hogs", _American Journal of
Agricultural Economics_, Volume 52, No. 4, November, 1970.

does not arise when the hypothesis to be tested has initially been formulated in terms of ratios.[11]

The above studies dealt with problems on a macro level in that the intent was to allocate resources in a large context and isolate variables important to the industry as a whole. The emphasis in the following section seems to be directed more toward the individual operator.

Facilitating Production Decisions

Decision Theory Models

Bullock and Logan[11a] applied decision theory to cattle feedlot marketing. They developed decision rules for whether to sell or feed cattle another month. The method of analysis employed was Bayesian decision theory. An historical distribution of monthly price changes constituted the a priori probabilities. Price change predictions conditioned the a posteriori probabilities. Cost estimates were made for feeding cattle an additional month. Decision rules could then be formulated using the estimated direction of price change in combination with the cost estimates to determine whether feeding for an additional month would be profitable. For example, if a predicted price change

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[11]Bullock, J. Bruce, "Monthly Supply-Demand Relationships for Fed Cattle and Hogs: Comment", American Journal of Agricultural Economics, Volume 53, No. 3, August, 1971.

[11a]Bullock, J. Bruce, and Samuel H. Logan, "An Application of Statistical Decision Theory to Cattle Feedlot Marketing", American Journal of Agricultural Economics, Volume 52, No. 2, May, 1970; and J. B. Bullock and S. H. Logan, Cattle Feedlot Marketing Decisions Under Uncertainty, Giannini Foundation Monograph No. 28, April, 1972.

for cattle over the next month was +$1.00 per cwt. and the cost for
another month was $0.80, the decision would obviously be to feed the
cattle for an additional month. The price prediction data would allow
the a priori distribution of actual price changes to condition a more
accurate a posteriori distribution of predicted price changes which had
a closer correspondence with actual price changes. Unfortunately it
has been reported that the technique met with unsatisfactory results
when the model was tested with data subsequent to the data base used
to formulate the model. However, the testing was done in the period
of abnormal conditions when there was an exceptionally high degree of
market interference by the government in terms of selected price
freezes.

Y. C. Chiang, R. B. Jensen, D. E. Kenyon, and R. G. Kline used
Bayesian decision theory to develop "sell or keep" decisions regarding
the cattle on a representative large beef farm in the Shenandoah area
of Virginia.[12] Linear programming was used to derive the data needed
to develop the payoff matrix. The states of nature included pasture
conditions and price levels. Historical information on prices was
conditioned by forecasts of high, medium or low prices. One problem
encountered in this analysis was the arbitrary setting of high, medium
and low prices at a certain absolute level and applying that same
scale to differing weight groups of cattle. The authors footnote that

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[12] Chiang, Y. C., R. B. Jensen, D. E. Kenyon, and R. G. Kline, "Bayesian Decision Strategies Applied to Production and Marketing Decision Strategies Applied to Production and Marketing Decisions for Cow-Calf Farms in the Shenandoah Area of Virginia", American Journal of Agricultural Economics, December, 1974.

"It is recognized, however, that the prices for heavier weights of cattle tend to increase or decrease less than the prices for lighter weights of cattle; thus, this method only serves as an approximation of investigating the impact of differing levels of price projection on the production and marketing decision".[13] The study indicated that under certain conditions it would probably be more desirable to finish heavy slaughters rather than sell cattle at feeder weight depending upon the relative prices of feeders and slaughters and the level of corn production.

Price Prediction Models

Foote, Williams and Craven formulated an impressive study of a set of quarterly three-equation models which were fitted statistically via three stage least squares to represent the economic forces which determine prices for cash pork bellies at Chicago, movement into consumption for the 48 states, and end-of-period U.S. stocks.[14] The models were formulated to allow price predictions to be made for cash and futures quotations. The models performed satisfactorily for most periods from the second quarter of 1971 forward. However, at times the models yielded prices which varied greatly from the actual values. The authors concluded that a month was too short a time span to allow the economic forces in the pork belly economy to be adequately

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[13]Chiang, _et al._, p. 19.

[14]Foote, Richard J., Robert R. Williams, Jr., and John A. Craven, "Quarterly and Shorter Term Price Forecasting Models Relating to Cash and Futures Quotations for Pork Bellies", ERS, USDA, Tech. Bull. No. 1482, Washington, D.C., July, 1973.

described in an econometric model of the type which was developed. A Nerlove model in which individuals adjust expectations according to the proportion of the error made in the previous period was used in the estimation of supply responses.

Davis[15] constructed an econometric model in which the primary goals were to predict feeder cattle prices after discovering the underlying relationships within and among the feeder cattle, slaughter cattle, and retail sectors of the beef industry. The model as specified had at least three signs on coefficients which did not correspond to what economic theory would suggest a priori. Some of these "incorrect" signs perhaps could have been rationalized by a discussion of the expectation argument in supply response as presented a number of times in the preceding studies. In the actual forecasts, a substitution of lagged values for current values was performed in order that data could be made available for predictions. This seemed quite irregular since the coefficients for the current variables were retained and the lagged values were used after having minimized the squared errors with respect to the current values. Finally, the model correctly predicted only two out of five directions of change for price and three out of five directions of change for quantity. Apparently the Davis study is the only attempt made to predict feeder cattle prices. In light of Davis' results, the present study, which makes explicit use of

[15]Davis, Joe T., An Econometric Analysis of the Quarterly Demand and Supply Relationships for Feeder Cattle in the United States, unpublished Ph.D. dissertation, University of Tennessee, August, 1974.

forecasting methods, could conceivably add a second approximation to the knowledge of feeder cattle price prediction.

Walter Myers[16] developed a sinusoidal function for predicting hog prices. He argued for de-emphasis of exposing and explaining the statistics of a given technique in favor of stressing the production of useful information. To this end, he stated that several statistical properties of his model either were violated or fell outside the bounds of conventional acceptability. More specifically, the model indicated extreme positive serial correlation due to the omission of a few important variables. These were eliminated when it was found that the error involved in forecasting future values exceeded their additional contribution to reducing the standard error of the predictive equation. In the evaluation of his model, Myers sought to determine whether hog futures should be bought or sold. In a 24 month period, he made only two identification errors, although be cautioned that he used exact rather than estimated values of the independent variables.

Forecasting Evaluation

Burch and Stekler[17] have written a note which evaluates the forecasting accuracy of the index of consumer sentiment constructed by the Michigan Survey Research Center. To evaluate the accuracy of the index, mean square error and mean absolute errors were calculated. For

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[16] Myers, Walter M., "Combining Statistical Techniques With Economic Theory for Commodity Forecasting", American Journal of Agricultural Economics, Volume 54, No. 5, December, 1972.

[17] Burch, S. W., and H. O. Stekler, "The Forecasting Accuracy of Consumer Attitude Data", Journal of the American Statistical Association, December, 1969.

purposes of the present study, it was decided that the mean square

error would be used to evaluate the forecasting models since that

statistic includes the two components, bias and variance.

The authors used the Cochrane-Orcult iteration technique to

eliminate autocorrelated disturbances which arose in the initial esti-

mations. Using Box-Jenkins methods makes unnecessary the separate

treatment of autocorrelated residuals since the methods explicitly

consider the autocorrelation function in the formulation of parameter

estimation.

Stekler[18] in a separate article evaluates the forecasts of a num-

ber of econometric models using Theil's U-coefficient. He notes that

it is inappropriate merely to count the number of true turning points

forecast for two reasons. First, a model that is expected to predict

quantitatively should be judged on that basis, and attention should

not merely be confined to the few turns that occurred. Second, the

right or wrong searing system for accuracy is inappropriate because

the extent of the error matters. For these reasons, he argues for use

of the U-coefficient. Calculation of the U-coefficient for a forecast

model can be compared with the U-coefficient generated by a naive ran-

dom walk model as a benchmark. A random walk model yields a U-

coefficient of 1. The predictive performance of any forecasting model

which also predicts change will always be equal to or better than that

of the random walk model. The Box-Jenkins models developed later will

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[18]Stekler, H. O., "Forecasting With Econometric Models: An Eval-uation", Econometrica, Volume 36, No. 3-4, July-October, 1968.

be compared to a random walk model in terms of both mean square errors and U-coefficients.

Theil[19] goes into greater detail by decomposing the U-coefficient into errors due to contral tendency, unequal variation and incomplete covariation. Errors of central tendency occur when the average predicted change differs from the average realized change. Errors of unequal variation occur when the standard deviation of predicted and realized changes are unequal. Errors of incomplete covariation exist when the correlation coefficient between predicted and realized changes is less than one. The purpose of decomposition is to make linear corrections in the forecasts.

When the error due to incomplete covariation constitutes most of the total error, the opportunity for making corrections in the forecast are dim. When the forecast error stems mostly from errors in central tendency or unequal variation, corrections can be made when it is believed that the forecaster will continue to make the same kind of systematic error in the future. However, there is considerable controversy over whether trend adjustments should be made. Only in the case where the trend is believed to be permanent should these types of adjustments be made. For this reason, no trend terms were employed in the Box-Jenkins methods and hence there is little point in decomposing the U-coefficient. In fact, the existence of a systematic error over a small range of forecast values would be spurious

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[19]Theil, Henri, _Applied Economic Forecasting_, North Holland Publishing Company, Amsterdam, 1966.

since the Box-Jenkins methods should account for all persistent systematic error.

Futures Trading as a Hedging Device

Theory of Futures Trading as Related to Hedging

A hedge is defined as the taking of equal and opposite (quantity) positions in the cash and futures markets. Since cash and futures prices in some markets tend to approach a fairly stable basis[20] as the futures contract matures, the gains or losses in the cash market approximately offset the losses or gains, respectively, in the futures market position. By hedging, a producer can "lock-in" on a certain price at the beginning of a production period as long as the cash and futures prices converge to a stable basis as the contract approaches its expiration. Cash and futures prices should ultimately be equated during the last month of a contract. Arbitrage between the two markets insures this, for at that time the futures contracts can be fulfilled in the cash market.

For some commodities, the cash and futures markets bear a consistent functional relationship during the life of a contract. These are the markets for storable commodities. The theory behind this functional relationship has been well developed.[21] The nonstorable

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[20]A basis is defined as the difference between cash and futures prices at any point in time.

[21]See for instance, Paul A. Samuelson, "Intertemporal Price Equilibrium: A Prologue to the Theory of Speculation", The Collected Scientific Papers of Paul A. Samuelson, Volume II, and Thomas A. Hieronymus, Economics of Futures Trading for Commercial and Personal Profit, Commodity Research Bureau, Inc., New York, 1971.

commodities have had only a relatively recent existence on the futures

markets and there has been generated a substantial amount of research

in the attempt to clarify the hedging potential of nonstorable

commodities.[22]

Futrell presented a paper in 1966 which noted some major differ-

ences between the typical storable commodity futures contract and the

newborn live beef futures contract.[23] At that time the live cattle

contract had been in existence a little less than two years. Some of

the limitations on the degree to which livestock futures markets can

perform hedging and pricing functions were offered. One problem he

noted was the wide range of quality and weight encompassed in the

choice grade. The producer may not be able to accurately estimate the

correlation between his cattle and that of the terms in the futures

contract. This would create a problem in estimating the price that is

"locked-in". He also conjectured that it would be difficult to close-

ly estimate supply patterns in the future since the producers have

great flexibility as to what weight they may opt to bring the stock

to slaughter. This would make future supply and demand a difficult

assessment. Futrell also pointed out that there may be a lack of

hedging incentive if the cash market consistently exceeds the futures

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[22]The storable commodities include the grain crops, soybeans, and
their by-products. The nonstorable commodities are those for which pro-
duction is continuous throughout the year.

[23]Futrell, Gene A., "Do Live Cattle Futures Differ From Other
Existing Futures Contracts?" Paper presented at Live Cattle Futures
Study Conference-Chicago on September 8, 1966 as appeared in Futures
Trading in Livestock Origins and Concepts, Mimis Publishers Inc.,
Madison, Wisconsin, 1970.

price during the term of the contract. In fact, this has occurred

quite frequently in cattle futures and the short hedgers[24] have

generally suffered.

A paper presented by Allen Paul[25] purported to argue that the cash

and futures markets for livestock should be functionally related in

much the same way that the storable commodities are related via the

cost of storage. He contended that a live beef futures contract was a

substitute for "contract farming" in which a feedlot operator agrees

to fatten a feeder on his lot for a certain price. The difference be-

tween the futures price of a choice 1100 pound steer and the spot cash

price would be the cost of the feeder plus feed cost to bring the

animal to 1100 pounds by the time the contract matures. The logic has

some appeal but unfortunately, history has shown that oftentimes the

cash price is greater than the futures price.

Elder[26] sought to develop a theoretical hedging decision model

for cattle feeders. He derived an optimal hedge by minimizing the

variance of income with respect to hedging proportion, given expected

net returns from cattle feeding. He concluded that the level of hedging

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[24]Hedging short refers to selling futures and buying in the cash market at time t_0 then buying futures and selling cash at t_1.

[25]Paul, Allen B., "A Forward Look at Futures Trading in Live-stock". Paper presented at the Livestock and Meats Futures Study Conference in Chicago on November 30, 1966, as appeared in Futures Trading in Livestock Origins and Concepts, Mimis Publishers Inc., Madison, Wisconsin, 1970.

[26]Elder, William A., "Risk, Uncertainty, and Futures Trading: Implications for Hedging Decisions of Beef Cattle Feeders", Staff paper P69-20, University of Minnesota, Department of Agricultural Economics, August, 1969.

as a proportion of expected output is negatively related to the
correlation between finished weight of cattle and the price received
for finished cattle, and also negatively related to the correlation
between the variable costs of production and the price received for
finished cattle.

Tomek and Gray,[27] have argued that hedging has historically been
thought of primarily as an aid in the carrying of inventories and only
recently have futures markets been thought of in terms of a forward
pricing function. The futures markets for non-inventory commodities
which asre continuously produced involve production hedges rather than
inventory hedges. Whether an optimal hedge can be placed is ques-
tioned since if the futures price is more variable than the cash price,
a routine hedge does not stabilize revenue. The gains in income
stability for a production hedge, they hold, while minimal for con-
tinuously stored commodities, may be substantial for other commodities.
For live beef cattle and other commodities, this of course is an em-
pirical question. Leuthhold addressed the forward pricing function in
an article discussed in the next section.

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[27]Tomek, William G. and Roger W. Gray, "Temporal Relationships
Among Prices on Commodity Futures Markets: Their Allocative and Sta-
bilizing Roles", _American Journal of Agricultural Economics_, Volume
52, No. 3, August, 1970.

Application of Hedging to the Livestock Sector

Heifner[28] has argued that price risks can be shifted through hedging almost as effectively in livestock as in grain. He found that overall price risk was minimized by hedging less than 100% of the cash position. In cattle feeding minimizing risk hedging levels and hedging level effectiveness tended to decline as distance from the delivery point increased. Quality differences affecting hedging potential was relatively less important in livestock than in grain storage. Apparently at least one of Futrell's caveats was unwarranted.

Heifner employed portfolio theory to obtain a preferred combination of expected profits and risks. The model he developed was quite sensitive to futures profit expectations and cash profit expectations in determining the optimal hedging levels. But in determining the expectations for cash profits he admitted that there may be substantial problems in defining a cash profit level. This problem notwithstanding, Heifner derived the optimal hedging level range for slaughter cattle to be between .56 and .88 unit of short futures per unit of slaughter cattle, disregarding trading costs and futures price bias.

Ehrich[26] tested the theory that the cash-futures price spread should be related to production costs. He concluded that the

[28]Heifner, Richard G., "Hedging Potential in Grain Storage and Livestock Feeding", ERS, USDA, Agricultural Economics Report No. 238, January, 1972; also "Optimal Hedging Levels and Hedging Effectiveness in Cattle Feeding", Agricultural Economics Research, Volume 24, No. 2, ERS, USDA, April, 1972.

[29]Ehrich, R. L., "Cash-Futures Price Relationships for Live Beef Cattle", American Journal of Agricultural Economics, Volume 51, No. 1, February, 1969.

cash-futures spread was appropriately specified as a function of the cost of feeding a calf from feeder weight to finished weight. Under the theory of perfect competition, price spreads will be forced into line with the cost structure of low cost firms. The cash price of feeder cattle are tied by economic forces to prices of futures contracts. The spread would be the price of feedlot services and as such the spread coordinates decision making in the industry. "However, unlike the case of storable commodities, where cash-futures spreads signal adjustments in quantity stored, it is not expected that quantities placed on feed will adjust to cash-futures price spreads for beef cattle. Rather, the price of feeder cattle will adjust to expected fed cattle prices, the latter being determined by inventories of available feeder cattle and expected demand".[30] As will be seen in the theory section discussed shortly, fed cattle prices are used as a signal to the producers of feeder cattle in the prediction model presented herein.

Leuthhold[31] examined the efficiency with which the beef cattle futures market fulfilled the forward pricing role by computing the mean square error on the difference between the price at delivery and the corresponding price j weeks prior to delivery. He found that live beef cattle cash prices are a more accurate indicator of cash

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[30]Ehrich, p. 38.

[31]Leuthhold, Raymond M., "The Price Performance on the Futures Market of a Nonstorable Commodity: Live Beef Cattle", American Journal of Agricultural Economics, Volume 52, No. 2, May, 1974.

price conditions after approximately four month than is the futures

price. He also concluded that futures price becomes less and less

efficient both absolutely and relative to the cash price estimates as

distance from maturity increases.

If a reasonable price forecasting model can be developed, it will

contribute additional information to the function of forward pricing.

The economic theory which serves as a basis for the development of the

price forecasting model is presented in the next section.

