APPLICATION OF THE ECONOMETRIC MODEL, DISTRIBUTED LAG, TO FORECASTING SLAUGHTER CATTLE PRICE

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1973

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PREFACE

This dissertation is concerned with the development of an econometric model that will assist cattle producers and commercial meat packers in production and purchasing decisions. Spectral analysis, linear regression, and a geometric distributed lag model were combined with economic theory in specifying and estimating a quantitative model that will provide advance predictions of Choice steer prices. The value of the model is based on its success in identifying opportunities for hedging or forward coverage with live beef futures contracts.

Special appreciation and gratitude are expressed to Dr. John Franzmann, Major Adviser, for stimulating my interest in price analysis and providing counselling and guidance throughout the course of this study. His supervision, understanding, and patience were strong incentives for completion of this dissertation. Special thanks are extended to the other members of my advisory committee: Dr. Richard Leftwich, Dr. Wayne Purcell, Dr. Odell Walker, and Dr. Vernon Eidman, for their assistance and instruction throughout my academic program. The author, as is customary, assumes full responsibility for all errors and shortcomings.

I am deeply indebted to Dr. William Cromarty of Connell

Rice & Sugar Co., Inc., for his invaluable assistance, encouragement, and personal interest in my professional career. Acknowledgement is also extended to Mr. William Wobbekind of Continental Grain Company for his many suggestions for improving the manuscript and to Mr. Andrew Kokinda for assisting with the calculations.

I extend my profound gratitude to Mrs. Linnea Murphy for her patience and understanding in typing and retyping the many preliminary drafts and for her care in preparing the final manuscript. Special thanks are given to Mrs. Joyce Copess for her assistance in editing the study.

I am deeply indebted to my parents, Mr. and Mrs. Dan Myers, for their continued encouragement and inspiration. I welcome this opportunity to express my deepest appreciation to my wife, Sharon, and sons, Bobby and Danny, for accepting the period of sacrifice with patience and understanding. Finally, I dedicate this dissertation to my father, whose untimely death preceded its completion. His courage and motivation are not to be forgotten.

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CHAPTER I

INTRODUCTION

Variations in the price of slaughter cattle are well documented. During the past two decades the price of Choice grade slaughter steers at Chicago ranged from a high of $36.93 per hundredweight in April 1951, to a low of $18.88 per hundredweight in February 1956. During these two decades the average price received (paid) for a Choice grade 1,000 pound slaughter steer was $269.40. The average deviation of prices from the mean, again in terms of a 1,000 pound steer, was $37.00. In 1970 alone, prices went from a high of $31.93 per hundredweight in March to a low of $27.42 per hundredweight in December.

Absolute price movements and the variation of prices about their mean are of concern to decision makers. More important, however, is the difference between what is expected (forecasted) and what actually occurs. It is only within this context that members of the beef industry can begin to consider the outcomes of alternative risk reducing procedures. If cattle feeders knew with confidence where prices would be at some future date in relation to where prices are today, they could: (effectively evaluate alternative enterprise combinations; (2) take advantage of favorable price movements for procuring feeder cattle and marketing fed cattle; (3) consider bilateral contractual agreements in either the cash or futures markets for the prepurchasing of feeder calves and the advanced marketings of fed cattle.

Meat packers, on the other hand, are primarily involved with the inventory of slaughter cattle. Given some knowledge of where prices will be in the future, several possibilities for adjustment are possible. First, the packer can conduct cattle feeding operations or engage the services of custom feed lots. Second, contractual agreements can be arranged with cattle feeders for future acceptance of slaughter cattle. Third, future inventory requirements can be covered with live beef futures contracts. Finally, the most common practice of "hand-to-mouth" purchasing may still be the best alternative.

In short, the major economic problem confronting managers in both the cattle feeding and beef processing industries alike is knowing where prices will be at some future date, and what, if any, production or marketing opportunities are available to reduce the risk of an unfavorable price move.

A Research Problem

The management problem outlined above points up the need for price forecasting research. Research in the area of price forecasting has attracted the attention of professional economists, but, by and large, such research has contributed little in any direct way to practical decision making. Three reasons may be cited for this failure. First, price researchers have tended to place major emphasis on the development and refinement of statistical techniques. While research leading to improved techniques is necessary, it appears to have detracted from an adequate recognition and specification of the problems to be solved. The result has been that the most recent discourse has been oriented towards finding solutions to the technical problems associated with structural systems rather than solutions to fundamental problems faced by businessmen.[1]

Second, preoccupation with the estimation of demand and supply relationships and interpreting their practical significance in terms of elasticities leads only incidentally to useful price forecasts. Price and income elasticities, price flexibilities, and responsiveness of price to other related factors, while important in some policy applications, are all based on the assumption of strict ceteris paribus. When used as forecasting instruments, elasticities fail to acknowledge the dynamics of those factors being held constant.[2]

Third, by establishing structural estimation as the major goal and forecasting as the subordinate, there is an inclination to overlook pertinent information or exclude results that appear inconsistent with conventional statistical practices. This tendency usually results in the failure to find models that can actually produce useable extrapolations. For example, in model estimation, whenever a fixed relation exists between independent variables, no meaningful interpretation can be gained. Rao and Miller[3] suggest that in applied econometrics "one should not, *a priori*, rule out estimation of any regression equation because of high simple correlations between any two independent variables."

Objectives of the Study

The foregoing considerations reveal the need to recognize price forecasting as a significant management problem involving uncertainty. It also indicates the need for a methodology designed to attack the price forecasting problem in the beef industry directly as opposed to one that yields useable price forecasts as a by-product. Consequently, having recognized price forecasting as an important element in the management of various beef enterprises, the primary objectives of this dissertation are: (1) to develop a research methodology leading to the specification of "workable" price forecasting models; (2) to estimate the parameters of the models that are specified; and (3) to evaluate the performance of the model(s) in reducing the uncertainty associated with the future levels of price.

Of secondary importance will be analyses of: (1) the internal statistical estimating and forecasting properties of the selected model; (2) the problems and shortcomings of the model(s) and recommendations on how adaptions may be made to satisfy alternative forecasting situations.

Plan of the Dissertation

Chapter II will survey briefly some of the more significant contributions to agricultural price forecasting. This body of literature will cover the period of time since the turn of the century and will be discussed in terms of the time periods 1910-38, 1939-50, and 1950 to date. Specific attention will be directed towards livestock price forecasting research.

Chapter III will deal with the economic structure of the cattle industry and the decision-making environment. Included in this chapter are discussions of the feeder cattle, cattle feeding, and slaughtering subsectors.

Chapter IV is devoted to an investigation of the time-varying characteristics of the basic price series through the use of spectral analysis. Included in this analysis is an investigation into the necessity of deflating the price series prior to constructing forecasting models.

In Chapter V attention is directed to the general mathematical specification of the model. Consideration is given to the specification of lag-type models to permit the incorporation of some of the dynamic aspects of the model. Specification of a model employing autocorrelated errors is also examined.

The model to be used for forecasting purposes is developed and the parameter estimates are presented in Chapter VI. A "naive" equation is also specified and its parameters estimated to provide a basis for evaluating the forecasting performance of the lag-type model.

Chapter VII sets forth the evaluating procedure and techniques and then applies them to the empirical results. The equations are evaluated in terms of their statistical properties, forecasting performance, and in terms of the usefulness of the forecasts in reducing the magnitude of the managerial problem associated with price variability.

Lastly, Chapter VIII deals with a summary of the work and the conclusions that may be drawn from it. Limitations of the work are recognized and recommendations made for future research.

FOOTNOTES

[1]William A. Cromarty, Paper presented at the A.A.E.A. Annual Meetings, University of Missouri, August 10, 1970.

[2]Lester V. Manderscheid, "Some Observations on Interpreting Measured Demand Elasticities," Journal of Farm Economics, Vol. 46, No. 1 (February, 1964). p. 128.

[3]Potluri Rao and Roger Miller, Applied Econometrics, Wadsworth Publishing Co., Inc. (Belmont, California, 1971), p. 48.

CHAPTER II

SURVEY OF IMPORTANT CONTRIBUTIONS TO AGRICULTURAL PRICE FORECASTING

The evolutionary process of price forecasting can be partitioned into three principal periods: 1910-38, 1939-50, and 1950 to date. Researchers in the first two periods not only manifested the necessity of objective price forecasting, but also stimulated the development of the mathematical and statistical methodology germane to the econometric models in current use. Only in the most recent period did technicians seriously portray price extrapolation as the cardinal.

Period I

The first period originated in 1914 with a remarkable series of books by Henry L. Moore.[1] Moore's contribution to price forecasting was stimulated by his apparent dissatisfaction with the subjective extrapolations heretofore exercised by the Department of Agriculture. He demonstrated that the more impartial procedure of correlating cotton yields with meterological data provided projections with a smaller variance than those presented by official crop reporters.[2] Not only were the forecasts statistically "better" but they were not a direct function of the opinion or judgment of crop officials.

In 1930, Ezekiel[3] published the first edition of his book on correlation analysis. Indirectly, this book made an outstanding contribution to price analysis for it comprised the most up-to-date and comprehensive work on correlation analysis then in print. It included an excellent exposition on measuring relationships between phenomena and the nature and meaning of statistical results. Then, in 1938, Henry Schultz[4] presented a carefully prepared book on the theory and measurement of demand. This book employed much of the quantitative techniques developed by Ezekiel and established the foundation for subsequent theoretical investigation in price forecasting.

Period II

The second major period was characterized by research that re-evaluated the validity of the linear, single-equation model and recommended alternative estimation procedures. This body of literature, which extended from 1940 to 1950, was basically preoccupied with not only the assumptions inherent in the general linear model, but also with the applicability of these assumptions in analyzing economic phenomena and what, if anything, could be done if these assumptions are inappropriate.

The first of these authors, Haavelmo,[5] suggested that a serious deficit is encountered if attention is focused on a single equation model when the very essence of economic theory centers on the interdependence of economic relations. Consequently, in order to prescribe a meaningful method of fitting an equation to data, it is necessary to simultaneously consider the stochastic properties of all variables involved.

Following the suggestion by Haavelmo on the need for a simultaneous equation approach, the necessity of considering the errors encountered in measuring economic phenomena was articulated by Wald[6] and again by Bartlett.[7] Of even more significance, was the problem associated with the assumption that successive disturbances are drawn independently of previous values. Sampling experiments conducted by Cochrane and Orcutt[8] confirmed the seriousness of unwittingly applying simple regression procedures to relationships in which successive disturbances are not independent. Immediately following the acknowledgment of auto-correlated disturbances, Durbin and Watson designed a suitable test for its presence.[9]

The final contribution that will be recognized in this period was actually conceived by Irving Fisher[10] in 1937. However, it was the book _Distributed Lags and Investment Analysis_ by Koyck[11] that popularized the applicability of distributed lag models to forecasting. Marc Nerlove gave additional support for lag models when he published an agricultural handbook that provided the methodological aspects of applying expectation models in analyzing demand for agricultural commodities.[12]

Period III

By the early fifties, difficulties associated with the general linear model had been thoroughly scrutinized. Economic analysts turned their attention to empirically evaluating the new additional dimensions in model specification and estimation. At first, it was believed by most economists that structural coefficients estimated by the "modern" procedures outlined by Haavelmo, Wald, Fisher, and others, would be statistically better than those produced by simple multiple regression. In fact, the new developments were so revolutionary that economists began looking askance at their previous empirical endeavors. An intensive effort was then inaugurated by the Cowles Commission[13] and later by the United States Department of Agriculture (under the leadership of Richard Foote[14]) to theoretically specify and empirically re-estimate previous research, only this time using simultaneous equations. Hildreth and Jarrett[15] accepted the responsibility from the Commission for empirically analyzing the livestock market complex. Their research emphasized the development, application, and testing of methods - both recent and traditional - that might prove effective in understanding the livestock complex.