CHAPTER III

STRUCTURAL DERIVATION OF THE FEEDER CATTLE MARKET

Only the most important variables in the feeder cattle market
should be selected for use in a forecasting model. The analytically
reduced form for the price of feeders will be considered for possible
use as an input series in a quarterly time series forecasting model.
For these reasons, it is necessary to develop a structural model of
the beef-cattle sector.

It is hypothesized that the beef-cattle sector can be subdivided
into four sectors: the retail market for beef, the slaughter market
for carcasses, the fed, or finished, cattle market, and the feeder
cattle market. Each of these markets will be analytically examined in
turn. Endogenous variables in the model are denoted by an asterisk.
Only the variables in the feeder cattle market are precisely defined
and that data appears in Appendix Table A. The demand for feeder cat-
tle ultimately originates at the retail level in the demand for beef.
It is assumed that the quantity of beef demanded is primarily a func-
tion of the price of beef, and the prices of its two traditionally
named substitutes, chicken and pork. In addition, income is also
cited as an important argument. Thus, the quantity demanded of beef
may be represented as:

(1) $$QB^{d*} = f(PB^*, PCH^*, PP^*, Y)$$

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where

QB^{d*} = quantity of beef demanded, per capita

PB^* = retail price of beef per lb.

PCH^* = retail price of chicken per lb.

PP^* = retail price of pork per lb., and

Y   = disposable personal income per capita

Since beef, pork and chicken all compete for consumers' meat dollar, it can reasonably be argued that at the retail level, the prices of chicken and pork are determined simultaneously with the quantity and price of beef. This is explicitly taken into account by formulating the following demand equations for pork and chicken:

(2) $PCH^* = f(QCH, QP^*, QB^*, Y)$

(3) $QP^{*d} = f(PP^*, PCH^*, PB^*, Y)$

where variables not defined above include

QCH = quantity of chicken demanded, per capita

QP^* = quantity of pork demanded, per capita

The choice of price or quantity as the dependent variable in a demand equation is arbitrary in a mathematical sense especially in a simultaneous system where both price and quantity are deemed endogenous. In many studies, price has been expressed as a function of quantities; in others, quantity has been expressed as a function of prices. In an analytical sense, it has been argued, the selection of normalized

variables is not arbitrary. In the present formulation, QB was expressed as a function of prices at each level because it was felt that in the elimination of explicit identities ($QB^d = QB^s$), price should be the variable that is maintained. It seemed reasonable to suggest that price rather than quantity is the more likely signal which is monitored at each level from wholesale to the feeder cattle market.

Supply functions at the retail level were specified for beef and pork. No supply function was specified for chicken because evidence suggests that at least monthly variations in cold storage holdings of broilers are quite small in relation to production.[1] For convenience, it did not seem unreasonable to assume this fact would hold for a quarterly model as well.

According to basic economic theory, the quantity supplied of a commodity is a function of its own final product price and the cost of other inputs in the production process. Hence, the quantity supplied of beef was considered to be a function of the price of beef, cold storage in the current quarter and the price of carcasses in the current quarter. The retail quantity supplied of beef is represented as:

$$(4) \qquad\qquad QB^{s*} = f(PB^*, CSB, PC^*)$$

where

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[1] L. H. Myers, and Joseph Havlicek, Jr.

CSB = cold storage of beef in the current quarter

PC^* = price of carcasses in the current quarter

The supply function for pork is treated similarly except that an index of the cyclical nature of hog quantities and prices is explicitly included along with the retail price of hogs, cold storage of pork lagged one period and the price of slaughter hogs lagged one period. The retail quantity supplied of pork is thus

$$(5) \qquad QP^{s*} = f(PP^*,\ CSP_{t-1},\ HCY,\ PSH_{t-1})$$

where

CSP_{t-1} = cold storage of pork in the previous quarter

HCY = an index of relative position on the hog production cycle[2]

PSH_{t-1} = price of slaughter hogs in the previous quarter

Included in the above five equations are six endogenous variables, PB^*, QB^*, PP^*, QP^*, PCH^*, and PC^*. Thus the retail block of five equations cannot be solved simultaneously. The sixth endogenous variable which renders the first five equations insoluble is the price of carcass beef (PC^*). In order to explain the determination of PC^*, the slaughter and fed cattle markets must be considered.

In the slaughter market the quantity demanded of carcasses is explicitly treated. Carcass beef may be considered a factor in the production of retail beef. The quantity demanded of carcasses is

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[2]See article by Myers and Havlicek previously footnoted.

therefore considered to be a function of its own price; the price of the final product, beef; another major input expense in the production of beef, butchers' wages; and cold storage holdings of beef. The quantity supplied of carcasses in the slaughter market is taken to be a function of its own price; and two major input costs in the slaughter market, packers' wages and the price of fed cattle. The slaughter market is thus specified:

(6) $$QC^{d*} = f(PC^*, PB^*, BW, CSB)$$

(7) $$QC^{s*} = f(PC^*, PW, PFC^*)$$

where

QC^* = quantity demanded (d) or supplied (s) of carcasses

BW = butchers' hourly wage rate

PW = packers' hourly wage rate

PFC^* = price of fed cattle

Again the problem arises that there are N equations and N+1 endogenous variables both when the slaughter market is considered in itself [equations (6) and (7)] and when it is considered along with the retail block of equations [equations (1) through (5)]. The problem is remedied, however, by the introduction of the next step in the derived demand sequence.

The variable not explained by any of the previous equations, yet introduced endogenously into the model, is the price of fed cattle. This variable is determined in the fed cattle market which describes the demand and supply for that commodity. The quantity demanded of

fed cattle is assumed to be a function of the price of fed cattle. Since the demand for fed cattle is also a derived demand and can be considered a factor of production of carcass beef, the remaining arguments in the demand for fed cattle are the factors of production in the slaughter cattle market. They include packing plant wages and the price of carcasses. The quantity supplied of fed cattle is a function of the price of fed cattle and variables indicative of other input costs in converting a 750 pound beef animal to approximately 1100 pounds. These would include the price of corn, the price of hay, and the number of head on feed. The price of feeders lagged two quarters would also be an important variable in the supply function. This price is lagged two quarters since feeders are generally placed in feedlots for approximately six months or two quarters. The fed cattle market can then be expressed as:

(8) $$QFC^{d*} = f(PFC^*, PW, PC^*)$$

(9) $$QFC^{s*} = f(PFC^*, PCN, HOF, PF_{t-2})$$

where variables not defined previously are:

QFC^* = quantity of fed cattle, demanded (d), or supplied (s),

PCN = average quarterly price of No. 2 yellow corn received by farmers,

HOF = head on feed,

PF_{t-2} = average quarterly price of 750 lb. feeders lagged two quarters.

By virtue of the production lag in the placing of feeders into feedlots for six months, the price of feeders lagged two periods can be considered predetermined. This fact considerably simplifies the model. The first nine equations involve nine endogenous variables and can be solved independently of the final factor of production, the feeder cattle market.

The noteworthy feature at this juncture is that the derivation of the feeder cattle market can now be treated as a block-recursive system. A block-recursive system is a model composed of distinct groups of equations. What distinguishes these groups is the fact that the errors in one group are assumed independent of other groups. The error in one equation is dependent on the errors of other equations within the same group and hence the endogenous variables within the group must be solved simultaneously. The labor-saving upshot of a block-recursive system is that the endogenous variables in one group may be treated as predetermined in succeeding groups.

The block-recursive construct was employed in this research for the theoretical development only. The first block was not empirically estimated but only served in the logical development as to which arguments should be considered in the feeder cattle market.

The block-recursive framework was used for three reasons:

1. The other feasible alternative for a derived demand factor of production was a simultaneous model of approximately ten equations. The data requirements for such a model are too demanding for predictive work. The block-recursive system simplifies the empirical estimation.

2. The block-recursive framework lends itself easily to derived demand. The demand for feeder cattle is a derived demand.

3. It is intuitively appealing that the factor market groups monitor prices in finished product markets and then react. The block recursive model seems justified in the present case because of the two quarter production lag between buying the input factor, feeder cattle and the production of the final output, fed cattle.

Since the feeder cattle market is the primary focus of analysis in this research, the selection of arguments in the demand and supply functions involved greater attention. In the formulation of this block of major interest, it was assumed that the most important signal to the production of feeders coming from the fed cattle market was the price of fed cattle. This variable enters the second block as pre-determined, having been solved in the first block. The second block, composed of the demand and supply functions for feeder cattle, forms the basis of variables which will be analyzed in the predictive model.

The quantity of feeders supplied is hypothesized to be a function of its own price; the cost of other inputs: the price of hay and and the price of calves lagged four quarters; and the inventories of heifers, steers, and bulls at the beginning of each quarter. The quantity of feeders demanded is assumed to be a function of its own price; the major input cost at the fed cattle level, i.e., the price of corn; the price of fed cattle; expectations of the price of fed cattle; and a fourth quarter seasonal dummy. In addition, the variable time was included in both the demand and supply functions to

account for slowly changing trends over the time period studied. The demand and supply functions for feeder cattle are thus:

(10) $\qquad QF^{d*} = f(Pf^*, PCN, PFC, PFC^E, Q4, TM)$

(11) $\qquad QF^{s*} = f(Pf^*, PH, PCV_{t-4}, HSB, HSB2, HSB3, HSB4, TM)$

where variables not defined previously are:

PF^* = average quarterly price of choice feeder steers, all weights combined, eight markets,

QF = quantity of steers, placed on feed by quarters, 22 states,

PCV_{t-4} = average quarterly price of calves 300-500 lbs., good and choice grades, lagged four periods, Omaha market,

PFC^E = expected price of fed cattle,

TM = time,

HSB = number of heifers, steers, and bulls on farms January 1, U.S. and

$HSBi$ (i = 2, 3, 4) = slope shifter for HSB in respective quarter,

PH = price of hay except alfalfa, per ton, received by farmers, U.S.

$Q4$ = fourth quarter dummy variable.

The eleven equations presented above constitute the theoretical underpinnings of an analysis of the feeder cattle market. The whole theoretical block-recursive construct can be represented in a simple diagram.

Block No. 1

```
┌─────────────────────┐
│ Retail Beef Mkt.    │
│ Carcass Beef Mkt.   │
│ Fed Cattle Mkt.     │
└─────────────────────┘
```
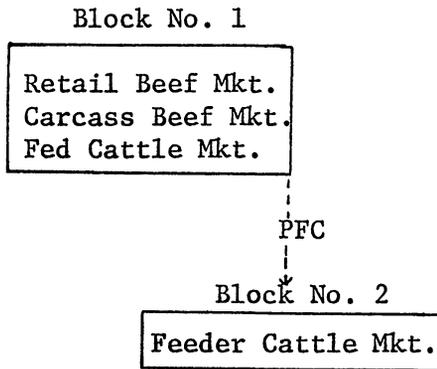
The first block represents 9 equations and 9 unknowns. This generally implies the system is soluble. From this solution, the price of fed cattle can enter Block No. 2 as a predetermined variable. The implicit assumption is that the errors in equations of Block 1 are independent of the errors of equations in Block 2.