Livestock Price Forecasts

Following the Cowles Commission manuscript by Hildreth and Jarrett, other isolated attempts were conducted to estimate beef and pork price relationships according to the precept of dynamic interdependency of economic variables. For example, Wallace and Judge[16] empirically estimated yearly price relationships via two simultaneous equation techniques; two-stage least squares and limited information. For comparative purposes these analysts presented similar estimates based on the classical method of least squares. Even though Wallace and Judge did not explicitly test the hypothesis that the coefficients obtained from these three estimating techniques differed significantly, the final results were surprisingly similar. Finally, in 1960, to the discouragement of many, a paper by Christ, Hildreth, Liu, and Klein entitled "Simultaneous Equation Estimation: Any Verdict Yet?" was presented at the annual meeting of the Econometric Society that portrayed the paradoxes of simultaneous equations.[17]

The difficulty at this point is to preclude using systems of equations for forecasting purposes solely on the premises that they will not pass the "acid" test of estimation. However, Hayenga and Hacklander, after an attempt in one article to enumerate economic factors believed responsible for monthly cattle and hog price fluctuations with simultaneous equations,[18] in another article conceded the task of forecasting to a single equation model.[19]

In 1958, and later in 1967, least squares occupied the research efforts of Maki[20] and Uvacěk,[21] respectively, in perhaps two of the most veritable attempts at explicit livestock price forecasting. In Maki's study, a recursive least squares procedure was applied in predicting quarterly price changes for each of the three major market levels - primary, wholesale, and retail. Maki rigorously subjected his estimates to statistical and economic scrutiny but in the final analysis the usefulness of his models as a forecasting instrument was left to the imagination of the reader. Uvacek, on the other hand, presented the supply and demand structure for the fed beef industry and then specified a recursive forecasting model for each period in question.

Fuller and Ladd[22] offered a slightly different approach to the single equation technique in their article, "A Dynamic Quarterly Model of the Beef and Pork Economy." Their efforts, although not directly yielding price forecasts, exposed the usefulness of a distributed lag technique in model estimation. This technique is especially meaningful if the researcher suspects a dependency between the error terms and the dependent variable. Not only do distributed lag techniques assail the problem of autocorrelated disturbances but they also, as illustrated by Koyck and Nerlove, address the behavioral problem of expectation.

Additional Research in Price Forecasting

Before concluding this chapter, a brief discussion of two recently published articles may be of value in subsequent price analysis. In the first article by Schmitz and

Watts,[23] a parametric modeling technique was applied to forecasting wheat yields. With this approach the data are used in identifying random components which are then captured by moving averages and autoregressive processes. This is an extremely useful procedure for it does not require the identification and measurement of structural relations. Also, as illustrated by the authors, its predictive accuracy was significantly better than those produced from the traditional exponential smoothing approach.[24]

In 1970, Waugh and Miller[25] published the results of their research in which harmonic analysis was engaged in measuring the length and amplitude of landings and price cycles for cod, haddock, and blackback founder. By assuming regular periodic movements of a fixed length and by obtaining statistically significant cosine and sine coefficients in the Fourier model, the authors were able to expose the existence of a discernible seasonal (twelve-month) cycle. Although not explicitly referenced, the article did illustrate the value of a cyclical analysis as a forecasting device. That is, since the sines and cosines are orthogonal an infinit series can easily be extrapolated.

Conclusion

The foregoing literature review abstracted several complexities encountered in adapting an econometric model to the peculiarities of observed economic relationships. However, as evidenced in the research presented during the past quarter century, these complexities are almost exclusively associated with the internal statistical problem of how perceptible the general linear model is to the existence of: (1) simultaneous relationships between the explanatory variables; (2) autocorrelation between the error terms and also autocorrelation between the time series themselves; and (3) measurement errors in observing each of the explanatory variables. The more difficult problem of relating the probable consequence that these statistical complexities will have on the forecasting potential of a model was only indirectly considered.

The review, although not exposing an objective choice criterion for specifying a forecastable model, did provide an insight into the types of phenomena that should be given special attention. For example, simultaneous equation systems, although extremely useful for understanding the economics of a market structure, were not found to be significantly better than simplified regression models in forecasting future events. The work by Schmitz and Watts on forecasting wheat yields and the harmonic analysis approach by Waugh and Miller accentuated the importance of knowing, at the outset, the statistical properties of a given time series process. If the series is characterized by significant seasonal or cyclical patterns, a much simplier unobserved components technique could manifest reasonable forecasts.

The forecasting model must account for the interrelationships within the system of explanatory variables as suggested by Haavelmo. The model, as outlined by Fisher, must also acknowledge the dynamic time dependency within the observed operational environment of the industry. That is, it is necessary to account for the dynamic adjustment process followed as variables move from one equilibrium to another.

FOOTNOTES

[1]Henry L. Moore, Forecasting the Yield and Price of Cotton, The MacMillan Company (New York, 1917), p. 173.

Henry L. Moore, Generating Economic Cycles, The MacMillan Company (New York, 1923), p. 141.

Henry L. Moore, Synthetic Economics, The MacMillan Company (New York, 1929), p. 186.

[2]Moore, Forecasting the Yield and Price of Cotton.

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[8]D. Cochrane and G. H. Orcutt, "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms," Journal of the American Statistical Association, Vol. 44 (1949), pp. 32-61.

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[10]Irving Fisher, "Note on a Short-Cut Method for Calculating Distributed Lags." International Statistical Institutional Bulletin, Vol. 29 (1937), pp. 323-327.

[11]L. M. Koyck, *Distributed Lags and Investment Analysis*, North Holland Publishing Company (Amsterdam, 1954).

[12]Marc Nerlove, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*, Agricultural Handbook 141, U. S. Department of Agriculture, 1958.

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[16]Thomas D. Wallace and George G. Judge, "Econometric Analysis of the Beef and Pork Sectors of the Economy," Technical Bulletin T-73, Oklahoma State University (August, 1958).

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[18]Marvin Hayenga and Duane Hacklander, "Supply-Demand for Cattle and Hogs," *American Journal of Agricultural Economics*, Vol. 52, No. 4 (November, 1970), pp. 535-544.