PFC

Block No. 2

```
┌─────────────────────┐
│ Feeder Cattle Mkt.  │
└─────────────────────┘
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Derived Demand Nature of the Feeder Cattle Market

The preceding sections have indicated the derived demand nature of feeder cattle through a description of the block-recursive framework. To further clarify theoretical foundations, a graphical analysis of the demand for feeder cattle is also presented. It should be borne in mind that the diagrammatic presentation assumes a perfectly competitive structure in that each firm in the industries presented is considered a price taker, and market equilibrium takes place where the value of marginal product equals supply.

Consider first the industry demand for retail beef. Explicit in diagram (a), Figure 3-A, is the quantity of beef as a function of price. Implicit are the shift parameters which include the price of substitute meats: chicken and pork, and personal income. Diagram (b) shows an industry supply curve as the summation of marginal cost (MC) schedules for retail beef which lie above the average variable cost curve (AVC). Explicit in the diagram again are quantity on the horizontal axis and dollar amount on the vertical. Implicit in the supply schedule are the shift parameters, comprised of other major

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RETAIL MARKET

P_b D_1 D'_1 (a) Q_b

$ $ ΣMC AVC Q_b Q'_b Q_b (b)

Q_b TP' TP Q_c Q'_c Q_c (c)

SLAUGHTER MARKET

P_c D'_2 D_2 D'_2 D_2 Q_c (d)

$ $ ΣMC AVC Q_c Q'_c Q_c (e)

Q_c TP' TP Q^+_c Q_{fc} Q'_{fc} Q_{fc} (f)

FED CATTLE MARKET

P_{fc} D'_3 D_3 D'_3 D_3 Q_{fc} (g)

$ $ ΣMC AVC Q_{fc} Q'_{fc} Q_{fc} (h)

Q'_{fc} TP' TP Q_{fc} Q_f Q'_f Q_f (i)

FEEDER CATTLE MARKET

P_f D_4 D'_4 D'_4 D_4 Q_f (j)
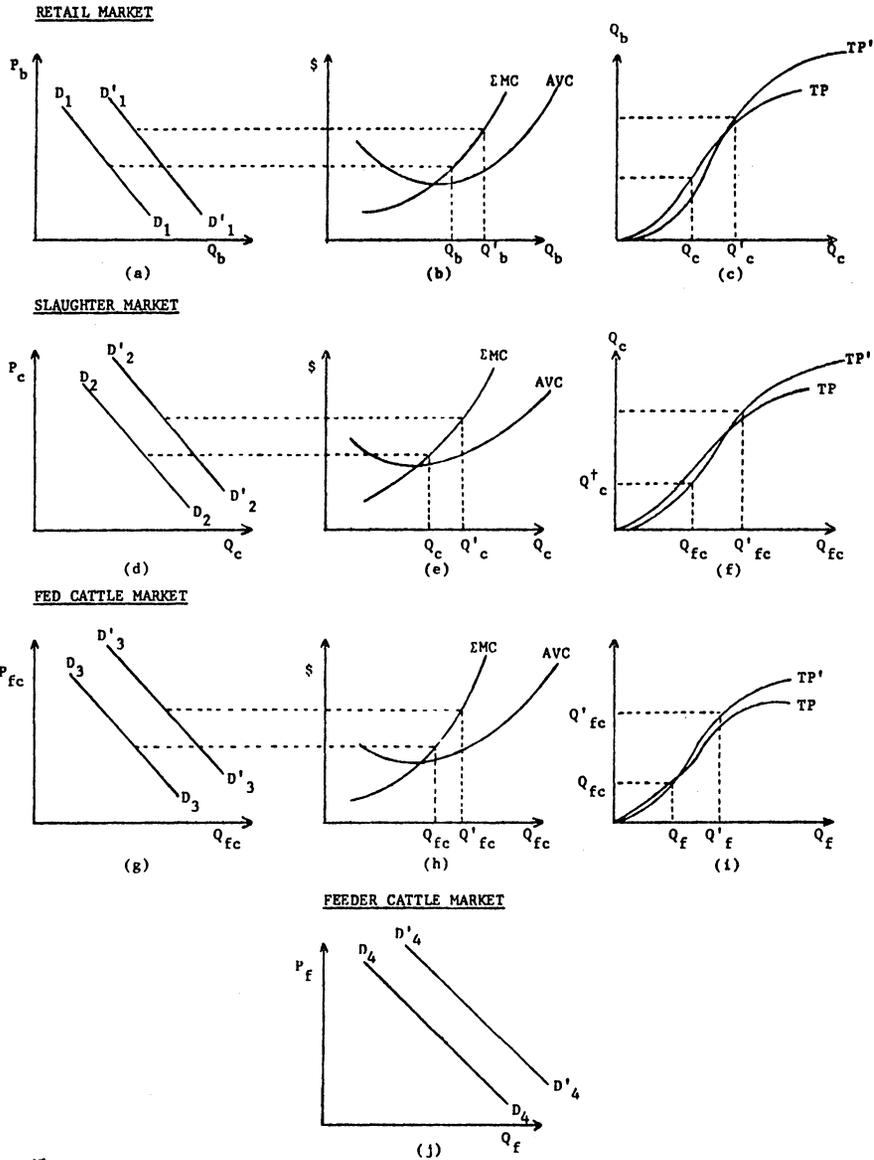
Where:

P_b = price of beef; Q_b = quantity of beef; Q_c = quantity of carcass beef; P_c = price of carcass beef; P_{fc} = price of fed cattle; Q_{fc} = quantity of fed cattle; P_f = price of feeder cattle; Q_f = quantity of feeder cattle.

Figure 3-A. Derived Demand Nature of the Feeder Cattle Market.

input costs in retail beef production: butchers' wages and the price

of carcass beef. If diagram (a) is superimposed on (b), the inter-

section of D and S gives the equilibrium quantity and price of beef

at the retail level.

The intersection of supply and demand in the retail beef market

yields an equilibrium quantity as well as an equilibrium price. The

technical relationship between the equilibrium quantity of retail

beef ($Q*$) and an input, the quantity of carcasses is shown in diagram

(c). Implicit in this diagram are the fixed levels of other inputs

in the production of retail beef such as the number of butcher-hours

employed and the amount of capital equipment (K_1) which exists in the

industry. The slope of the total product curve at each point multi-

plied by the price of retail beef indicates the value of marginal

product (VMP) curve for carcasses. The case for more than one vari-

able input in deriving a VMP curve is analogous except that the

schedule is comprised of a locus of points from shifting VMP curves.[3]

The production function can be expressed as $QB = f(QC, \overline{BMH}, \overline{K_1})$.

The VMP curve constitutes the derived demand for carcasses

which is depicted in diagram (d). The implicit arguments in the

derived demand function for carcass beef include: the price of the

final product for which carcass beef is a factor of production, i.e.,

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[3]It may be argued that the VMP relation multiplied by output
price breaks down in the aggregate in which case the derived demand
for a product should be expressed as a function of prices. The
standard derived demand discussion using quantities as arguments is
presented here for simplicity of exposition. The estimated feeder
cattle derived demand employs prices as arguments.

the price of retail beef; the other major input price in the production of retail beef, butchers' wage rate. The demand for carcass beef can be shown then as $QC^d = f(PC, PB, BW)$.

The industry supply schedule shown in (e) is composed of a horizontal summation of identical MC schedules when MC > AVC. Implicit shift parameters include other major input costs in the production of carcass beef: packers' wages and the price of fed cattle. The superimposition of schedule (d) on (e) renders the equilibrium price and quantity of carcass beef.

The technical relation between the amount of carcasses produced and the number of fed cattle required as input, given all other inputs is given by the production function in diagram (f). The important implicit inputs include packing plant man-hours (PPMH), and capital in the beef slaughtering industry, (K_2). Thus the production relation may be represented as $QC = f(QFC, \overline{PPMH}, \overline{K}_2)$.

The fed cattle market describes the demand and supply for that commodity. Since the demand for fed cattle is also a derived demand, and can be considered a factor of production of carcass beef, the logic of diagrams (g), (h), and (i) are exactly analogous to (a) through (c) and to (d) through (f).

The industry demand for fed cattle, shown in diagram (g) includes the implicit "fixed variables" packers' wages and price of carcass beef.

The industry quantity supplied shown in diagram (h) includes the shift "fixed variables" price of corn, price of hay, head on feed, and the price of feeder cattle lagged two periods (since the major factor

in the production of fed cattle is feeder cattle which is held in feedlots approximately six months).

The technical relation shown in diagram (i) relates the output, fed cattle, with the input requirement, feeder cattle, given the level of all other inputs in the production of fed cattle. These other inputs include the quantity of corn (C) and soybean meal (S) available, the number of steers on feed (SOF), and a measure of feedlot capacity (K_3). The production function can thus be written:

$$QFC = F(QF, \overline{C}, \overline{S}, \overline{SOF}, \overline{K}_3)$$

Finally, the demand for feeder cattle, derived thrice removed from the retail beef demand may be shown in diagram (j). The diagram depicted can be obtained by taking the first derivative of the total product curve in (i) and multiplying the resultant marginal physical product of feeder cattle by the "final" product price of fed cattle. This diagrammatic presentation, of course, again assumes all arguments other than feeder cattle in the production relation remain unchanged. In the actual aggregate derived demand relation which is estimated, prices rather than the quantities of a physical product relation are employed.

Having discussed verbally and diagrammatically the derivation of feeder cattle demand, a presentation of how some of these variables interact with the supply of feeder cattle and ultimately affect the price of feeder cattle is now in order.

A Priori Signs on Coefficients in the Feeder Cattle Market

The supply and demand function which comprise the feeder cattle market are treated as a block independent of the rest of the system. Changes in any of the endogenous variables in the retail, carcass, or fed cattle market affect the feeder cattle market only through the effect which these variables have on the price of fed cattle. This can be recognized by observing that the price of fed cattle is simultaneously determined with other endogenous variables in equations (1) through (9). The relationship which the feeder cattle market has with the first block enters recursively into the demand for feeders, equation (10), through the price of fed cattle. A theoretical analysis of the coefficients in the first block of equations will generally be made through an analysis of how the price of fed cattle is affected.

The analysis may be presented diagrammatically. First, consider a few arguments at the retail level. Economic theory would dictate that the demand for retail beef would shift outward and to the right given an increase in income or the prices of retail beef substitutes, chicken and pork. In the series of diagrams presented earlier, this is indicated by a broken line labeled $D_1'D_1'$ in diagram (a). When diagram (b) is superimposed on (a), a new, higher equilibrium price (P') and quantity (Q') are achieved. In terms of the technical relationship in diagram (c), there is an outward shift in this curve since it is assumed that a change in the retail demand brings to bear forces which would tend to alter the proportion of factors to the variable input, carcasses. The implicit assumption is

that profit maximization criterion assures movement along an expansion path which employs more than one input. As a result of a change in demand, there will be a movement of the curve in diagram (c) to the new higher level of carcasses QC'.

In diagram (d), the derived demand for carcass beef is obtained by multiplying the final product price, PB times the marginal physical product of carcass beef, MPP_C. Since PB has increased and the MPP_C has changed only slightly, (implicitly assuming that employment of carcasses as a factor is not close to stage III of production), the derived demand for carcasses shifts outward to $D_2'D_2'$. The final product price argument acts as a shift parameter in all derived demand equations. In this case, for example, PB is included in the derived demand for carcass beef equation (6).

Tracing the effect of a shift in retail demand with analogous logic through the remaining market levels leads to outward shifts in the demand for fed cattle and finally to feeders. Thus arguing from the source at the retail level, changes in personal income, the price of chicken or the price of pork is seen to have a positive sign with respect to the price of feeders.

Changes in arguments affecting the supply schedule are more complicated than changes affecting demand functions. This is because changes in supply factors shift the marginal physical product schedules, as well as the price of the final product, due to factor substitutions. For example, a decrease in butchers' wages cause two opposing forces to come into play. First, the industry supply schedule

for retail beef shifts to the right. Given the unchanged retail de-
mand for beef, the retail price of beef will fall. However, as more
butchers' man-hours are employed due to lower wages, the marginal
physical product of carcasses (MPP$_C$) would increase. If the increase
in MPP$_C$ outweighs the decrease in PB, the derived demand for carcasses
would increase, and conversely. The derived demand for fed cattle and
for feeders will shift in the same direction as that for carcasses via
the same reasoning as presented above in the income, chicken and pork
prices argument. Thus it is not possible to state absolutely what
a priori sign should be posited for changes in the prices of final
product supply functions with respect to changes in the demand for
feeders.

Other arguments in the retail, carcass, and fed cattle markets
can be similarly traced as to their effect on the demand for feeders
via the price of fed cattle.

Now consider equation (10). Each argument in the demand func-
tion for feeders will be examined as to its a priori sign.

(10) $QF^{d^*} = f(PF^*, PCN, PFC, PFC^E, Q4, TM)$

The first argument, PF*, needs little explanation. The demand
for any normal good is a negative function of its own price.

The price of corn, PCN, is a factor in the production of fed
cattle. An increase in the price of corn is thus an increase in the
factor cost of fed cattle. Ceteris paribus, the increase in factor
cost would decrease the supply of fed cattle and concomitantly decrease

the demand for all factors in the supply of fed cattle, including feeder cattle. Hence, the a priori sign on the price of corn with respect to the demand for feeders is expected to be negative.

Implicit in the above arguments, it has been established that the a priori sign of the price of fed cattle with respect to the quantity of feeders is positive. This conclusion obtains from the fact that the derived demand for a factor is equal to final product price multiplied by the factor's marginal physical product.

The expected price of fed cattle consists of a variable which will hopefully capture anticipated final product price. Perhaps a relevant argument in this regard would be the price of fed cattle two quarters hence since this is the point at which 750 lb. feeders would be sold as fed cattle. The variable used to capture this expectation is the price of fed cattle lagged two periods. This reasoning implies that feedlots look at the price of the quarter in which they will sell their fed cattle as of one year ago to form an opinion of what price they may expect. The a priori sign with respect to quantity of feeders demanded would again be positive.

Preliminary investigation indicated the feeder placements increased in the fourth quarter but price did not consistently fall in that quarter. The latter would be expected if demand did not exhibit a seasonal change and the supply function did. This suggested the possibility of including a dummy variable in the fourth quarter to account for a seasonal change in demand. In fact, the underlying reason for an increased demand in the fourth quarter may be the lower expense of feed. The dummy, Q4, was expected to have a positive sign.

The final argument in the demand for feeders is time (TM). The time variable involves the sequential numbering of successive quarters to account for slowly changing trends in the feeder cattle industry. Since the number of feeder cattle marketed has increased monotonically for the last 100 years, the a priori sign is expected to be positive.

Equation (11) represents the supply function for feeders. Each of the variables in the equation will be examined as to its a priori sign with respect to the quantity supplied of feeders.

$$(11) \qquad QF^S = f(PF, PCV_{t-4}, HSB, HSB2, HSB3, HSB4, TM)$$

The first argument in the supply function, Pf, is the price of feeders. Basic economic theory dictates that the price of a good in a supply function should be positive if the schedule is to be upward sloping.

The price of hay, as a factor of production was expected to enter the supply function negatively. On a national basis, however, the price of hay can be dramatically different and the variable was ultimately dropped due to lack of significance.

The third variable, the price of calves lagged four quarters (PCV_{t-4}), represents one of the basic costs in the production of feeders, i.e., the cost of calves lagged four quarters. Items involved in the cost of production are expected to have a negative sign with repect to the quantity of feeders supplied.

The next four variables (HSB, HSB_i, i = 2, 3, 4) represent the inventory situation. The supply of feeders in any given year is for the most part biologically determined. HSB refers to the number of

heifers, steers, and bulls under 500 lbs. on farms January 1. In

order for this variable to provide information for each quarter, a

dummy slope shifter was introduced to account for the differing

effects the January 1 stock would have on feeder marketings through-

out the year. The quarterly coefficients on this variable structure

can be determined by the data.

A diagram of how this dummy structure works is presented below:

	HSB	HSB2	HSB3	HSB4
1960 I	X	0	0	0
1960 II	X	X	0	0
1960 III	X	0	X	0
1960 IV	X	0	0	X

X represents the reported January 1, 1960, inventory of heifers,

steers, and bulls under 500 lbs. The same variable appears as a slope

shifter in the second, third, and fourth quarters. The value for X

changes each year. No a priori sign can be given for this set of

variables other than HSB4. Since historically, fall has been the most

active trading season for feeders, HSB4 should have a positive sign

with respect to the quantity supplied of feeders.

Time (TM) is also included in the supply function. Since the

number of feeders traded has increased almost monotonically over time,

the a priori sign on the coefficient should be positive.

A priori signs for the demand and supply functions for feeders

have been presented above. The empirical estimation of these equations

will be presented in the next Chapter. In addition, since the primary

goal of this research is the forecasting of feeder cattle prices,
analytically reduced forms will also be presented in order that PF
may be presented as a function of predetermined variables.

CHAPTER IV

EMPIRICAL ESTIMATION OF STRUCTURAL EQUATIONS AND THE
CONVERSION TO ANALYTICALLY REDUCED FORMS

Every empirical piece of work has its share of data problems.

The research herein was no exception. Some of the more significant

problems encountered are noted below.

Data

The data base employed in this quarterly model were the years

1960 through 1975. 1960 was chosen as the starting point since a few

of the more important series involved in the study originated in that

year.

Considerable time and effort was devoted to discovering a struc-

tural model which remained fairly stable from 1971 through 1975. The

quixotic objective of those ill-spent months was to confront the pre-

dictive model with an acid test by extrapolating beyond the range of

the data for five consecutive years starting in 1971. Anyone familiar

with the cattle industry will appreciate the fact that 1971 separates

the "easy years" from the "model scrapping years". Starting in 1972,

the industry was subjected to selective price controls, acute shortages

of feed grains, significant foreign grain deals, and unprecedented

inflation.

Although a structural model was obtained for which most of the

variables remained significant and of the correct theoretical sign for

the five models estimated from 1971 through 1975, the analytically
reduced forms derived from the structure failed grotesquely to provide
a satisfactory fit of the actual data in the turbulent years beyond
1971. Ultimately it was decided to extend the data base through 1975
in order to concentrate on a predictive model. Recall that initially
the intent was to use the analytically reduced form for the price of
feeders as an input series in the application of Box-Jenkins methods.

The nature of the predictive model also argued for an extension