[19]Marvin Hayenga and Duane Hacklander, "Short Run Livestock Price Predicting Models," Research Bulletin 25, Michigan State University (1970).

[20]Wilbur R. Maki, "Forecasting Beef Cattle and Hog Prices by Quarters - Years," Research Bulletin 473 (Ames, Iowa).

[21]Edward Uvacek, Jr., "An Economic Analysis and Forecasting Model of the Beef Cattle Industry" (Ph.D. dissertation, Texas A & M University, 1967).

[22]W. A. Fuller and G. W. Ladd, "A Dynamic Quarterly Model of the Beef and Pork Economy," *Journal of Farm Economics*, Vol. 43 (November, 1961).

[23]Andrew Schmitz and Donald G. Watts, "Forecasting Wheat Yields: An Application of Parametric Time Series Modeling," American Journal of Agricultural Economics, Vol. 52, No. 2 (May, 1970), p. 247.

[24]Ibid, p. 252.

[25]Frederick V. Waugh and Morton Miller,"Fish Cycles: A Harmonic Analysis," American Journal of Agricultural Economics, Vol. 52, No. 3 (August, 1970), p. 422.

CHAPTER III

THE ECONOMIC STRUCTURE AND DECISION MAKING ENVIRONMENT

Introduction

Before relevant relationships can be displayed in an econometric model, some familiarity with the economic reality of the industry producing these relationships is necessary. The traditional economic approach is one of deriving behavioral hypotheses from the assumptions that the reality in question, whether by design or by pressure of circumstances, coincides with the response of producers to underlying supply and demand schedules.

In this research, the operational decisions relating to (1) feeder calf production, (2) slaughter cattle production, and (3) beef slaughtering and processing activities are of major concern. Specifically, in this chapter the economic concentration, regional location, and general ownership of the firms within each of these production activities will be reviewed. In addition, the procedures followed by the primary operators in interpreting and initiating fundamental decision rules and the manner in which these decisions are related to the short run supply and demand for beef will be theoretically and empirically analysed.

Cow - Feeder Calf Industry

Beef Supplies

Biological requirements dictate that, by and large, controllers of basic beef breeding herds influence both present and future beef supply patterns. Figure 1 demonstrates that the outgrowth of actions taken by these participants can influence supply at almost any stage in the beef production process. First, at any time period (t) total slaughter supplies can be stimulated by rapid adjustments in dairy and beef cow culling rates. Second, within approximately 18 months after a particular cow inventory is established, the better cowmen can prepare an animal that will require only six months of intensive feeding before becoming a Choice or Prime grade slaughter steer or heifer. Third, by retaining heifers for placement in future breeding herds, these operators decrease present feeder calf supply and final slaughter numbers. As indicated in Figure 1 the elapsed time between the decision to enlarge the beef herd and the production of a finished animal is approximately four years.

Finally, the initiation of improved management practices, such as decreasing death loss and increasing weaning weights, is another way in which cow-calf operators can substantially increase total beef production. By increasing