of the data base through 1975. Since a quarterly model was estimated,
only 64 observations were available. In the structural regression
model, this was not found to be a significant problem. The limited
number of observations did, however, present some difficulty in at-
tempting to apply Box-Jenkins methods in identifying and fitting a
time series model to the data. Fifty observations is considered the
bare minimum required to apply such techniques.

Considerable difficulty was encountered in the construction of
the individual data series of the model in two respects:

1) There was a lack of exact correspondence between the two
most important endogenous variables, the price and quantity of feeders.
Whereas the price series employed was obtained from a weighted average
cost per 100 pounds for eight national markets combined and referred
only to steers, the quantity variable consisted of cattle and calves,
regardless of sex, placed on feed in 22 states. Although these two
variables do not correspond exactly, it was felt that these series
were the best choice of available data.

2) Perhaps the most important single independent variable in the determination of the price of feeders was the inventory of heifers, steers and bulls. Unfortunately, until very recently, this variable was only available once a year, on January 1. In order to handle this problem, the dummy variable construct mentioned at the end of Chapter II was devised.

Empirical Estimates

Two Stage Least Squares (TSLS) method of analysis was used to obtain the empirical estimation of equations (10) and (11). The co-efficients of a simultaneously estimated system are known to be biased. The adequacy of the model is difficult to judge since there has really been no definitive criteria set on the magnitude of the standard errors in relation to their associated coefficients. Christ has suggested that t-values as low as 1.0 on an independent variable could be con-sidered to have a statistically significant effect on the dependent variable.[1] However, a more conservative view would be to ascribe the more stringent criteria of single equation estimation to the coeffi-cients and demand t-values of approximately 2.0, that value represent-ing the 95% level of significance. The point is, that in viewing the significance of the following coefficients, the acceptable conserva-tive standard seems to be t-values of approximately 2.0.

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[1]Christ, Carl F., _Econometric Models and Methods_, New York, John Wiley and Sons, Inc., 1966.

The Structural Demand Estimation for Feeder Cattle

Recall the demand equation for feeders posited in the last Chapter was:

$$(10) \qquad QF^{d*} = f(PF^*, \ PCN, \ PFC, \ PFC^E, \ Q4, \ TM)$$

The result of the empirically estimated demand equation through 1975 was:

$$(12) \quad QF^d = -1701.08 - .5985 \ PF + .8962 \ PFC + .9914 \ PFC$$

$$ -1.09 \qquad\quad 1.77 \qquad\quad 2.23^{t-2}$$

$$ -138.07 \ PCN \qquad -1126.60 \ SLPCRN + 2562.86Q4$$

$$ - .14 \qquad\qquad - 2.10 \qquad\qquad 9.63$$

$$ + 69.295 \ TM$$

$$ \quad 5.23 \qquad\qquad\qquad\qquad\qquad R^2 = .83$$

The a priori sign on the price of feeders in the demand equation was, as expected, negative. The t – statistic of 1.09 meets the more liberal significance criterion of $> |1.0|$.

The final product price for which feeder cattle serve as an input, the price of fed cattle, had a positive coefficient as expected. It can be argued that a one-tailed test of significance could be applied, in which case, the coefficient for the price of fed cattle was significant at the 95% level.

The price of fed cattle lagged two periods served as a proxy for the expected price of fed cattle which feedlot operators could obtain

at the time they sold an 1100 to 1300 pound steer. The estimated coefficient on this variable was positive and consequently corresponded to a priori expectations. The t-value was 2.23.

The price of corn had a negative coefficient and conformed to a priori expectations. This variable did not exhibit a significant t-value. An examination of the data indicates that this should not be surprising. Not until 1972 did the price of corn play an important role in the cattle marketing decisions. The price of corn was historically very stable but came to the fore starting in 1972. For this reason, a slope shifter on the price of corn, SLPCRN was included in the model for 1972 and succeeding years. As was expected, SLPCRN had a negative sign and entered the equation with a significant t-value of −2.10.

The fourth quarter dummy variable in the demand equation, Q4 entered the equation positively as expected, with a highly significant t-value at 9.63.

The time coefficient had a positive sign with a t-value of 5.23. Since demand by feedlots for feeder cattle has increased secularly, the coefficient conformed to a priori expectation.

The Structural Supply Estimation for Feeder Cattle

Recall the supply equation hypothesized in the last chapter was:

(11) $\quad QF^{S^*} = f(PF^*, PH, PCV_{t-4}, HSB, HSB2, HSB3, HSB4, TM)$

The result of the empirically estimated supply equation was:

$$(13) \quad QF^{s*} = 5696.32 + .5085 \ PF - .6270 \ PCV_{t-4} - .146 \ HSB$$

$$2.75 \qquad -5.67 \qquad -2.11$$

$$- .0140 \ HSB2 \quad + \ .0084 \ HSB3 \quad + \ .0800 \ HSB4 \quad + \ 85.38 \ TM$$

$$- 1.89 \qquad\qquad 1.13 \qquad\qquad 10.64 \qquad\qquad 5.58$$

$$R^2 = .89$$

$$DW = 1.62$$

The a priori sign on the price of feeders was positive as expected in the supply equation. The t-value obtained was significant at 2.75. Although cow-calf operators and backgrounders cannot produce many more 750 pound steers than they have during any quarter, they can elect to respond positively to an increase in the price of feeders with their available stock on hand. The sign indicates that they do so.

The price of hay, as mentioned previously was not significant and the variable was dropped from the equation. The price of calves lagged four quarters represents an input cost to the producer of 750 pound feeder cattle, whether the cost is explicit, as in the case of a backgrounder, or implicit as in the case of a cow-calf operator. The price of calves lagged four quarters has a negative sign which conforms to a priori expectations.

The inventory situation, as has been alluded to previously, was perhaps one of the most important variables in the determination of price. "Heifers, steers, and bulls under 500 pounds on farms January 1"

has been the only figure released on this important series until recently. (Now the inventory situation is reported semi-annually.)

The coefficients on the inventory variables fluctuated considerably for estimations based on five annual data extentions from 1960-1971 to 1960-1975. The coefficient for HSB in the 1975 estimation was unusually large and negative. Although no a priori sign was hypothesized, it was assumed that the slope shifter HSB4, when added to HSB, would result in a positive coefficient. 1975 is the only year in which this did not occur. However, it was encouraging to note that HSB4 had the correct positive sign in relation to the first quarter placements, HSB.

Time as a variable in the supply equation was expected to be positive as the supply of feeder cattle has increased secularly. The coefficient corresponded to expectation with a t-value of 5.58.

Analytically Reduced Forms

The estimated equations for the demand and supply of feeders are for the most part, sterile in the form cited above. In order that the equations may be used for the input series of the forecasting model, analytically reduced forms were calculated. The purpose of this transformation is to make the endogenous variables in the model (PF and QF) solely a function of the predetermined variables. The analytically reduced forms may be obtained as follows:

Rewriting equations (12) and (13) with the endogenous variables on the left-hand side of the equations,

$$(14) \quad QF^d + .5985 \ PF = 1701.08 = .8962 \ PFC + .9914 \ PFC_{t-2}$$

$$-138.07 \ PCN - 1126.60 \ SLPCRN + 2562.86Q4 + 69.295 \ TM$$

$$(15) \quad QF^s - .5085 \ PF = .5696.32 - .6270 \ PCV_{t-4} - .146 \ HSB$$

$$- .0140 \ HSB2 + .0084 \ HSB3 + .0800 \ HSB4 + 85.38 \ TM$$

Letting $QF^s = QF^d = QF$, and rewriting equations (14) and (15) in matrix form yields the desired analytically reduced forms after inverting the 2 x 2 matrix. The operation is indicated in Table 4-A.

In this form, impact multipliers, the simultaneous system's conceptual substitute for elasticities may be computed. Since the primary motivation of this research is forecasting, a calculation of the impact multipliers along with a discussion of the biasness which is to be expected as a result of simultaneity has been relegated to an appendix.

The more important function of analytically reduced forms is the possibility of using the forms for predicting the price of feeder cattle. Since PF is a function of predetermined variables, there is no conceptual difficulty in using values of the predetermined variables in order to forecast. Using the analytically reduced form for PF as an input to the forecast function (discussed subsequently) proved satisfactory until the data base was extended beyond 1972. In the turbulent years that followed, the analytically reduced forms produced egregious results which ultimately led to their rejection in favor of employing the first stage OLS equations used in the TSLS estimation of the structural model. The first stage OLS equation presents no

TABLE 4-A

ANALYTICALLY REDUCED FORMS FOR THE PRICE AND QUANTITY OF FEEDERS

$$
\begin{bmatrix} \hat{Q}_f \\ \\ \hat{P}_f \end{bmatrix}
=
\begin{bmatrix} 1 & -.5085 \\ \\ 1 & .5985 \end{bmatrix}^{-1}
\begin{bmatrix} 5696.32 & -.6270 & 2.146 & -.0140 & .0084 & .0800 & 85.38 & 0 & 0 & 0 & 0 & 0 \\ \\ -1701.08 & 0 & 0 & 0 & 0 & 0 & 69.295 & .8962 & .9914 & -138.07 & -1126.60 & 2562.86 \end{bmatrix}
\begin{bmatrix} 1 \\ PCV_{t-4} \\ HSB \\ HSB2 \\ HSB3 \\ HSB4 \\ TM \\ PFC \\ PFC_{t-2} \\ PCN \\ SLPCRN \\ Q4 \end{bmatrix}
$$

conceptual problem insofar as PF is expressed as a function of pre-determined variables. There is, however, an almost insurmountable practical difficulty – data on most of the independent variables does not become available until the same time the dependent variable data becomes available, thus making current period forecasts unnecessary and future period forecasts impossible.

This overwhelming practical difficulty suggests the use of methods developed expressly for predictive purposes. Box and Jenkins have recently developed a body of purely mechanical techniques which may serve our purposes. A heuristic explanation of the models used to forecast feeder cattle prices will be presented in the next Chapter.

APPENDIX CHAPTER IV

ELASTICITIES IN A SIMULTANEOUS MODEL[1]

In a single equation model, with the dependent variable as the only endogenous variable, measures such as elasticities have meaning, practical value, and are calculated in a straightforward manner. The elasticity indicates the responsiveness of the dependent variable to a change in one of the exogenous variables, ceteris paribus. The computation has obvious policy implications in that a desired response in the dependent variable can be evoked by an appropriate change in one of the exogenous variables.

The computation of elasticities in a simultaneous system are of dubious meaning, questionable value, and are not calculated in a straightforward manner. This conclusion obtains from the fact that 1) simultaneous system coefficients are biased and 2) the ceteris paribus assumption required for elasticity computational validity is explicitly violated by virtue of simultaneity.

An example will serve to illustrate the point. The elasticity of a variable Q with respect to variable X is given by

(1) $E_i = \frac{dQ}{dX_i} \cdot \frac{\overline{X}_i}{\overline{Q}}$ where $\overline{X}_i$ and $\overline{Q}$ represent respective means.

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[1] The content of this appendix borrows heavily from Chapter 19 of Lecture Notes in Econometric Methods and Analysis by Joseph Havlicek, Jr.

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The assumptions which allows this interpretation in a straight-forward way as an elasticity are that the quantity is endogenous and functionally related to the X variables and that the responsiveness of quantity to a change in any i^{th} exogenous variable may be interpreted individually with all other exogenous variables non-variant.

Now consider a simultaneous system with two engogenous variables (Y_1 and Y_2) and two equations. Let Y_1 represent quantity and Y_2 represent price. Z_i, i=0, 1, 2, 3 are exogenous variables and u_1 and u_2 are random disturbances.

$$(2) \qquad B_{11}Y_1 + B_{12}Y_2 + \delta_{11}Z_1 + \delta_{12}Z_2 + \delta_{10}Z_0 = U_1$$

$$(3) \qquad B_{21}Y_1 + B_{22}Y_2 + \delta_{23}Z_3 + \delta_{24}Z_4 + \delta_{20}Z_0 = U_2$$

Normalizing equation (2) with respect to Y_1 and equation (3) with respect to Y_2 and estimating by a simultaneous method, the two equations may be rewritten as:

$$(4) \qquad Y_1 = \hat{B}_{12}Y_2 + \hat{\delta}_{11}Z_1 + \hat{\delta}_{12}Z_2 + \hat{\delta}_{10} - \hat{U}_1$$

$$(5) \qquad Y_2 = \hat{B}_{21}Y_1 + \hat{\delta}_{23}Z_3 + \hat{\delta}_{24}Z_4 + \hat{\delta}_{20} - \hat{U}_2$$

In this form, the ambiguities of elasticity computations are more readily apparent. Equation (1) representing the calculation for an elasticity involves partial differentiation. In equations (4) and (5) partial differentiation is improper since Y_1 and Y_2 affect each other and change simultaneously. Consider in equation (4), an exogenous one unit change in say Z_1. Y_1 changes by $\hat{\delta}_{11}$. In equation (5), this brings about a change in Y_2 of $\hat{\delta}_{11}\hat{B}_{21}$. This in turn affects

Y_1 via equation (4) through Y_2. The ceteris paribus condition of elasticities has not been fulfilled.

In addition, the estimated coefficient are biased. Monte Carlo studies have indicated that this is an inescapable result in using simultaneous methods. Therefore, even if elasticities were computed with abandon on simultaneous equations, they would be wrong to an unknown extent.

Having decried the use of elasticities in simultaneous models, a conceptual substitute will be proffered. In Chapter III, analytically reduced forms were derived in which the endogenous variables were presented as a function of only predetermined variables. Net impacts of changes in exogenous variables on the endogenous variables can be evaluated. The technique of impact multipliers is common parlance in the area of monetary theory and these derived net impacts are commonly used in making policy decisions in many fields.

Any impact multiplier or elasticity desired can be obtained by taking the partial derivatives of the dependent variables with respect to the independents or applying equation (1), respectively, to the equations set out below. The following equations are the analytically reduced forms of Table 3-A, Chapter III, after having determined the coefficients:

(6) $QF = 2298.41 - .3390 \ PCV_{t-4} - 079 \ HSB - .0076 \ HSB2 + .0046 \ HSB3$

$+ .0433 \ HSB4 + 78.0 \ TM + .4117 \ x \ PFC + .455 \ PFC_{t-2} - 63.43 \ PCN$

$- 517.56 \ SLPCRN + 1177.38 \ Q4$

$$(7) \quad PF = -6683 + .5665 \ PCV_{t-4} + .1319 \ HSB + .0127 \ HSB2 - .0076 \ HSB3$$

$$- .0723 \ HSB4 - 14.53 \ TM + .809 \ PFC + .895 \ PFC_{t-2} - 124.73 \ PCN$$

$$- 1017.77 \ SLPCRN + 2315.29 \ Q4$$

CHAPTER V

THE FORECASTING MODEL[1]

Forecasting has been of great importance in a variety of fields
including physics and economics. While the area of physics is gener-
ally considered to be a deterministic (exact) science, to a varying
degree almost all phenomenon in the universe are subject to random
variation. As such, a mathematical model which purports to explain
a particular phenomenon is almost always stochastic to some extent.
In the case of economics, the stochastic nature of a mathematical
model is more apparent since a social science encompasses a myriad
of nonquantifiable "human" elements. Accordingly, it may be possible
to develop stochastic rather than deterministic models which can be
used to calculate the _probability_ of a future value lying between two
specified limits.

Box and Jenkins have developed a number of stochastic models for
describing and forecasting time series. In this Chapter, a heuristic
presentation of some of their models will be given followed by the
empirical results of applying those models to feeder cattle data.

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[1]The explanation of forecasting models in this Chapter draws
heavily from Time Series Analysis Forecasting and Control, George E. P.
Box and Gwilym M. Jenkins, Holden-Day, 1970.

The Logical Framework of Time Series Models

The stochastic models employed by Box and Jenkins are based on the hypothesis that a time series in which successive values are highly dependent can be regarded as having been generated from a series of independent "shocks", a_t. These shocks are random selections from a fixed distribution which is assumed to be normal, having mean zero and variance a^2. Such a sequence of random variables, a_t, a_{t-1}, a_{t-2}, $\cdots$ is called a white noise process.

The white noise is supposedly transformed to the observed time series Z_t by a linear filter, as shown in Figure 5-A. The linear filtering operation is a weighted (by $\psi(B)$) sum of previous values of Z_t. Stochastic model construction involves finding the weights in the linear filter which renders a white noise series from a particular time series of interest discussed later. The model shown in the figure can be expressed as

$$(1) \qquad \tilde{Z}_t = \psi_0 a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \cdots$$

In regression analysis, a dependent variable Z is regarded as a function of several independent variables X_1, X_2, etc. In the basic time series models, however, Z_t is considered to be a function of past values of itself, Z_{t-1}, Z_{t-2}, $\cdots$ Hence, these models are called autoregressive.

The series Z_t which is observed is viewed as one realization of a stochastic process. A stochastic process is a statistical phenomenon that evolves in time according to probabilistic laws. In constructing

$\psi(B)$ weights

white noise

a_t

```
Linear
Filter
```

observed time series

Z_t
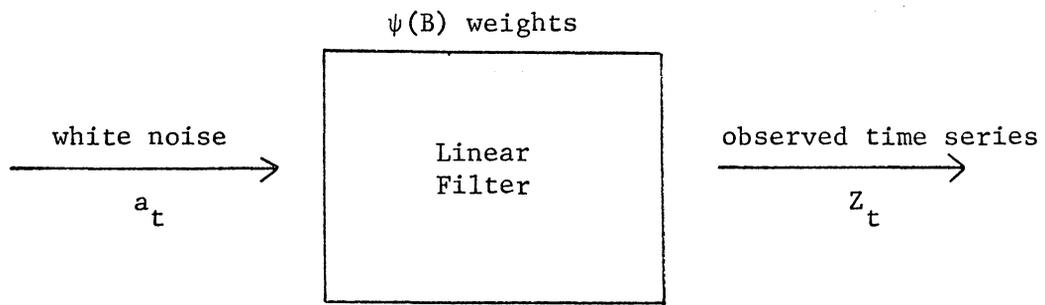
$$\hat{Z}_t = \psi_0 a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \cdots$$

Figure 5-A. White Noise as a Transformation of an Observed Time
Series Through a Linear Filter.

such a model, the underlying probabilistic generating mechanism is sought.

Maximum likelihood estimation is the technique employed to obtain model specification and estimates of the parameters of a time series model. Once the model has been specified, optimal forecasts can be made. The optimality refers to minimizing the mean square error of forecasts. The observations Z_t composing the realization can be described by an N-dimensional random variable $(Z_1, Z_2, \ldots, Z_n)$ with joint probability distribution $p(Z_1, Z_2, \ldots, Z_n)$. This follows from the fact that an observation Z_t at a given time, say t = 25, is a realization of a random variable Z_t with probability density function $p(Z_t)$. Similarly, the observations at any two times, say $t_1 = 25$ and $t_2 = 27$ may be regarded as realizations of two random variables Z_{t_1} and Z_{t_2} with joint probability density $p(Z_{t_1}, Z_{t_2})$.

The joint density of the N-dimensional random variable will be considered a likelihood function from which the population parameters will be estimated. Since the Z_t series is a linear combination of the white noise process, which is assumed to be normal, the Z_t series is completely described by a knowledge of the mean and autocovariances of Z_t. The autocovariances and mean of the process must be estimated from the data.

The principal tools used in constructing a model deal with the analysis of the autocovariance structure of an observed series. These are the Autocovariance Function (ACF) and the Partial Autocovariance Function (PACF). The Autocovariance Generating Function yields the

autocovariances of a linear process at succeeding lags. Initially it may not be known which order of autoregressive process to fit to an observed time series. The problem is analogous to deciding on the number of independent variables to be included in a multiple regression. The PACF is a device which by its very nature can describe an autoregressive process of pth order in terms of p non-zero _functions_ of the autocorrelations. What constitutes an autoregressive process of order p may be clarified in the next section wherein a few models are presented.

An intuitive feel for what these models attempt to describe may be gained by considering a bicycle being propelled over a level surface. Let Z_t represent the speed of the bicycle after t revolutions of the bike's pedals. The a_t's are the force applied on the tth revolution. In this example, the ψ weights would most likely be exponentially decreasing from 1.0. This would indicate that the most recent stroke of the pedal would have the greatest influence on the present speed of the bicycle. The model would be represented as $Z_t = u + a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \cdots$

The Basic Models and Some Additional Concepts

Before describing the models, a few notational definitions are in order:

B is a backshift operator.

$$BZ_t = Z_{t-1}$$
$$B^2 Z_t = B(BZ_t) = BZ_{t-1} = Z_{t-2}$$

In general,

$$B^k Z_t = Z_{t-k}.$$

∇ is a backward difference operator which can be written in terms of B.

$$\nabla Z_t = Z_t - Z_{t-1} = (1 - B)Z_t.$$

The Autoregressive Model

In the autoregressive stochastic model, the current value of a process may be expressed in terms of a _finite_ number of previous values of that process and a shock a_t. Let $\tilde{Z}_t = Z_t - \mu$ where μ = population mean. The autoregressive process of order p, AR(p) can then be written.

(2) $$\tilde{Z}_t = \phi_1 \tilde{Z}_{t-1} + \phi_2 \tilde{Z}_{t-2} + \ldots + \phi_p \tilde{Z}_{t-p} + a_t$$

If the autoregressive operator of order p is written

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p$$

(3) $$\phi(B)\tilde{Z}_t = a_t$$

We can also write (2) in terms of previous shocks. For example $\tilde{Z}_{t-1}$ can be eliminated from the right-hand side of equation (2) by substituting $\tilde{Z}_{t-1} = \phi_1 \tilde{Z}_{t-2} + \phi_2 \tilde{Z}_{t-3} + \ldots + \phi_p \tilde{Z}_{t-p-1} + a_{t-1}$.

Other substitutions can likewise be made for $\tilde{Z}_{t-2}$, $\tilde{Z}_{t-3}$, $\ldots$ to yield an _infinite_ series in the a's.

So equation (3) is equivalent to

(4) $$\tilde{Z}_t = \phi^{-1}(B)a_t = \psi(B)a_t$$

The Moving Average Model

Another model very similar to the above is the moving average model of order q, MA(q). While the AR(p) model expressed the current value $\tilde{Z}_t$ as a finite number p of previous $\tilde{Z}_t$ values, the moving average model of order q expressed $\tilde{Z}_t$ as linearly dependent on a <u>finite</u> number of previous a's.

The moving average process of order q can thus be expressed as:

$$(5) \qquad \tilde{Z}_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}$$

If the moving average operator of order q is defined

$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$$

then the moving average model can be written as

$$\tilde{Z}_t = \theta(B) a_t .$$

Mixed Autoregressive-Moving Average Models

To minimize the number of parameters required to describe a particular observed series and to provide greater flexibility in identifying a stochastic model, it is sometimes desirable to include both autoregressive and moving average terms in the model. The mixed autoregressive-moving average (ARMA) model of order p and q, respectively, can be written

$$(6) \qquad \tilde{Z}_t = \phi_1 \tilde{Z}_{t-1} + \ldots + \phi_p \tilde{Z}_{t-p} + a_t - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q}$$

This model can be more economically expressed as

$$\phi(B) \tilde{Z}_t = \theta(B) a_t$$

or

$$\tilde{Z}_t = \phi^{-1}(B)\theta(B)a_t$$

Discussion of all three models has made reference to the parsimonious expression of a series in terms of its required parameters. The value of the AR model is that it can be expressed as a _finite_ number p of past values rather than an infinite MA series. Similarly, the value of the MA model is that it can be considered as a _finite_ number q of random shocks rather than an infinite AR series. The ARMA model considers the case between the two extremes. The parsimonious representation is very important in practical estimation. If it were not for the opportunity to express an observed series as a finite linear combination rather than an infinite linear series, it would be impossible to estimate the infinite number of parameters. In fact, the parsimonious representation offers a lot of intuitive appeal. For example, the daily stock price of General Motors most likely depends more on what the price was yesterday rather than on what the prices were in the infinite past.

Stationarity

The stochastic processes described above may be either stationary or nonstationary. A stationarity stochastic process is in a particular state of statistical equilibrium such that its properties are unaffected by a change of time origin. More specifically, the joint probability distribution associated with m observations Z_{t1}, Z_{t2}, ..., Z_{tm}, made at

<u>any</u> set of times t1, t2, ..., tm is the same as that associated with m

observations Z_{t1+k}, Z_{t2+k}, ..., Z_{tm+k} made at times t1+k, t2+k, etc.

Stationarity imposes conditions on the autocovariance matrix.

Any linear function of random variables Z_t has a variance which can be

expressed as a positive definite quadratic form. The positive definite-

ness implies that the determinant and all the principal minors of the

autocovariance matrix are positive.

All of the above stationarity conditions can be embodied in the

single condition that the series $\psi(B)$ in equation (1) must converge

for $|B| \leq 1$, when viewing the equation as a polynomial in B. A more

pedestrian explanation of stationarity would be that the process has

a finite variance, and the ψ weights die out "sufficiently rapidly".

Invertibility

A very similar condition to that of stationarity, though indepen-

dent of the stationarity condition, is applicable both to stationary

and non-stationary models. This is the invertibility condition and

applies to the $\pi(B)$ series where $\pi(B)$ is defined by $\pi(B) = \psi^{-1}(B)$.

A series of $\tilde{Z}_t$ satisfies the invertibility condition if $\pi(B)$ con-

verges for all $|B| \leq 1$. This condition prevents the π weights from in-

creasing as they become more remote.

To illustrate the basic idea of invertibility, consider the model

(7) $\tilde{Z}_t = (1 - \theta B)a_t$

(Note this is a moving average model as in equation (5) where $\theta_o = 1$

and $\theta_1 = \theta$). Expressing the a's in terms of the Z's, equation (7)

(8) $\quad a_t = (1 - \theta B)^{-1} \tilde{z}_t = (1 + \theta B + \theta^2 B^2 + \ldots + \theta^k B^k)(1 - \theta^{k+1} B^{k+1})^{-1} \tilde{z}_t$

or

(9) $\quad \tilde{z}_t = -\theta \tilde{z}_{t-1} - \theta^2 z_{t-2} - \ldots - \theta^k z_{t-k} + a_t - \theta^{k+1} a_{t-k-1}$

and if $|\theta| < 1$, on letting k tend to infinity, we obtain the infinite

series

(10) $\qquad \tilde{z}_t = -\theta \tilde{z}_{t-1} - \theta^2 \tilde{z}_{t-2} - \ldots + a_t$

and the π weights of the model in (9) are $\pi_j = -\theta^j$. Whatever the value

of θ, (7) defines a perfectly stationary process. However, if $|\theta| > 1$,

the current deviation $\tilde{z}_t$ in (9) depends on $\tilde{z}_{t-1}$, $\tilde{z}_{t-2}$, $\ldots$, $\tilde{z}_{t-k}$ with

weights which increase as k increases. This situation is avoided by

requiring that $\pi(B) = (1-\theta B)^{-1}$ converges for all $|B| \leq 1$. The series

is then said to be invertible.

Expansions on the Basic Models

Nonstationary Models

An important group of series encountered empirically have no

fixed mean as do the stationary models described above, and yet they

do exhibit some sense of homogeneity over time. If this homogeneity

involves one part of the series behaving much like any other part ex-

cept for its local level or perhaps local level and trend, then the

series may be accommodated by a differencing operation. Taking first

or second differences will transform these series to stationary pro-

cesses. Many economic series exhibit this kind of homogeneous non-

stationary behavior. When differencing is employed, the models are

called "integrated". An example of two autoregressive integrated moving average (ARIMA) models are given below in Figure 5-B.

Seasonal Models

In representing a seasonal model it is desirable for the forecast function to trace out a periodic pattern. The fundamental fact of a seasonal series is that it repeats itself for each season k intervals apart. Box and Jenkins offer a general multiplicative seasonal model in which the interseasonal autocorrelations identify one of the models already described in exactly the same manner as the intraseasonal auto- correlations identify a possible model.

The seasonal model thus emphasizes two important time intervals. Specifically, the forecast function should show (a) relationships be- tween observations for successive intervals within a season and (b) re- lationships between observations for successive intervals between seasons. Let it suffice to say that if (p, d, q) represent respective- ly the number of autoregressive parameters, differencing, and moving average parameters for a within season stationary model and (P, D, Q) represent analogous parameters for a between season stationary model, then the general multiplicative seasonal model (p, d, q) x (P, D, Q) requires examination of the autocorrelation function and partial auto- correlation function in order to derive estimates for the differencing and parameter requirements of p, P, q, and Q.

A hypothetical stationary ACF with a seasonal component of 12 months may look like Figure 5-C below.
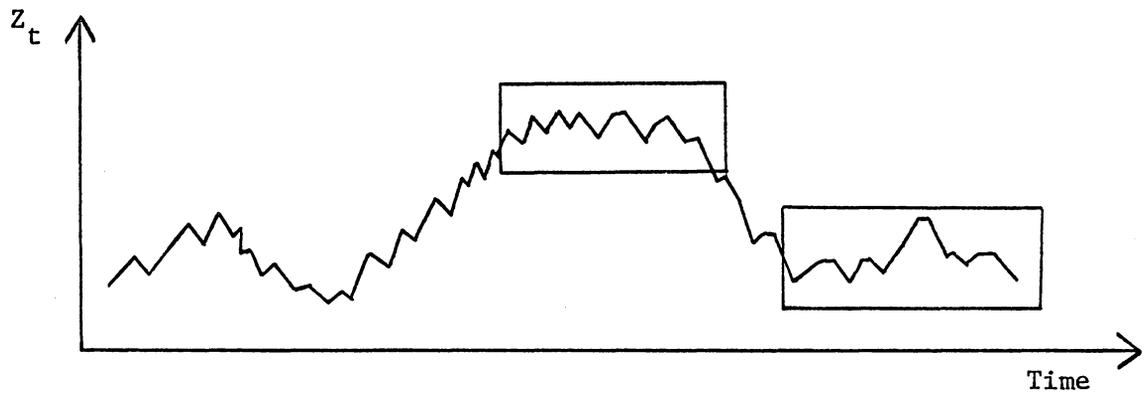
a) A Series Showing Nonstationarity in Level Such as can be
Represented by $\phi(B)\nabla Z_t = \theta(B)a_t$
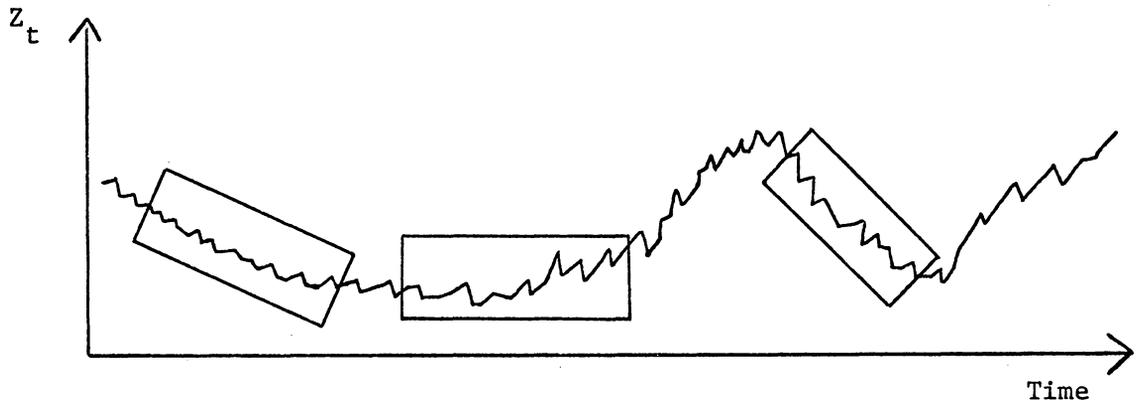
b) A Series Showing Nonstationarity in Level and Slope Such as
can be Represented by $\phi(B)\nabla^2 Z_t = \theta(B)a_t$

Figure 5-B. Two Types of Nonstationary Time Series
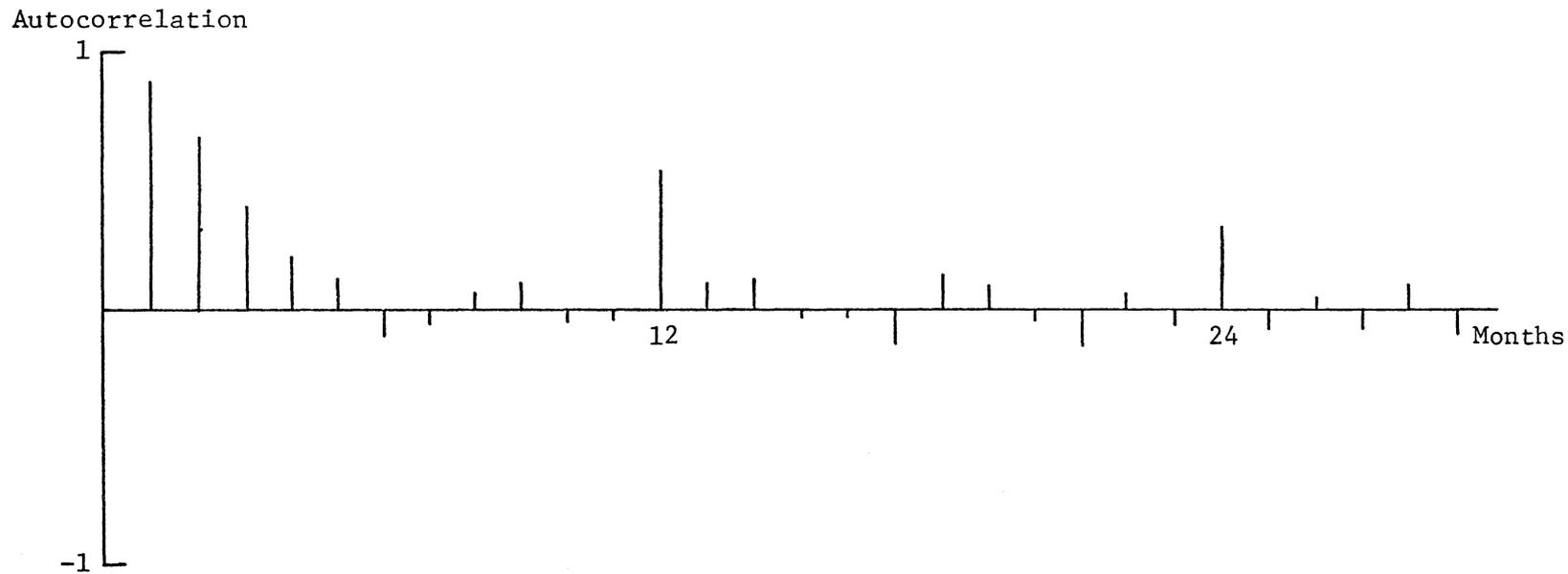
Figure 5-C.   Hypothetical Stationary Autocorrelation Function With a Seasonal Component
at Twelve Months.

Transfer Function Models

The transfer function model is dynamic in nature and is applicable in situations where it is impossible to realistically assume that a series is a function of only itself. The transfer function model expresses an output series Y_t as the function of an input series X_t plus a noise series N_t. The model is most effective when the input series is a natural "leading indicator" of the output series. In the case of price forecasting for feeder cattle, the futures market price of feeders would be a natural input series save for the fact that the data base would be seriously eroded since feeder cattle futures have only been traded since 1971.

Recall that in the univariate cases discussed previously, the observed series was assumed to be generated by a linear stochastic process with an unknown autocorrelation function (which was estimated from the data). In the case of transfer function models, the ordered pairs of observations (X_1, Y_1), ... X_m, Y_m) are treated as the realization of a <u>bivariate</u> stochastic process. As a result, not only the ACF's of X_t and Y_t must be examined, but so must the cross-covariances between X and Y.

In most respects, the transfer function is very analogous to the univariate models in the identification and fitting stages in model building. Both the X and Y series must be properly differenced in order to obtain a stationary bivariate series. Stationarity is assumed when the estimated autocorrelations for X and Y and the cross-correlations between X and Y die out "sufficiently rapidly".

The objective of the transfer model is the same as that of the univariate case to transform X and Y to white noise, or randomness, via a judicious selection of parameter values. Clues to the judicious selection are provided by estimations of the ACF's, PACF's of X and Y, cross-correlations between X and Y, and the ACF and PACF for N. Equation (11) expresses the general form of the transfer function model:

(11) $(1 - \delta_1 B - \ldots - \delta_R B^R) Y_t = (W_0 - W_1 B - \ldots - W_s B^s) B^b X_t$

and

$$Y_t = \frac{(W_0 - W_1 B - \ldots - W_s B^s)}{(1 - \delta_1 B - \ldots - \delta_R B^R)} \; B^b X_t + \phi^{-1}(B)\theta(B)a_t$$

when a noise series is added to the model.

B^b represents the number of lags between a change in the input and the beginning of an output response, and $\phi^{-1}(B)\theta(B)a_t = N_t$.

Model fitting involves estimation of the W's, δ's, φ's, θ's, and b.

For all of the above models, there are formulas available for computing the standard errors of the coefficients. It is also possible to compute confidence intervals for the forecasts which are made from the derived models.

<center>Empirical Estimations</center>

The Seasonal Model

A cursory glance at the feeder price time series shown on the graph in Chapter I indicates that the series is nonstationary from

1960 through 1975. This is evidenced by the fact that there is an obvious upward trend in the data, the local mean level changes over time. It was found that application of the differencing operator displayed in Figure 5-B (a) was able to bring about the desired stationarity. In more common parlance, first differences were taken.

Working with the series of feeder prices only, a simple model such as the autoregressive and moving average types discussed earlier in the chapter, were attempted. The identification program specified an intraseasonal random walk model. This means the feeder price series (differenced once to obtain stationarity) was a white noise process and no specification of autoregressive parameters (p) or moving average parameters (q) were required to obtain a random residual series. The forecast function of a random walk model implies that the optimum forecast for period $t + 1$ is the value of the series in period t plus a random shock, a_{t+1}. Since the expected value of the random shock is zero, the optimum forecast for period $t + 1$ is the price in period t. The model can be represented as (12) $\tilde{Z}_{t+1} = \tilde{Z}_t + a_{t+1}$.