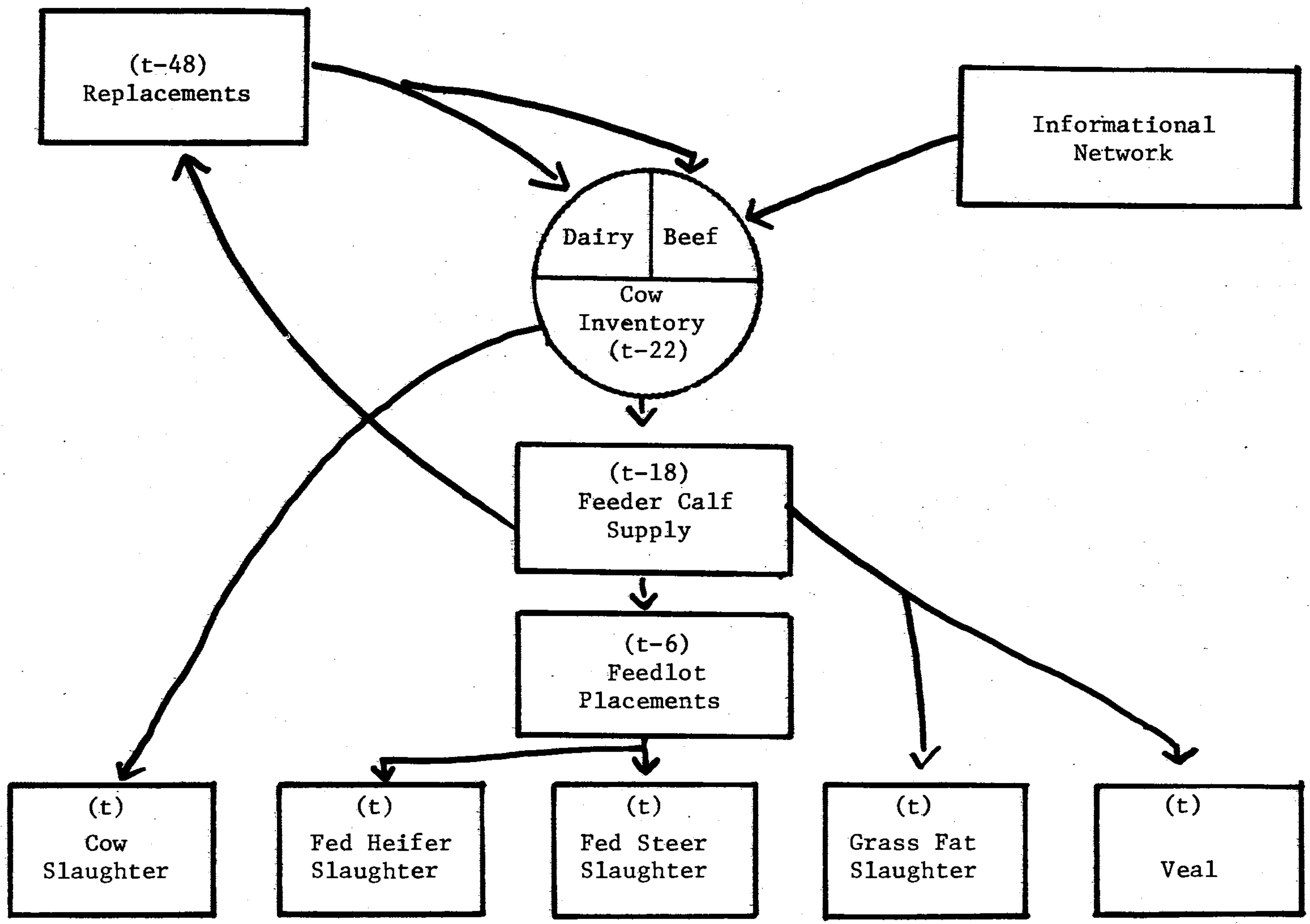

Figure 1. Simplified Production Flow For Beef Animals

weaning weights from 400 to 600 pounds, calf production per cow is increased 50 percent.

Reference has been made to the fact that dairy producers, through the production of feeder calves and the sale of the discarded dairy cows, contribute to total cattle slaughter. However, since 1950 the increased efficiency of the dairy cow combined with the substantial increase in the number of beef cows, reduced the relative position of dairy cows to total cows from 58 percent in 1950 to 27 percent in 1970 (Table I). Therefore, the operational practices within this segment of the cattle industry will be ignored in this analysis.

Operational Behavior

The basic cow inventory still remains one of numerous diversified operations in which fixed costs are low and resource flexibility is easily supported.[1] This creates an atmosphere in which the operator must simultaneously consider not only the profitability of the cow enterprise itself, but also the competitive, complementary, and supplementary production relationships set up within the total farm program.

From conventional economic theory, the producer will observe the present net value of expected future feeder calf returns and compare this with the net value that can be shortly realized by marketing the cows. When the

TABLE I

U.S. COW INVENTORY, JANUARY 1, BY CLASSES
(1,000 Head)

Date	Milk Cows & Heifers 2 yr. >	Beef Cows & Heifers 2 yr. >	Total Cows Beef & Dairy	Dairy as a Fraction of Total
1950	23,853	16,743	40,596	.587
1951	23,568	18,526	42,094	.559
1952	23,060	20,863	43,923	.525
1953	23,549	23,291	46,840	.502
1954	23,896	25,050	48,946	.488
1955	23,462	25,659	49,121	.477
1956	23,213	25,516	48,729	.476
1957	22,916	24,754	47,670	.480
1958	22,357	24,427	46,784	.477
1959	20,132	25,112	45,244	.444
1960	19,527	26,344	45,871	.425
1961	19,361	27,102	46,463	.416
1962	19,167	28,305	47,472	.403
1963	18,730	29,960	48,690	.384
1964	18,088	31,811	49,899	.362
1965	17,592	32,784	50,376	.349
1966	16,607	32,636	49,243	.337
1967	15,198	34,685	49,883	.304
1968	14,644	35,405	50,049	.292
1969	14,152	36,227	50,379	.280
1970	13,875	37,433	51,308	.270

Source: Livestock and Poultry Inventory 1950-1970, Crop Reporting Board, SRS, USDA expected marginal contribution attributed to the beef herd becomes less than the additional costs, the producer will theoretically make operational adjustments by stepping up the culling rate.

Another factor - besides present cow prices and expected feeder calf price - in formulating decisions about beef cow marketing and/or feeder calf production is the ecological balance between animal units and feed supply in the range areas. Present and potential feed stocks have an effect on not only subsequent production costs, but also the physical possibility of even keeping animals on pasture for breeding purposes. Following a prolonged drought, relocation of beef cows and interruption of the seasonal flow of feeder calves from pasture to feedlots are not uncommon.

Finally, there is evidence that operators at this particular production level are not rational calculators, nor do they react instantaneously to dynamic economic phenomena. Emotions, habits, and standard operational practices play an important role in describing their operational behavior. Owning cow herds is still a popular pastime for off-farm investors requiring tax advantages, and in many instances, small farmers attach sentimental value to owning beef herds. Consequently, only after an extended period of rising (falling) beef-fed price ratios are noticeable adjustments made in the beef cow slaughter industry.

Cattle Feeding Industry

Industrial Stucture

During the past two decades increasing population and rising personal income, combined with a growing consumer preference for fed beef, stimulated one of the most dramatic adjustments within the meat industry. From 1930 to 1953 the American consumers were receiving almost equal pounds of beef and pork. However, as depicted in Figure 2, from 1954 to 1970 a phenomenal increase was noted in the per capita consumption of beef whereas the consumption of pork actually decreased.

In order to accomodate this increasing demand for fed beef, spectacular changes were made in the structure and conduct of the cattle feeding industry. Beef producers substantially reduced the slaughter of calves and "grass-fat" cattle and directed their efforts to large scale production of grain-fed cattle. By 1970, 72 percent of total commercial cattle slaughtered were marketed by feedlot operations. In 1955 only 42 percent of the cattle slaughtered were actually placed on high concentrated rations, Table II.

Adjustments were also made in the dominant cattle feeding areas. In the early 1950's cattle feeding was primarily concentrated in the Midwest where small volume farmer feeders (1,000 head or less) utilized excess labor during

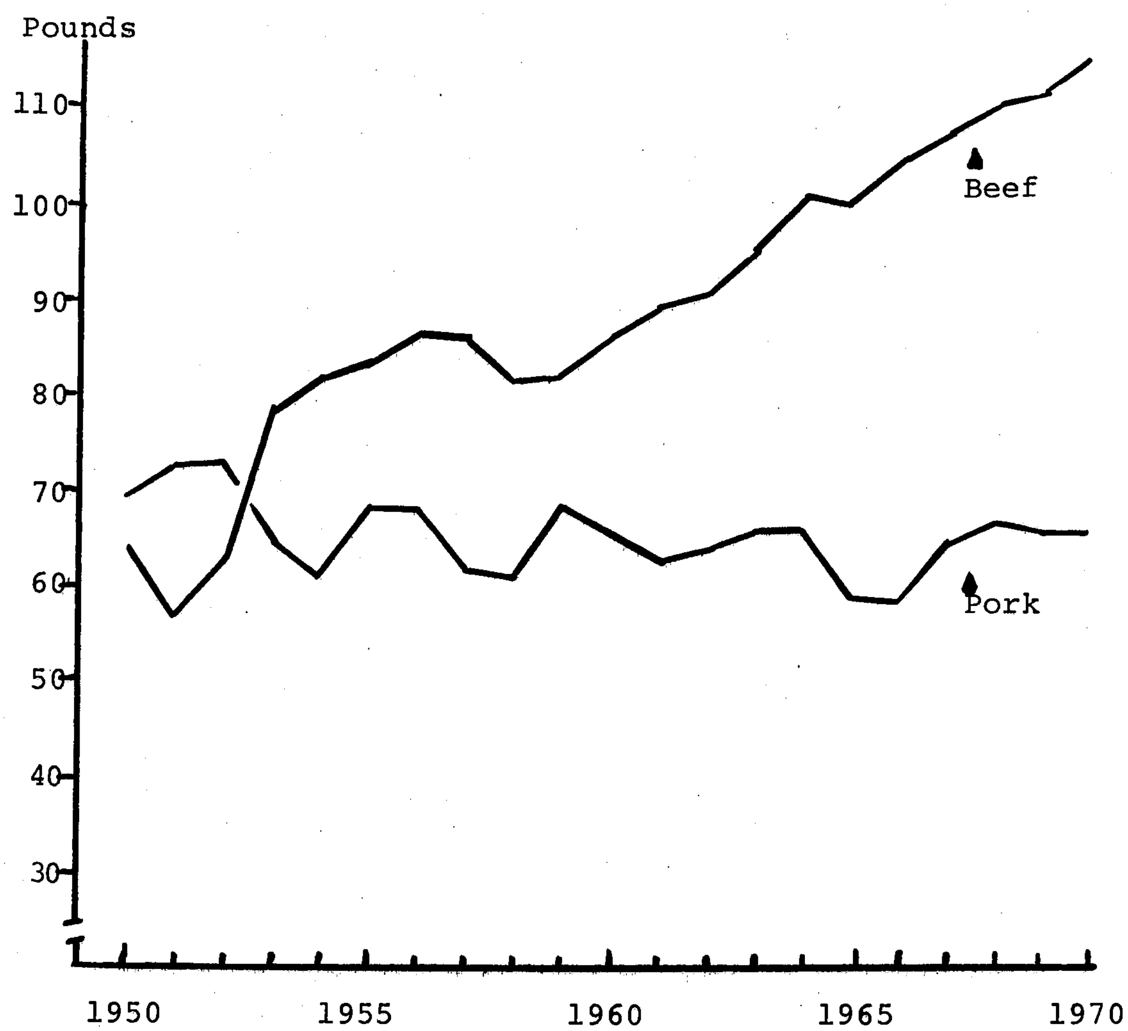

Figure 2. Per Capita Meat Consumption, by Class
1950 - 1970

Source: U.S.D.A., Neg. ERS 442 - 71(2)

TABLE II

FED CATTLE MARKETINGS FOR 39 STATES AS A PERCENTAGE OF TOTAL CATTLE SLAUGHTERED U.S. 1950-1969

Year	Fed Cattle Marketings (000 head)	Total Commercial Cattle Slaughtered (000 Head)	Percent Fed Cattle of Total Commercial Cattle Slaughtered (%)
1955	10,762	25,722	41.8
1956	11,331	26,862	42.2
1957	11,285	26,232	43.0
1958	11,787	23,555	50.0
1959	12,843	22,930	56.0
1960	13,621	25,224	54.0
1961	14,561	25,635	56.8
1962	15,434	26,083	59.2
1963	16,807	27,232	61.7
1964	18,319	30,818	59.4
1965	18,936	32,347	58.5
1966	20,597	33,727	61.1
1967	22,046	33,869	65.0
1968	23,570	35,026	67.2
1969	25,234	35,237	71.6

Source: Livestock and Meat Statistics, Supplement for 1970 to Statistical Bulletin 333 non-crop seasons to market their roughage and a portion of the grain stock through cattle. By the mid-1960's the discovery of hybrid grain sorghum and close proximity of feeder cattle spurred the development of exceptionally large commercial feedlots in the plains states of Texas, Oklahoma, Kansas, Colorado, Arizona, and New Mexico. The corn belt states still prepare the greater absolute number of fed beef. However, the rate of growth and scale of operations has been more dramatic in the Great Plains. Table III illustrates that in 1970, 90 percent of the slaughter cattle marketed in Texas were fed in commercial feedlots (1,000 head or more) whereas in Iowa only 3 percent of the total cattle marketed came from commercial lots.

Noticeable changes are observed in the legal ownership patterns of the expanding cattle feeding industry. A recent study by Gustafson and VanArsdall[2] reported that the corporate form of organization is most common among the commercial feedlots, but the single proprietorship and partnership arrangements still characterized the smaller farmer feeder type operations. In terms of the ownership and control of the cattle in feedlots, the National Commission on Food Marketings[3] found that 86 percent of the cattle in farm feedlots were owned by farmers and ranchers while only 67.8 percent of the cattle in commercial lots were owned by persons directly involved in agriculture. Because of the possible influence of pricing policy, approximately 6.8 percent of the total number of fed cattle