The above model has limited practical value. Fortunately the autocorrelation function (ACF) for the feeder price series exhibited a high correlation, or spike, between the current price and that at $t = 6$, indicating the possibility of a significant seasonal component of six quarters. In terms of the previous seasonal model discussion, the existence of a P or Q parameter was suggested. When this possibility was explored using the data base 1960-1971, a multiplicative seasonal model was fitted to the data and the forecast function

provided more information than the simple random walk model. Now in addition to the current price and a random component, the price one period hence was found to be correlated with the price 6 periods ago. The autocorrelation function of the feeder price series is shown in Figure 5-D.

When the data base was extended through 1975, the spike at t = 6 in the ACF was lost and a white noise series was again obtained. However, examination of the white noise residuals indicated marked heteroskedasticity as feeder prices climbed to higher levels in the 1970's. A log transformation on the data succeeded in reestablishing a seasonal component at 6 quarters and ridding the white noise series of the heteroskedastic characteristic.

The seasonal moving average model with a season of 6 quarters and transformed by logs can be represented as:

$$(13) \qquad \nabla \text{Log} \ (Z_t) = (1 - \theta B^6) \ \text{Log} \ a_t$$

The actual value assumed by θ, determined by maximum likelihood estimation, was .4757, using the data base through 1975. The 95% confidence limits for this parameter did not include zero, implying that a moving average seasonal component of 6 quarters was significantly different from zero at the 95% level.

Tracing through an example based on equation (13) may help to clarify its interpretation. Regrettably, some new notation is required:

$\tilde{Z}_t$ (1) represents the forecast from base t, 1 period ahead.

Where brackets indicate conditional expectation:
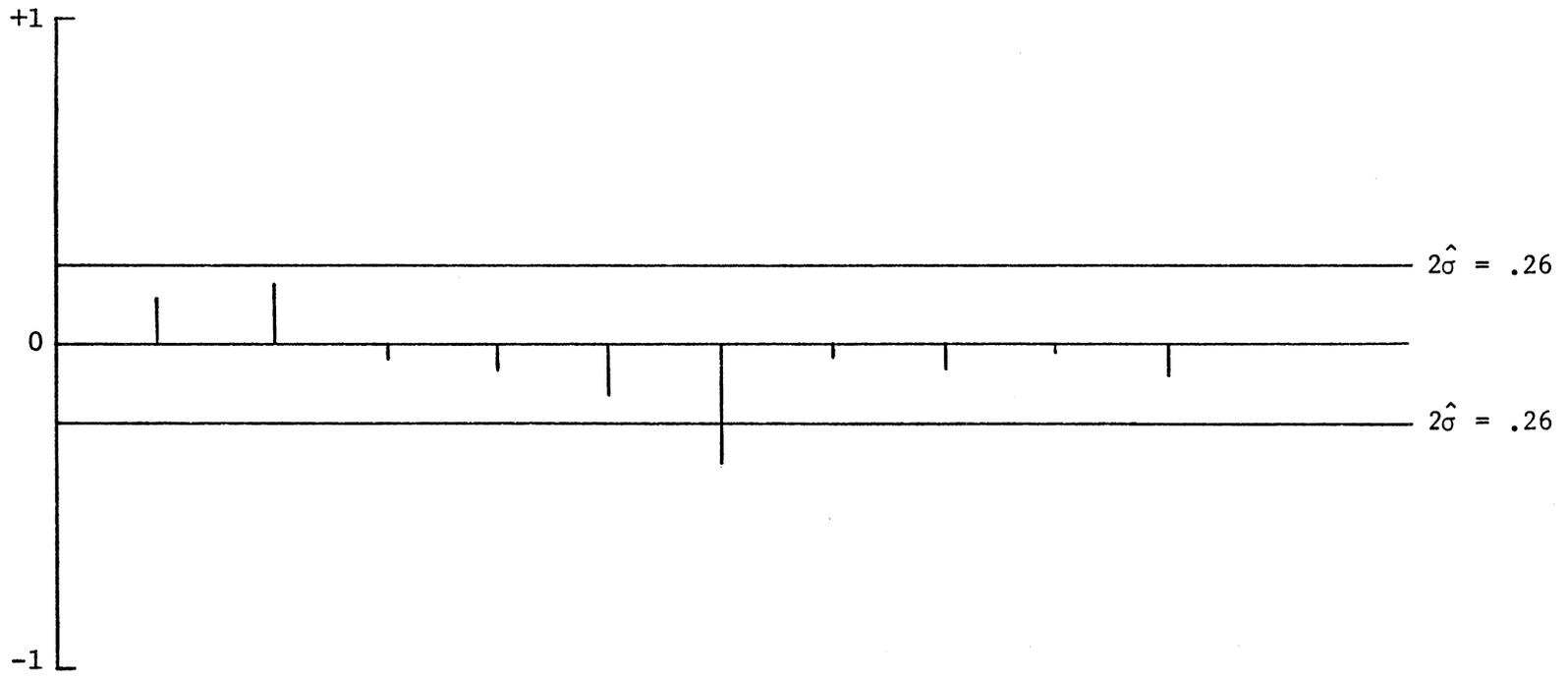
Figure 5-D. Autocorrelation Function for Feeder Cattle Price Series, Differenced Once

Note: The $2\hat{\sigma}$ bounds represent the 95% level of significance on the auto-correlations. Any autocorrelation exceeding these bounds is different from zero at the 95% level. One such autocorrelation occurs at t = 6.

$$[a_t] = Z_t - \hat{Z}_{t-1} \quad (1)$$

$$[a_{t+j}] = \begin{cases} a_{t+j} & j \le 0 \\ 0 & j > 0 \end{cases}$$

$$[Z_{t+j}] = \begin{cases} Z_{t+j} & j \le 0 \\ \hat{Z}_{t(j)} & j > 0 \end{cases}$$

Rewriting (13) in difference equation form,

$$\log Z_t - \log Z_{t-1} = \log a_t - \theta\log a_{t-6}$$

$$\log Z_t = \log Z_{t-1} + \log a_t - \theta\log a_{t-6}$$

Similarly,

$$\log Z_{t+\ell} = \log Z_{t+\ell-1} + \log a_{t+\ell} - .4757 \log a_{t+\ell-6}$$

Now to obtain the mean square error forecast at lead time $\ell=1$ quarter and origin say 1976 I, the above expression can be written

$$(14) \quad \log \hat{Z}_t(1) = \log Z_t + \log a_{t+1} - .4757 \log a_{t+1-6}$$

More explicitly,

$$\log \hat{Z}_{1976I}(1) = \log Z_{1976I} + \log a_{1976II} - .4757 \log a_{1974IV}$$

$$= \log 3919 + 0 - .4757 (\log 2825 - \log 3173)$$

$$= 8.273592 - .4757 (7.946264 - 8.062438)$$

$$= 8.3288559$$

The antilog of 8.3288559 = 4139 which means that the forecast for the second quarter of 1976 at origin 1976I is $41.39. Equation (14) above can be used to make one step ahead forecasts as new data becomes available. Through appropriate substitutions of the conditional expectations $\hat{Z}_t$ for Z_t in equation (14), updated forecasts of all future quarters can be made. Via this method, forecasted prices for the third and fourth quarters of 1976 at time origin 1976(I) are $42.22 and $38.88, respectively.

A comparison of actual and predicted values for this model are presented in Table 5-A. An examination of the mean square errors (MSE) indicate that the forecast error gets larger as the number of quarters ahead, for which the forecasts are made, increases. This makes intuitive sense. The farther away from the data base is the forecast, the more tenuous is the prediction since there is more opportunity for a variety of influences to come into play.

The one quarter ahead forecast has a MSE of 18.64. This means that the root mean square (RMS) error during the turbulent years from 1972 through 1975 is approximately $\sqrt{18.64} \approx \$4.32$.

The two quarter ahead forecast has a MSE of 38.52, indicating the RMS error for the given years is $\sqrt{38.52} \approx \$6.21$.

The RMS error for a three quarter ahead forecast is $\approx \$8.82$. The RMS error for a four quarter ahead forecast is $\approx \$10.30$.

Figure 5-E is a graphical comparison of the two quarter ahead and four quarter ahead forecasts for the output series model versus the actual series.
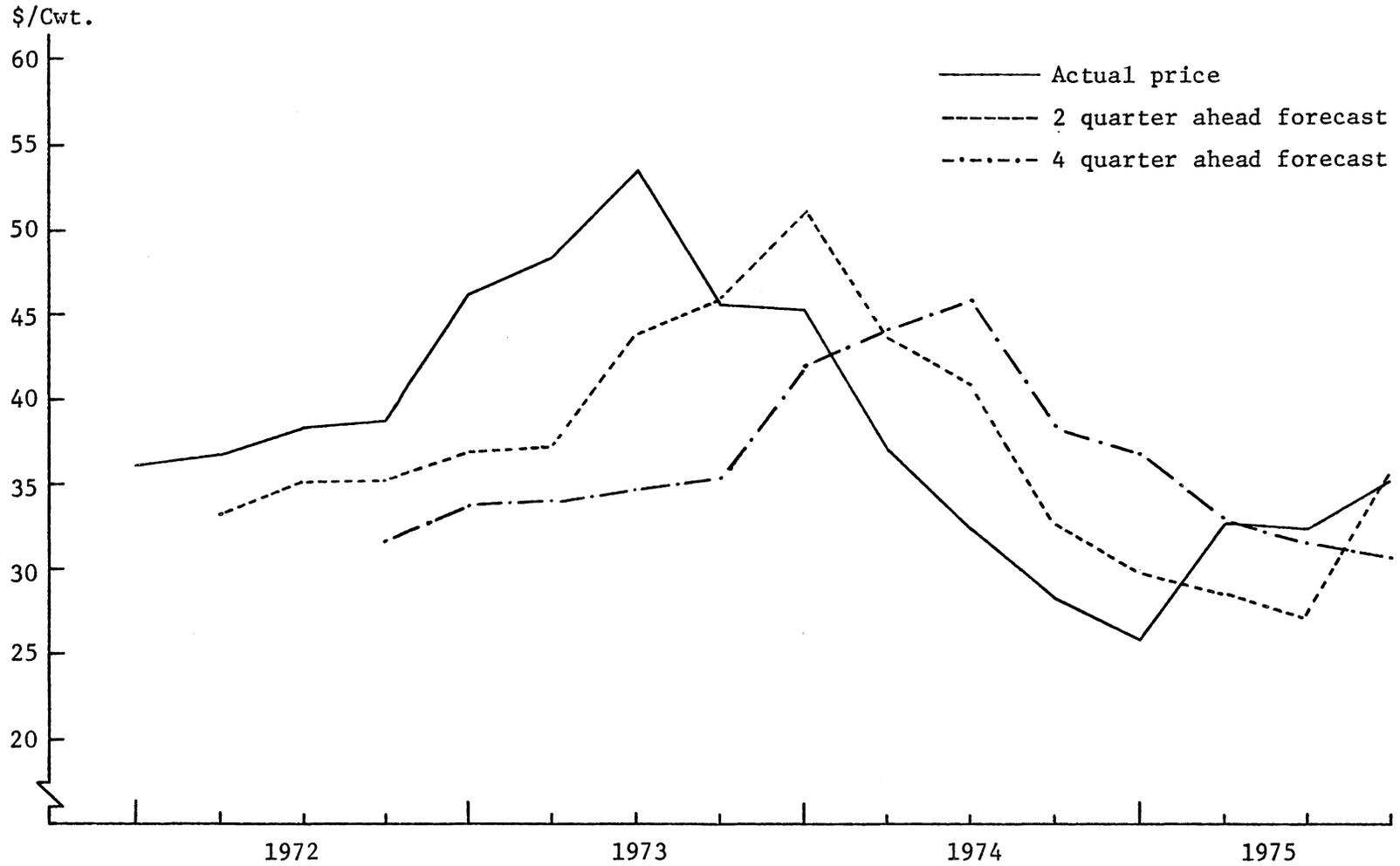
Figure 5-E.   Actual Feeder Cattle Prices per Cwt. Versus Two Quarter Ahead Forecast Output Series
Model and Four Quarter Ahead Forecast Output Series Model, 1972-1975

TABLE 5-A

OUTPUT SERIES FORECASTS
SEASONAL MODEL

Price of Feeder Cattle, All Weights, in Cents per Cwt.

-------- 1972 --------				
Actual	3606	3672	3833	3888
Predicted				
1 Qt. Ahead	3348	3565	3610	3750
2 Qt. Ahead		3310	3505	3533
3 Qt. Ahead			3254	3429
4 Qt. Ahead				4184
-------- 1973 --------				
Actual	4628	4855	5355	4564
Predicted				
1 Qt. Ahead	3822	4519	4687	5280
2 Qt. Ahead	3687	3733	4363	4621
3 Qt. Ahead	3473	3601	3603	4302
4 Qt. Ahead	3371	3391	3476	3553
-------- 1974 --------				
Actual	4536	3694	3238	2825
Predicted				
1 Qt. Ahead	4436	4459	3373	3173
2 Qt. Ahead	5132	4361	4071	3260
3 Qt. Ahead	4491	5045	3982	3935
4 Qt. Ahead	4181	4415	4606	3848
-------- 1975 --------				
Actual	2572	3261	3235	3518
Predicted				
1 Qt. Ahead	2651	2757	3227	3538
2 Qt. Ahead	2978	2842	2727	3529
3 Qt. Ahead	3059	3192	2812	2983
4 Qt. Ahead	3693	3279	3158	3075
-------- 1976 --------				
Actual				
Predicted				
1 Qt. Ahead	3563			
2 Qt. Ahead	3583	3766		
3 Qt. Ahead	3574	3787	3821	
4 Qt. Ahead	3021	3777	3842	3527

The Transfer Function Model

In a transfer function model, it is assumed that it is impossible to realistically consider a series to be a function of only itself. The transfer function expresses the output series, Y_t, as a function of an input series, X_t, plus a noise series, N_t.

Transfer functions work best when the input series is a "leading indicator" of the output series. Since futures prices for feeder cattle are not available for a suitably large data base, another input series was used.

Initially, it was felt that the analytically reduced form for the price of feeders derived from the structural model would serve well as an input series since the reduced form is really a linear combination of variables considered to be important in the determination of the price of feeders. In fact, the analytically reduced form input series did render satisfactory results until 1973. Beginning in 1973 though, the reduced forms produced a gruesome substitute for the actual series, having a significant downward bias accompanied by a large variance. The reduced forms were thus abandoned as a candidate for the input series of the transfer function in favor of the first stage OLS equations from the TSLS estimation of the feeder cattle structural model. Figure 5-F is a comparison of the actual price of feeder series with the analytically reduced form series and the OLS series. The graph indicates why the OLS series was favored over the analytically reduced form series.
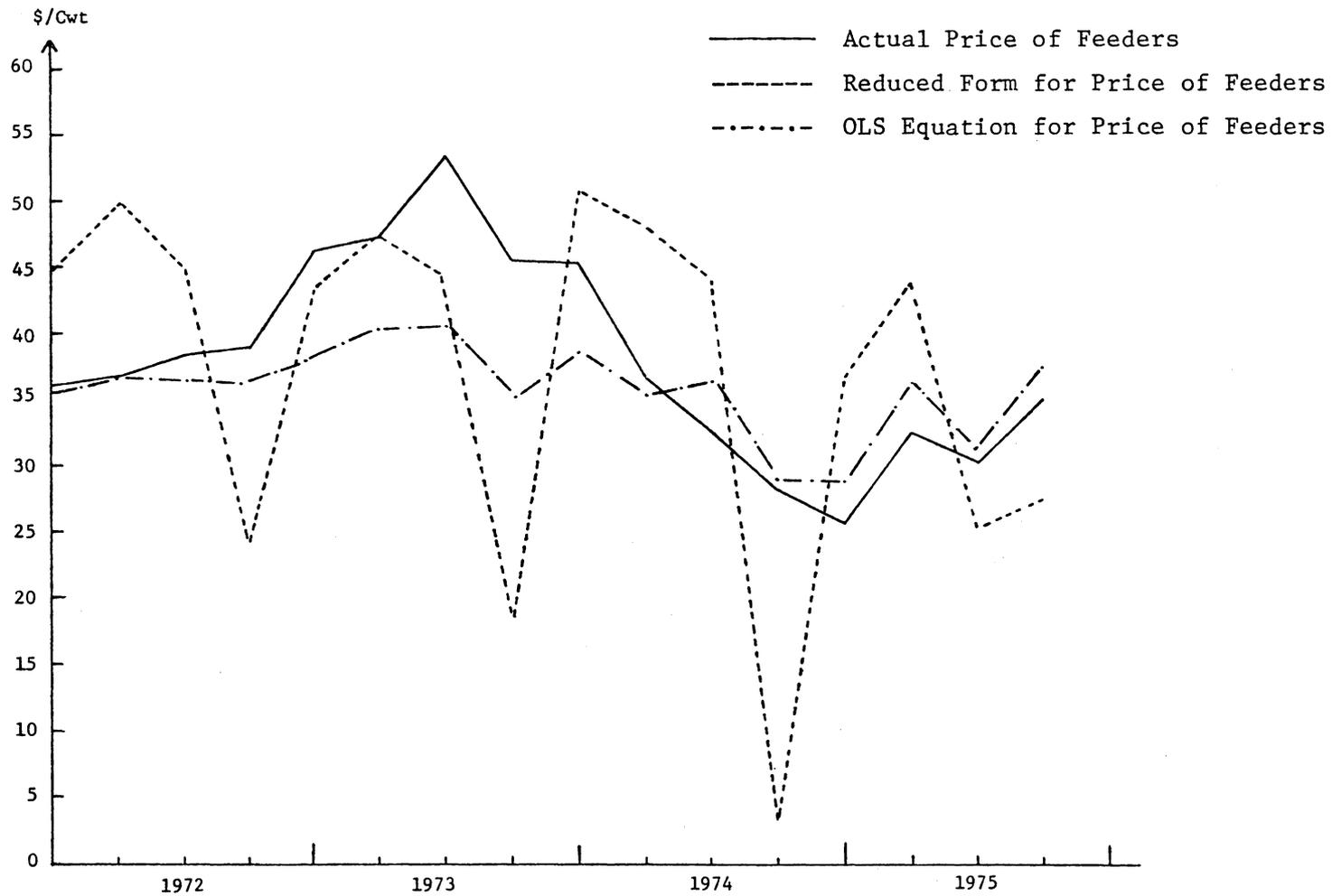
Figure 5-F. Comparison of Actual Price of Feeders, Analytically Reduced Form for Price of Feeders, and the First Stage OLS Equation for Price of Feeders, 1972-1975.

The first stage of a TSLS estimation expresses one endogenous variable in terms of all the predetermined variables in the system. Recalling equations (12) and (13) from Chapter III, the endogenous price of feeders is expressed as a function of the predetermined variables:

PCN, SLPCRN, PFC, PFC_{t-2}, Q4, TM, PCV_{t-4}, HSB, HSB2, HSB3, and HSB4.

The input series used in the transfer function was generated by the OLS coefficients estimated from the following equation, based on data from 1960 through 1975, but omitting the four quarters in 1973 and the first quarter of 1974 as outliers.

(15) $PF = 1589.98 + .2543\ PCV_{t-4} - .0938\ HSB - .0007\ HSB2$

$\qquad\qquad\qquad\qquad 3.81 \qquad\qquad -2.84 \qquad\quad -.21$

$\qquad -.0026\ HSB3 + .0019\ HSB4 + 18.62\ TM + .8913\ PFC$

$\qquad\quad -.74 \qquad\qquad\quad .38 \qquad\qquad 2.97 \qquad\quad 6.12$

$\qquad + .2938\ PFC_{t-2} - 891.06\ PCN - 17.80\ SLPCRN - 227.63\ Q4$

$\qquad\quad 2.09 \qquad\qquad -3.03 \qquad\qquad\quad -.09 \qquad\qquad -1.47$

$$R^2 = .91$$

$$DW = .86$$

The transfer function ultimately identified used a log transformation on the data due to the same reasons which appear in the seasonal

model discussion. Expressed in the general form of equation (11), the empirically estimated transfer function is:

(16) $\quad \nabla \text{Log } (Y_t) = [(.8601 + .2728B) \text{ Log } X_t] + [(.3319B^6) \text{ Log } a_t]$

The parameters .8601 and .3319 were significant at the 95% level; the other parameter was significant at the 90% level. This was considered very satisfactory considering the small number of observations and the fact that the latter parameter assumed a value which was more difficult to discriminate from zero. Although the former model lent itself to a fairly intuitive description in terms of applying the parameter estimates to the feeder cattle series, the transfer function model offers no such intuitive appeal. A one quarter ahead forecast equation is available but a somewhat complicated discussion of transformations and conditional expectations would be required. As an alternative, the interested reader should consult Box and Jenkins text, pp. 403-405 for a more thorough treatment.

A chi-square test at the 95% level confirmed that the estimated residuals were not significantly different from white noise. Evidently then the transfer function model succeeded in reducing the observed series to a white noise process through judicious selection of parameter values.

An additional check of whether the transfer model specification is correct is to examine the cross-correlations between the pre-whitened input series and the estimated residuals. These cross-correlations were not significantly different from zero.

Again the problem of comparing the actual series with the fore-
casted series arises as in the case of the seasonal model. In similar
fashion, a few of the most recent years were selected and the fore-
casts of up to 4 quarters from the forecast origin are displayed in
Table 5-B.

As in the case of the output series forecasts, the transfer
function forecasts converge to the actual value as the length of the
forecast period decreases. The one quarter ahead forecast for the
volatile years 1972 through 1975 indicated a mean square error of
23.68 which implies a RMS of $\approx$\$4.87. The two quarter ahead forecast
produced a mean square error of 46.72, or a RMS of $\approx$\$6.84. The three
quarter ahead forecast produced a RMS of \$9.03. The RMS for a four
quarter ahead forecast was $\approx$\$10.70.

Although the MSE's of these two predictive models give some
indication of how well the forecasts perform, another benchmark for
comparison is offered in the form of a dissertation by Joe T. Davis
and an article by Leuthhold, previously cited. Leuthhold found for
live cattle that current cash price was a more accurate predictor
of future cash prices than the futures market for periods longer than
4 months. For periods less than 4 months, he found that the futures
market was a better predictor of future cash prices. Leuthhold used
MSE as his basis for evaluation.

Apparently the only attempt, other than this study, at fore-
casting feeder cattle prices is the Davis study. However, direct com-
parison with Davis' forecasts would be difficult due to the technique
he employed. Davis offered three predictive models. Recognizing that

TABLE 5-B

TRANSFER FUNCTION FORECASTS

Price of Feeder Cattle, All Weights, in Cents per Cwt.

——————————————— 1972 ———————————————				
Actual	3306	3672	3833	3888
Predicted				
1 Qt. Ahead	3329	3590	3608	3750
2 Qt. Ahead		3292	3514	3524
3 Qt. Ahead			3236	3440
4 Qt. Ahead				3169
——————————————— 1973 ———————————————				
Actual	4628	4855	5355	4564
Predicted				
1 Qt. Ahead	3822	4527	4689	5277
2 Qt. Ahead	3677	3713	4340	4596
3 Qt. Ahead	3458	3578	3576	4274
4 Qt. Ahead	3377	3366	3446	3521
——————————————— 1974 ———————————————				
Actual	4536	3694	3283	2825
Predicted				
1 Qt. Ahead	4403	4521	3663	3638
2 Qt. Ahead	5141	4361	4179	3550
3 Qt. Ahead	4493	5060	4048	4030
4 Qt. Ahead	4179	4422	4697	3903
——————————————— 1975 ———————————————				
Actual	2572	3261	3235	3518
Predicted				
1 Qt. Ahead	2966	2761	3275	3408
2 Qt. Ahead	3542	3135	2730	3472
3 Qt. Ahead	3466	3765	3011	2923
4 Qt. Ahead	3820	3685	3616	3142
——————————————— 1976 ———————————————				
Actual				
Predicted				
1 Qt. Ahead	3604			
2 Qt. Ahead	3452	3806		
3 Qt. Ahead	3502	3672	3883	
4 Qt. Ahead	2949	3726	3746	3576

the dependent variable and most of independent variables were contemporaneous as he specified his model, he reformulated the model to accommodate the lack of data on the independent variables for making forecasts. Keeping the same coefficients, all of the independent variables were lagged one quarter. The third predictive model lagged all of the independent variables two quarters. In essence, Davis was assuming a random walk for all of the independent variables. It would seem logical to extend that implicit assumption to the dependent variable as well, in which case, the Davis model would be equivalent to using the cash price in one quarter as the best forecast for the succeeding quarter. Had Davis assumed this, his model would approach Leuthhold's statement that the current cash is a better predictor than the futures market. Parenthetically, two other comments might be made on the Davis models. First, the models are only capable of forecasting two quarters in advance. Secondly, his results indicated a smaller MSE on the two quarter ahead forecast than on the one quarter ahead forecast. This seemed peculiar.

The Leuthhold study and the implicit nature of the Davis study argue for comparison of the MSE among the forecasting models presented herein and that of a random walk model. In the latter, of course, the actual price of feeders serves as the estimator for succeeding quarters.

Table 5-C presents a summary of the MSE's for the three models. It is seen that the output series model consistently has the lowest MSE, the transfer function ranks second in overall performance.

TABLE 5-C

MEAN SQUARE ERROR

Forecasts	Output Series Model	Transfer FCN Model	Random Walk Model
Ahead 1 Qt.	18.64	23.68	21.44
Ahead 2 Qt.	38.52	46.72	49.35
Ahead 3 Qt.	77.79	81.50	101.41
Ahead 4 Qt.	106.14	114.42	154.63

U-coefficients based on data from 1972-1975 were also computed

for the one, two, three, and four quarter ahead forecasts of both

the output series model and the transfer function model. The U-

coefficient is a measure of how well the forecast function picks up

turning points. It accounts for the seriousness of a prediction error

through the quadratic loss criterion in such a way that the zero cor-

responds with perfection and the unit with the loss associated with

no-change extrapolation. The coefficient as defined below has no

finite upper bound, which means that it is possible to do considerably

worse than by extrapolating on no-change basis. A presentation of the

U-coefficients are given in Table 5-D. It can be seen that only in