TABLE III

NUMBER OF CATTLE FEEDLOTS AND FED CATTLE MARKETED - BY SIZE OF FEEDLOT CAPACITY, BY STATES - 1970

State	Under 1,000 Head Feedlot Capacity		Over 1,000 Head Feedlot Capacity		Total All Feedlots	
	Lots No.	Cattle Marketed 1,000 Head	Lots No.	Cattle Marketed 1,000 Head	Lots No.	Cattle Marketed 1,000 Head
Pennsylvania	5,997	119	3	9	6,000	128
Ohio	9,472	391	28	38	9,500	429
Indiana	14,473	445	27	66	14,500	511
Illinois	23,952	1,064	48	103	24,000	1,167
Michigan	1,673	209	27	44	17,000	253
Wisconsin	7,793	205	7	12	7,800	217
Minnesota	18,162	811	38	57	18,200	868
IOWA	41,829	4,124	171	460	42,000	4,584
Missouri	15,966	617	34	67	16,000	684
N. Dakota	1,179	57	21	33	1,200	90
S. Dakota	9,049	463	51	89	9,100	552
Nebraska	18,400	1,590	514	1,973	18,914	3,563
Kansas	8,868	495	132	1,395	9,000	1,890
Oklahoma	752	50	48	492	800	542
TEXAS	1,300	98	306	3,040	1,606	3,138

TABLE III (Continued)

State	Under 1,000 Head Feedlot Capacity		Over 1,000 Head Feedlot Capacity		Total All Feedlots	
	Lots No.	Cattle Marketed 1,000 Head	Lots No.	Cattle Marketed 1,000 Head	Lots No.	Cattle Marketed 1,000 Head
Montana	424	12	77	172	501	184
Idaho	546	60	89	374	635	434
Colorado	908	298	184	1,617	1,092	1,915
New Mexico	23	5	45	388	68	393
Arizona	8	2	53	858	61	860
Washington	262	36	30	312	292	348
Oregon	319	35	37	129	356	164
California	153	19	272	1,947	425	1,966
23 States	181,508	11,205	2,242	13,675	183,750	24,880

Source: Cattle on Feed, January 1971, Crop Reporting Board, SRS, USDA marketed were fed by packers of feed for packers on a custom basis. This percentage, partly as a result of government regulations, has remained almost constant since 1954.[4]

Contrary to recent suggestions, actual data does not substantiate the hypothesis that as a result of current structural changes in the beef feeding industry there is a decreasing trend in the variance of monthly cattle slaughter.[5] The data in Table IV illustrate that even though there has been a significant increase in the mean number of cattle slaughtered each month, the oscillations about this mean are not decreasing with time. In both 1968 and 1969 the average monthly variance of 32.687 million head and 32,641 million head, respectively, exceeds the mean monthly (1950-70) variance of 26,964 million head.

Operational Behavior

Interviews with several members within the cattle feeding industry indicated that their operational behavior is dominated by two major production decisions: (1) the amout of available farm or non-farm resources that will be committed to beef production, and (2) once the resources have been committed, the optimum duration of the feeding period.

This paper postulates that both the short run supply schedule and the "market" supply curve for slaughter cattle are manifested by the actual realization of actions taken by feeders on these two decisions, respectively. The number of cattle and calves placed on feed during a specified

TABLE IV

TOTAL COMMERCIAL CATTLE SLAUGHTER, MEAN MONTHLY SLAUGHTER AND AVERAGE VARIANCE ABOUT THE MEAN (1,000 Head)

Year	Total Slaughter	Mean Monthly Slaughter	Average Monthly Variance
1950	17,900	1,492	10,272
1951	16,376	1,365	23,830
1952	17,855	1,488	31,745
1953	23,605	1,967	55,366
1954	25,016	2,085	20,108
1955	25,722	2,154	32,748
1956	26,861	2,238	26,414
1957	26,231	2,183	32,175
1958	23,555	1,963	23,403
1959	22,930	1,910	17,510
1960	25,224	2,102	23,536
1961	25,634	2,136	21,037
1962	26,083	2,173	28,514
1963	27,231	2,269	23,799
1964	30,818	2,568	23,707
1965	32,347	2,695	31,872
1966	33,726	2,810	20,513
1967	33,868	2,822	18,494
1968	35,025	2,919	32,687
1969	35,236	2,936	32,641
1970	35,042	2,920	19,867
		Mean Variance =	26,964

interval represents the available short run stock of slaughter cattle, whereas action taken on the second decision constitutes the final supply during the market period. Further, by exercising the assumption of constant factor costs, the horizontal summation of these decisions over all cattle feeders will establish the industries' short run and market period supply curves.

<u>Short run supply of slaughter cattle</u>: When the production decision is related to the initial placement of cattle on feed, actual behavior should coincide with optimizing expected net farm income. This requires that each producer be observant of the following five factors:

(1) the limitations imposed by the availability and flexibility of fixed resources;

(2) the supply curve of each variable factor used in producing fed beef, including those factors that are in the form of on-farm inventories, e.g. corn, roughage, feeder calves and feeder pigs;

(3) the technical production function for beef;

(4) returns from alternative investment opportunities and a time preference for income;

(5) the producers own ability and confidence in estimating final product prices of both slaughter cattle and the alternative production possibilities.

The cost curve or supply curves ss_1, ss_2, ss_3, in Figure 3 represents a momentary realization of these five factors. Each curve illustrates the minimum expected price