one case, the two-quarter ahead forecast of the output series model,

was the model a better predictor than a no-change extrapolation. The

other coefficients were very close to unity, indicating a close cor-

respondence to a random-walk model when judged on the basis of a

quadratic loss criterion.

The input series in the transfer function model, recall, was

an OLS series with a truncated data base (1973 and the first quarter

of 1974 were omitted). Since the transfer function offered more

flexibility and opportunity for improvement of forecasts under dif-

ferent input series, it was decided that the transfer function fore-

cast would be used in formulating the hedging strategies discussed

in the next Chapter.

TABLE 5-D

U-COEFFICIENTS DATA BASE 1972-1975

	Output Series Model	Transfer Function Model
1 Quarter Ahead	1.29	1.32
2 Quarters Ahead	.96	1.06
3 Quarters Ahead	1.43	1.42
4 Quarters Ahead	1.22	1.24

CHAPTER VI

INCORPORATING THE FORECAST FUNCTION INTO THE DEVELOPMENT

OF A FUTURES MARKET STRATEGY

Unstable prices not only make forecasting difficult, they have contributed to both substantial gains and losses to producers in the feeder cattle market during the last few years. The thousands of small cow-calf operators in Virginia may not be able to sustain heavy losses. It would seem desirable to develop, if possible, a strategy which has as its goal a reduction in income variance without a substantial reduction in average income in the trade-off.

In order to accommodate the majority of producers and to incorporate the futures market in the development of a mangement tool, it was assumed that the two months of greatest trading interest are October and April. In fact, they are the heaviest trading contract months in feeder cattle futures.

Most feeder producers do not make use of the futures market. In effect, they are speculating in the cash market, betting that the cash price at the time of delivery (April or October) will be high enough to cover costs and make an adequate rate of return.

The returns under three different conservative strategies will be compared to an exclusively cash market operation in the following situation. A producer is assumed to own 450 lb. calves in October.

He must decide at that time whether to hold the calves until April, at which time they will weigh about 600 lbs. He then must make a second decision on whether to hold the animals for another six months, until October, when he would sell them as 750 lb. feeders. The above two decisions will be determined by the following strategies and will be evaluated by calculating the difference between revenue generated under a particular strategy and a break-even point (henceforth BEP) which serves as a cost of operation estimate.[1] Calculation of actual BEP's and estimates of BEP, designated $\widehat{BEP}$, are presented in Table 6-A. The only difference between BEP and $\widehat{BEP}$ is that $\widehat{BEP}$ is an estimate of the break-even point based on the previous quarter's hay price. BEP is the actual break-even point which is based on the actual hay prices that exist during the quarters in which the cattle feeding operation takes place. $\widehat{BEP}$ is used in the strategy decision process while BEP serves as the basis against which profits and losses are calculated.

It should be noted that in the calculation of the profitability of the various strategies, the simplifying assumptions of zero basis on both 600 lb. and 750 lb. feeder cattle can be made in using the futures markets. In fact, there is a discount on animals of heavier weight.

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[1]BEP calculation is based upon a series of publications by James M. Moore of the Cooperative Extension Service, Virginia Poly-Technic Institute and State University. His budgets have been modified somewhat for the sake of convenience.

TABLE 6-A

CALCULATION OF BREAK-EVEN PRICE

October - April For Raising a 450 lb. steer to 600 lbs.

October (Oklahoma City) Price 450 lb. calf   = $_____

Feed

    Hay   .375 tons @ _____ per ton   =   _____

    Salt   1.00
                                                           Subtotal

Interest (12% per annum) = 1.06 x subtotal   =   _____

Other variable costs

    5.87¢/day x 180 days   10.57

    Fixed cost and management   14.46
                                                             Total

    BEP = Total/6 cwt.

April - October For Raising a 600 lb. steer to 800* lbs.

April (Omaha) Price 600 lb. choice steer   = $_____

Variable expense   8.60

Pasture rent   25.000
                                                            Subtotal

Interest (12% per annum) = 1.06 + subtotal   =   _____

Marketing   3.50

Fixed cost and management   6.80
                                                            Total

    BEP = Total/8 cwt.

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*Additional assumptions: BÊP is calculated by using average hay price from the previous quarter rather than the actual hay price for a 6 month period.

Also, 800 lb. choice steers are assumed to have approximately the same fixed and variable costs per cwt. as 750 lb. steers.

Strategy I

(1) The producer will hold the 450 lb. calves in a cash posi-
tion until April when the April futures contract for feeders is $\geq$ B$\hat{\text{E}}$P.
The April futures contract price used on the decision rule will be
the average April contract price during the last week in October.
When trading in the April futures does not begin until November, the
first April futures quotation that becomes available will be used.
If the April futures contract price is < B$\hat{\text{E}}$P, the producer will sell
his 450 lb. calves at the current market price during October.[2] In
this latter event, the producer will not be engaged in the enterprise
of raising feeders for at least 6 months and consequently he experi-
ences zero profit (and loss) on his feeding operation for that time
period. In all succeeding strategies as well, a decision to sell
rather than feed will be indicated by a zero profit on the feeding
operation for that time period.

(2) In April the producer may enter (or maintain) his feeder
production. He will decide to hold his herd, now at 600 lbs. when the
October futures contract price $\geq$ B$\hat{\text{E}}$P. It is assumed that the producer
can purchase 600 lb. cattle in April if the situation looks favorable,
even if he sold his 450 lb. calves due to decision rule (1). The
October futures contract price used in the decision rule will be the
average price for the contract during the last week of April. If

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[2]In some years, the April futures contract is not traded until
November. In this case, the first April futures trade that becomes
available is used in the decision rule.

the October futures price is < B$\hat{E}$P, the producer should sell his 600

lb. animals at the current price for feeders during April.

Strategy II

(1) The producer will hedge using the April contract month if

at any time during October (or the first trade in November if the

April contract is not introduced until then) the April futures price

≥ B$\hat{E}$P. Otherwise the producer will sell his 450 lb. calves at the

current price during October.

(2) In April, the producer decides to hedge his herd, now at

600 lbs., if at any time during April, the October futures price

≥ B$\hat{E}$P. Otherwise the producer will sell his 600 lb. calves at the

current price during April.

Strategy III

(1) The producer will hedge using the April contract month if

at any time during October (or the first trade in November if the

April contract is not introduced until then) the April futures price

is ≥ both the upper bound on the 75% confidence limit for the April

(2 quarters ahead) price forecast and B$\hat{E}$P.

He will maintain a cash position if the April futures price is

≥ B$\hat{E}$P but < the 75% bound.

Otherwise the producer will sell his 450 lb. calves at the cur-

rent price during October.

(2) In April, the producer decides to hedge his herd, now at

600 lbs., if at any time during April the October futures price ≥ both

the upper bound on the 75% confidence limit for the October (2 quarter

ahead) forecast and B̂EP. He will maintain a cash position if the

October futures price, averaged during the last week of April $\geq$ B̂EP.

Otherwise the producer will sell his 600 lb. feeders at the

current price during April.

Table 6-B summarizes the data needed for calculation of profits

and losses involved in each strategy. Table 6-C is a presentation

of the results for each strategy in addition to the results generated

under an exclusively cash operation. The cash operation essentially

involves speculation in the cash market in the manner mentioned pre-

viously.

An example of the use of Table 6-B in the calculation of profits

or losses shown in Table 6-C may better illuminate the essence of the

different strategies.

Consider the October - April period for 1973-74 shown in the

upper section of Table 6-B. $56.28 represents the estimated break-

even point based on the budget given in Table 6-A with the hay price

from July - September, the previous quarter, used in the computation

of this estimate.

Strategy I dictates maintaining a cash position if the average

April futures price during the last week of October is > B̂EP, other-

wise sell. Since the April futures contract price during that month

averaged $53.20 which is < $56.28, under strategy I, the producer

sold his 450 lb. calves and hence made zero profit on a feeding opera-

tion from October 1973-April 1974. This is duly recorded in Table

5-C under strategy I, 1973-74, October - April.

TABLE 6-B

DATA ON STRATEGY CALCULATIONS

OCTOBER - APRIL

	BEP	BÊP	Upper Limit on 75% Conf. Int. for 2nd Qt. Forecast	Avg-Apr Fut. Last Wk. in Oct.-Nov.	Daily Apr. Fut. Ever > BEP and 75% Bound in Oct. - Nov.	Daily Apr. Fut. Ever BEP in Oct.-Nov.	Okla. City 450 lb. Oct. Cash	Omaha 600 lb. Apr. Cash
1972-73	$45.89	$45.52	$41.31	$44.19	$(no)	$(no)	$49.36	$52.72
1973-74	$56.74	$56.28	$57.77	$53.20	$(no)	$(no)	$62.04	$46.10
1974-75	$31.65	$31.63	$38.99	$32.50	$(no)	$32.50	$30.16	$31.69[a]
1975-76	$35.65	$36.38	$38.78	$36.00	$(no)	$(no)	$36.04	$39.69[b]

APRIL - OCTOBER

	BEP	BÊP	Upper Limit on 75% Conf. Int. for 4th Qt.	Avg. Oct. Fut. Last Wk. in Apr.	Daily Oct. Fut. Ever > BÊP and 75% Bound in Apr.	Daily Oct. Fut. Ever > BÊP in Apr.	Omaha 600 lb. Apr. Cash	Omaha 750 lb. Oct. Cash
1972	$37.64	$37.64	$39.48	$36.40	$(no)	$(no)	$40.63	$41.69
1973	$47.65	$47.65	$48.77	$51.95	$50.20	$50.20	$52.72	$51.33
1974	$42.39	$42.39	$46.96	$41.48	$47.00	$44.80	$46.10	$31.58
1975	$30.93	$30.93	$30.68	$32.50	$31.90	$31.90	$31.69	$38.09[a]
1976	$37.29	$37.29	$42.76	$43.80	$44.88	$44.88	$39.69	?

[a]Price for 600-700 lb. steer, Kansas City.

[b]Average price in March, since this was the latest quotation at this writing.

TABLE 6-C

PROFITS AND LOSSES GENERATED UNDER VARIOUS STRATEGIES[a]

1972 - 1975

(on a per head basis)

	OCTOBER - APRIL				APRIL - OCTOBER			
	Strategy I	Strategy II	Strategy III	Exclusively Cash	Strategy I	Strategy II	Strategy III	Exclusively Cash
1971-72	Feeder Futures not yet Available				$ 0	$ 0	$ 0	+30.38
1972-73	0	0	0	+40.98	+27.60	+19.20	+19.20	+27.60
1973-74	0	0	0	-63.84	0	+18.07	+34.58	-81.08
1974-75	+.36	+5.22	+.36	+ .36	+53.70	+ 7.28	+ 7.28	+53.70
1975-76	0	0	0	+24.24				

	Mean Income/Head	Standard error Including zeroes	Standard error Excluding zeroes
Strategy I	10.21	18.75	27.63
Strategy II	6.22	7.56	8.82
Strategy III	7.68	11.97	15.08
Exclusively Cash	4.03	43.33	43.33

[a] It should be noted that the criterion of maximizing profit on the feeding operations is not necessarily the best. A better criterion may be to maximize the returns to fixed resources.

Under strategy II, the producer hedges if the April futures price ever exceeds the B$\hat{E}$P in October or November. In 1973, this never happened. As part of the strategy, the producer would elect again to sell the 450 lb. animals in October or November. Again this shows up in Table 6-C as a zero profit on cattle feeding operations in October to April.

Following strategy III, the producer would hedge if the April futures price ever exceeded both B$\hat{E}$P and the 75% upper bound on the price forecast during the months of October or November. This did not happen in 1973 so this strategy also led to a zero profit in cattle feeding operations during this six month period.

The benchmark for comparison is the strategy presumably employed by a great number of cow-calf operators, i.e. engage in a cattle feeding operation at all times. Under this strategy, the producer always engages in the feeding enterprise, accepting the risk of a loss determined by prices which exist in the cash market at the time he sells. The revenue which is received when the producer sells in the cash market in April 1974, based on quotations at Omaha is $46.10 per cwt. This implies that a producer who engaged in a cattle feeding operation incurred a loss of 6 · ($46.10 − $56.74) = $−63.84 on a 600 lb. animal. This loss is recorded in the Exclusively Cash column in Table 5-C which corresponds to the October − April period for 1973-74.

Another example more fully demonstrates the differences in profits which can occur. Again consider the year 1974 but this time the April to October feeding season. BEP = B$\hat{E}$P during the April −

October period of the year based on the budgets presented in Table 6-A. The budget for this period assumes that no hay need be purchased.

Under strategy I, the decision would have been made not to feed cattle since the price of the October futures during the last week of April averaged $41.48 which was less than the B$\hat{E}$P of $42.39. In the profit/loss Table 6-C, strategy I registers a zero for this period.

Strategy II on the other hand would have led to the locking in of a fairly good profit. Recall the strategy dictates the selling of a futures contract if the October futures in April ever exceeds BEP. In fact this occurred on April 1, at which time the October futures traded for $44.80 per cwt. Since actual B$\hat{E}$P for the April - October period was calculated to be $42.39, the total profit received on the cattle feeding operation equaled (7.5 cwt) · ($44.80 - $42.39) = $18.07. This figure appears in the appropriate cell in Table 6-C.

Following strategy III in April 1973, the producer would hedge if the October futures price in April ever exceeded both B$\hat{E}$P and the upper 75% bound on the October forecast. The upper bound of that forecast was $46.96. The October futures exceeded that bound on April 11 with a trade of $47.00. Thus under strategy III a per head profit of (7.5 cwt) · ($47.00 - $42.39) = $34.58 was locked in through the futures market. This contrasts markedly with the following exclusively cash operation.

If the producer decided to speculate in the cash market by feeding his 600 lb. steers to 750 lbs. during the April - October 1974 feeding period, he would have experienced the substantial loss of

(7.5 cwt.) · ($31.58 - $42.39) = $-81.08 per head since the cash price per cwt. on choice feeders had fallen to $31.58 by October, 1974.

The above examples illustrate the computations involved in arriving at Table 5-C. An overall evaluation of the different strategies may be gleaned from the summary statistics presented in the lower half of Table 5-C, though it should be noted that the computations were based on a very small number of observations.

The highest mean income of $10.21/head was generated through the use of strategy I. That ranking was obtained through an extremely profitable April - October 1975 season which resulted in a profit of $53.70. That fact is reflected in the standard error for strategy I. The standard error for strategy I including the feeding season in which the strategy dictated an abstention from a feeding cattle operation, hence a zero profit, was $18.75. If the standard error is calculated only for those seasons in which the producer actaully engaged in the operation of feeding cattle, the standard error was a very large $27.63, though based on only 3 observations.

Strategy III offered a mean income of $7.68/head and ranked second over the 1972-75 period. Although the mean income was significantly lower than in strategy I, the standard errors were significantly lower as well with an $11.97 standard error for all eight seasons of the analysis and a $15.08 standard error for the four seasons in which the feeding operation was implemented under the strategy.

Strategy II ranked third with a mean income of $6.22 for the period of study but this strategy rendered the lowest standard errors

of $7.56 and $8.82 for all eight seasons and the four seasons in which the feeding operation was implemented, respectively.

It is noteworthy that most of the profit generated through strategies I, II, and III occur in the April - October feeding season when producers are not forced to purchase hay as must be done in the winter months.

The exclusively cash strategy resulted in a mean of $4.03 per head with a standard error of $43.33. Presumably this is the strategy that a substantial community of cow-calf operators employ. The results under this strategy under the volatile years 1972-1975 are perhaps the most telling justification for research which presents the producers with strategical alternatives which demonstrate the trade-offs between the mean and variance of income in the enterprise of cattle feeding.

An interesting footnote might be added to this study. It was implied through a comparison with Leuthhold's article, that the forecast models for feeder cattle prices may predict better than the futures market. A comparison of the MSE's among the forecasting models and the futures market was made for the eight semi-annual feeding periods during which the three strategies were evaluated, i.e., 1972-1975. The futures market forecast for October was taken to be the price of that contract averaged during the previous April. The futures market forecast for April was taken to be the price of that contract averaged during the previous October or the first available quotation in November when there were no trades on the April contract during October. The forecast models used two quarter ahead

forecasts to predict second and fourth quarter prices representing April and October, respectively.

Both the output series and transfer function forecasting models had lower mean square prediction errors than the futures market for this period. The futures market exhibited a MSE of 74.74, the output series model a MSE of 29.34, and the transfer function model a MSE of 5.80. It will be interesting to observe whether the forecasting models will continue to outperform the futures market as the data base expands.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This study was an attempt to develop a price forecasting model for feeder cattle in the United States. A structural model was developed in order to provide the basis for isolating the most important variables affecting price in the feeder cattle sector. A linear combination of these variables would then serve as an input series in the more sophisticated methods developed expressly for forecasting. A brief summary of the findings and conclusions are presented in this Chapter.

Summary

Structural Model

The structural model of the feeder cattle market was hypothesized to be a demand derived from retail beef. A system of nine equations described the simultaneous interaction among three market levels: retail beef, wholesale carcass beef and fed cattle. By virtue of a six month production lag between feeder and fed weights, feeder cattle entered the supply of fed cattle as a predetermined variable. This allowed the feeder cattle market to be estimated separately from the first block of nine equations. The price of fed cattle could enter the demand for feeders recursively.

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The simultaneous block of nine equations was theoretically discussed but not estimated empirically since it was intended only as the vehicle through which the derived demand nature of the feeder cattle market was presented. Primary emphasis was placed on developing a forecasting model rather than constructing a model of the entire beef-cattle sector.

The herculean objective initially was to obtain a stable structure for the feeder cattle market, reestimate the coefficients upon expanding the data base for the five successive years 1971-1975, and use the analytically reduced forms as input series in a forecasting model.

Through 1972, problems were minimal. A structure with all of the "correct" theoretical signs was achieved fairly readily and the analytically reduced forms provided very satisfactory results. When 1973 was added to the data base, the model began to strain in terms of weak t-statistics and unstable coefficients on the variables. Adding 1974 and 1975 to the data base produced such bizarre results that rebuilding the structure to accommodate all of the tumultuous 1970's was no mean task. (In another sense it was extremely mean). Eventually a structure which could contain the volatile years was achieved, although there were one or two variables with the wrong theoretical sign. However, when the analytically reduced forms were computed for 1975, the forecasted series which resulted was singularly disastrous. The variables employed in the structural estimation for the most part come into the equations estimated from 1971-1975 as significant and of the proper theoretical sign. This fact seems

remarkable given the unstable conditions and serves to justify the presence of the variables in a structure of the feeder cattle industry.

In order to obtain an input series for the forecast model, the original plan of depending on the structure only to indicate the most important variables affecting feeder prices was reinstated. The first stage of the two-state least squares estimation was employed as an estimator of the price of feeders. In fact, this single equation ordinary least squares technique proivded a fairly good series of estimates for the price of feeders.

The so-called Box-Jenkins methods provided the basis for formulating three different forecasting models. The simplest model was the fitting of an autoregressive, moving average, or autoregressive-moving average model to the output series, feeder prices, itself. The model which was identified was a random-walk, which suggests that the best (minimum MSE) forecast of next quarter's price is the present quarter's price. This forecast of course proved to be of questionable value and the search continued for a better predictor.

A seasonal model was identified in which a moving average parameter was discovered at period 6. This meant that the present price is correlated with the price six quarters previous. The suggestion that there is a lag in production response of six quarters in the feeder cattle market seems very appealing. The forecasted series based on this relationship performed fairly well.

A transfer function model was constructed using the estimated price of feeders as an input series. A transfer function is warranted

when it is impossible to assume that a time series is a function only of itself. It was felt that a linear combination of variables which significantly affect the price of feeders would be a valuable adjunct to the output series itself in explaining the variation in the price of feeders. The forecast performed quite well given the limited number of observations which are required to estimate the parameters in the model.

Development of Futures Market Strategies

Three strategies were developed to reduce income variance of feeder cattle producers. They were evaluated by comparing the profits or losses generated over the six month intervals October - April and April - October. Cost estimates were obtained through budgets constructed by Cooperative Extension personnel. The revenue side of the ledger was of course determined by the particular strategy involved.

Perhaps the true benchmark for comparison of the strategies was the exclusively cash operation which many small cow-calf operators employ. These producers in effect speculate in the cash market by betting that the price of their finished product (a 600 lb. - 750 lb. feeder) will be high enough to reward their efforts.

In the years that were tested, 1972-1975, the strategy that paid the highest average return was the strategy which recommended a cash position when the two quarter ahead futures price exceeded the current $\hat{BEP}$. Strategy III, which employed futures market entry when warranted by the forecast model predictions, ranked second in mean income per head but had a lower variance than Strategy I. Noteworthy

is the fact that the lowest average return was generated by the modus

operandi engaged in by most small producers, the exclusively cash

market operation.

Conclusions

Based on the structural model, some of the more important vari-

ables in the determination of the price of feeder cattle are the in-

ventory of heifers, steers and bulls under 500 pounds, the price of

corn, the price of fed cattle, the price of fed cattle lagged two

periods.

In forecasting the price of feeder cattle, analytically reduced

forms are of limited value and a better policy would seem to be using

a simple OLS model to generate an estimator of the price of feeders.

An OLS estimator can then be used as an input series in the

transfer function forecasting model. If a leading indicator series

can be found which can be used as an input series the transfer func-

tion model will perform at its best. The futures market seems an

ideal source for such a series but the data base is not large enough

at this time to incorporate futures prices in a feeder cattle price

forecast function.

A few simplistic strategies incorporating futures markets in

conjunction with price forecasts hold promise for not only reducing

the income variance which would be experienced under an exclusively

cash market operation, but also in raising the average income re-

ceived by producers of feeder cattle. Further research in the area

of developing strategies seems encouraging.

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APPENDIX TABLE A

DATA BASE

Year and Quarter	FDPL22[a]	PALLFS[b]	PFC113[c]	PCV35[d]	HSB[e]	PCORN[f]	SOF[g]	PHAY[h]
	(000) hd.	--------- cost/cwt. --------			(000) hd.	$/bu.	(000) hd.	$/ton
1960 I	2687	24.18	26.49	30.20	22813	0.99	1071	23.60
II	2024	24.10	26.94	30.02		1.07	1261	22.30
III	2693	21.48	24.50	26.57		1.07	587	20.00
IV	5366	22.91	25.12	27.54		0.92	1168	21.30
1961 I	2699	24.20	25.87	29.01	23120	0.99	1168	21.60
II	2229	22.79	23.33	28.71		1.01	1420	20.10
III	3157	22.50	23.14	27.53		1.04	561	19.90
IV	5485	23.33	24.75	28.49		0.97	543	20.90
1962 I	2804	23.70	26.07	28.63	28032	0.96	1186	22.20
II	2411	24.11	25.85	29.38		1.02	1508	21.20
III	3494	24.53	27.70	24.77		1.03	762	19.70
IV	6071	25.30	28.94	32.60		0.98	659	21.20
1963 I	2761	23.90	24.44	31.01	25437	1.05	1402	23.20
II	2592	23.04	22.35	29.37		1.11	1764	21.90
III	3574	23.12	24.14	29.51		1.20	831	22.30
IV	5776	21.49	22.54	28.42		1.06	1384	24.30
1964 I	3395	21.20	21.04	27.15	26619	1.10	1384	24.90
II	2643	19.11	20.64	25.20		1.15	1633	22.60
III	3978	19.15	24.37	24.39		1.14	707	21.90
IV	6549	18.87	23.65	23.88		1.09	813	24.00

Year and Quarter	FDPL22[a]	PALLFS[b]	PFC113[c]	PCV35[d]	HSB[e]	PCORN[f]	SOF[g]	PHAY[h]
	(000) hd.	--------- cost/cwt. --------			(000) hd.	$/bu.	(000) hd.	$/ton
1965 I	3742	19.87	23.05	23.55	27530	1.17	1583	25.60
II	3445	22.86	26.10	26.17		1.23	1943	24.50
III	4295	22.90	26.67	27.73		1.19	953	22.20
IV	6885	23.08	25.48	28.05		1.04	808	23.30
1966 I	4602	25.32	26.93	30.08	27752	1.19	1619	24.40
II	3660	25.21	26.01	30.31		1.20	2020	23.10
III	4530	24.86	25.61	30.13		1.32	1057	23.20
IV	7310	24.27	24.05	30.23		1.28	921	24.60
1967 I	4567	24.10	24.14	29.50	28125	1.27	1681	25.30
II	3818	24.56	24.53	29.61		1.26	2151	23.70
III	5024	25.42	26.57	31.12		1.15	1007	22.10
IV	5092	24.27	25.63	30.19		1.02	999	22.90
1968 I	5043	25.04	26.14	29.32	28502	1.05	1821	23.80
II	4407	26.13	26.37	30.19		1.07	2029	22.40
III	5744	25.95	27.60	30.71		1.01	1057	21.50
IV	8190	25.90	27.71	30.53		1.02	1188	22.40
1969 I	5070	27.02	28.17	30.66	28800	1.09	2100	24.20
II	5186	31.34	32.63	35.74		1.16	2367	23.50
III	5752	29.24	29.06	36.07		1.17	1303	22.30
IV	5431	28.87	27.66	35.45		1.09	1298	23.10

Year and Quarter	FDPL22[a]	PALLFS[b]	PFC113[c]	PCV35[d]	HSB[e]	PCORN[f]	SOF[g]	PHAY[h]
	(000) hd.	--------- cost/cwt. --------			(000) hd.	$/bu.	(000) hd.	$/ton
1970 I	5099	31.08	29.29	36.76	29704	1.13	2071	25.00
II	5231	30.99	29.94	38.75		1.18	2347	23.40
III	6136	29.56	30.12	38.72		1.30	1325	22.60
IV	7960	28.57	27.46	37.09		1.33	1354	24.50
1971 I	5709	30.84	30.82	36.35	31723	1.43	2000	25.70
II	5448	31.54	32.36	37.63		1.41	2287	25.40
III	6358	31.63	32.97	37.07		1.22	1410	24.30
IV	8800	33.31	33.39	39.30		1.02	1533	25.40
1972 I	5914	36.06	35.54	45.23	32342	1.09	2254	29.30
II	6350	36.72	35.85	49.51		1.14	2611	30.00
III	6215	38.33	36.09	51.47		1.17	1672	29.20
IV	8824	38.88	34.89	51.92		1.27	1800	34.40
1973 I	6019	46.28	43.05	59.18	32229	1.37	2488	35.13
II	5681	48.55	45.74	65.17		1.67	2694	35.53
III	5274	53.55	48.70	69.27		2.29	1788	39.43
IV	7449	45.64	39.49	57.87		2.25	1608	46.33
1974 I	5792	45.36	45.06	55.70	33942	2.68	1952	46.53
II	3985	36.94	39.46	47.00		2.48	2220	48.70
III	4617	32.83	44.12	36.56		3.19	1334	50.20
IV	6513	28.25	38.35	28.06		3.35	1069	50.83

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Year and Quarter	FDPL22[a]	PALLFS[b]	PFC113[c]	PCV35[d]	HSB[e]	PCORN[f]	SOF[g]	PHAY[h]
	(000) hd.	---------- cost/cwt. ---------			(000) hd.	$/bu.	(000) hd.	$/ton
1975 I	4376	25.72	25.72	26.75	36302	2.86	1365	49.67
II	5082	32.61	32.61	33.69		2.67	1569	54.10
III	6029	32.35	32.35	32.56		2.81	1084	51.00
IV	8317	35.18	35.18	35.38		2.44	1467	50.70

[a]Feeder placements in 22 states, Livestock and Meat Statistics, USDA, ERS/SRS, Agricultural Marketing Service.

[b]Feeder steer prices: weighted average cost per 100 pounds, 8 markets combined, Livestock and Meat Statistics, USDA, ERS/SRS, Agricultural Marketing Service.

[c]Price of choice fed cattle, 1100-1300 pounds, Omaha market, Livestock and Meat Statistics, USDA, ERS/SRS, Agricultural Marketing Service.

[d]Price of choice calves, 300-500 pounds, Omaha market, Livestock and Meat Statistics, USDA, ERS/SRS, Agricultural Marketing Service.

[e]Heifers, steers, and bulls under 500 pounds on farms January 1, in U.S., Livestock and Meat Statistics, USDA, ERS/SRS, Agricultural Marketing Service.

[f]Average price of corn per bushel received by farmers in U.S., Agricultural Prices Annual Summary, USDA, SRS, Crop Reporting Board.

[g]Steers and steer calves, number on feed 500-699 pounds, 23 states, Cattle on Feed, USDA, SRS, Crop Reporting Board.

[h]Average price of hay paid by farmers in U.S., Agricultural Prices Annual Summary, USDA, SRS, Crop Reporting Board.

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A QUARTERLY FEEDER CATTLE PRICE FORECASTING MODEL

WITH APPLICATION TOWARDS THE DEVELOPMENT

OF A FUTURES MARKET STRATEGY

by

Paul K. Blakely

(ABSTRACT)

The specific objectives of this study were: 1) to develop a
price forecasting equation for feeder cattle and 2) to examine the
possibility of reducing the variance in income and raising the level
of revenue relative to that which would be achieved under the common
practice of consistently selling feeder cattle in the cash market.

To these ends, a structural model for the feeder cattle market
in the United States was developed in order to isolate the important
variables to be used in the construction of a quarterly price fore-
casting model. Time series methods described by Box and Jenkins were
employed in the construction of the forecasting equations.

Selected strategies were developed which incorporated trading
in the futures market for feeder cattle based on the price forecasts.
The trade-off between mean income and the mean square error of in-
come is indicated by a test, within the range of the data base, of
the various strategies for the volatile years 1972-1975.