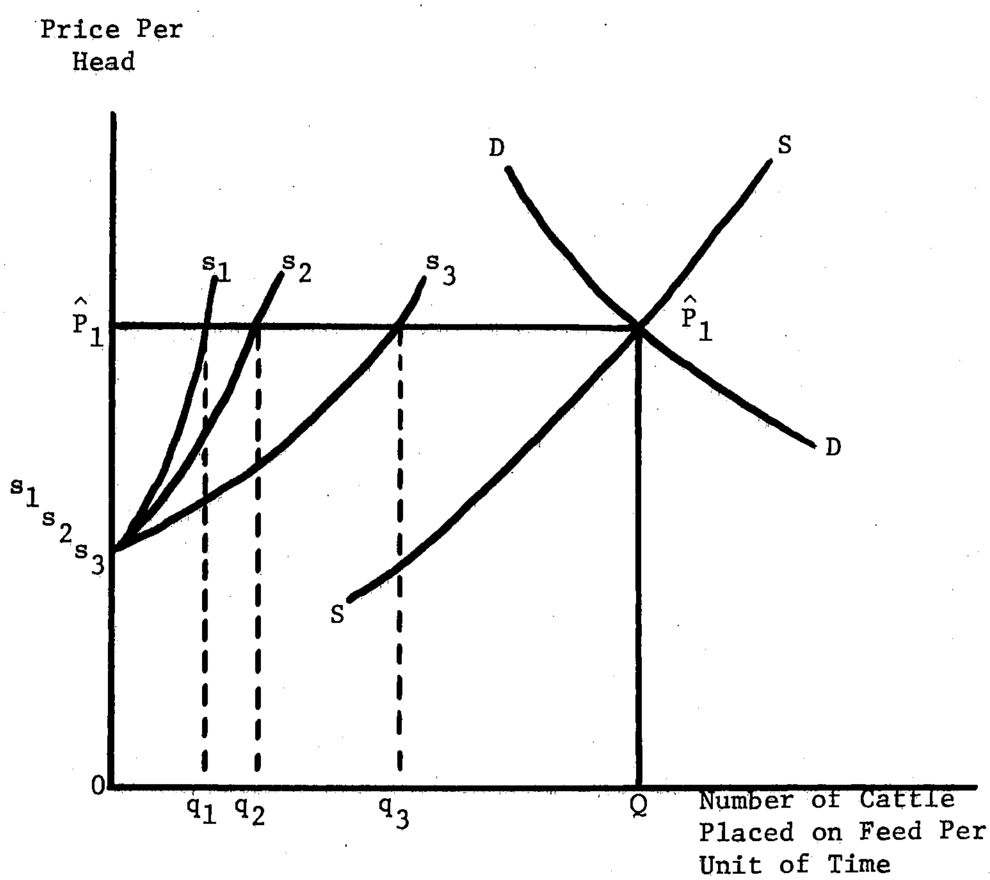

Figure 3. Short Run Individual Firm and "Industry" Supply Curves

for which a given number of cattle and calves will be placed on feed by each producer s_i (i=1,2,3).

From the foregoing industry review it can be concluded that these producers operate in an almost purely competitive environment. Therefore, suppose that at time period (t) a consensus of cattle feeders indicate that prices are expected to average $\hat{P}$ during the period (t + 8 months). Being unable to influence market prices and faced with the decision to maximize profits within the framework of the above five conditions, producer s_1 will place Oq_1 cattle on feed. Correspondingly, producer s_2 will place Oq_2 head on feed and producer s_3, Oq_3 head.

In Figure 3, the curve SS represents the total number of cattle and calves placed on feed by all producers s_i. Curve SS is the "industry" supply curve in that for given conditions with respect to the factors above, in particular the shape of the supply curves of inputs to the industry, there exists some minimum price for which a given quantity of cattle will be placed on feed. If the industry demand curve is DD, the market equilibrium price will be OP_1 and the number of cattle forthcoming will be OQ where $OQ = Oq_1$, $+ Oq_2 + Oq_3$.

Needless to say, the validity of deriving behavioral hypotheses from the assumptions of optimal behavior can only be assessed by empirical tests. The econometric equation derived below does support the hypothesis that the short run supply of slaughter cattle (i.e. the number placed on feed) is positively influenced by current slaughter steer prices (a proxy for expected future prices), seasonal feeder calf supply, and a linear trend term; and negatively influenced by the price of corn.

$$(1)\quad \hat{F}_{p_t} = \underset{}{1502.4} + \underset{(29.4)}{60.44\ P_{ss_t}} - \underset{(6.2)}{6.14\ P_{c_t}}$$

$$+ \underset{(131.6)}{2883.7\ D_1} + \underset{(11.17)}{74.3\ T}$$

$$R^2 = .96$$

where

F_p = number of cattle and calves placed on feed during the quarter - 22 states

P_{ss} = average price per cwt. for Choice grade 900-1,100 pound slaughter steers Chicago

P_c = weighted average price per bushel No. 2 yellow corn Chicago

D = fourth quarter seasonal dummy variable

T = time (1960 = 1)

All of the coefficients agree with the underlying economics with respect to sign and all, except P_c, are statistically significant at the 97th percentile of the t distribution. Even though the relative influence of corn prices is only statistically different from zero at the 87th percentile, the sign on the coefficient is theoretically correct and, as always, by adding an additional variable, the coefficient of correlation is increased.

<u>Market period supply of slaughter cattle</u>: Once

resources have been committed to cattle feeding there is some confusion with respect to an optimum criterion for determining the duration of the feeding period. In general, for the farmer feeder where intermittent crop and cattle feeding enterprises are observed, economic theory would suggest that each animal be fed to the point where the contribution of an additional pound of beef to total costs is exactly equal to the contribution of an additional pound to total receipts. On the other hand, for enterprises such as commercial cattle feeding that are of a sequential nature, Faris[6] indicates that "the optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the enterprise immediately following." Recent research efforts by Dunn,[7] however, indicated that as an operational goal, cattle feeders in Oklahoma attempted to maximize returns per head to each lot of cattle as opposed to maximizing returns over some selected time period. This study also found that farmer feeders exhibited a tendency to seek a more stable, satisfying feeding program rather than a profit maximizing goal.

Nevertheless, on an empirical footing the following two equation models will explain 84 percent of the total variance in the number of cattle marketed from feedlots each quarter. Because of the presence of intercorrelation between the independent variable, a two stage least squares estimating procedure was used. In the first equation the number of slaughter cattle marketed is assumed to be a linear function of the average price of slaughter steers or:

$$(2)\quad \hat{F}_{m_t} = -1672.5 + \underset{(49.75)}{243.89}\, Pss_t$$

$$R^2 = .37$$

Second, the residual Z_t, where $Z_t = F_{m_t} - \hat{F}_{m_t}$ was expressed as a function of the number of cattle and calves on feed during the previous time periods, the average price of replacement cattle, and a linear trend term, i.e.

$$(3)\quad \hat{Z}_t = 301.0 + \underset{(.06)}{.17}\, F_{o_t} + \underset{(.07)}{.095}\, F_{o_{t-1}}$$

$$- \underset{(21.8)}{99.3}\, P_{fc_t} + \underset{(12.9)}{33.99}\, T$$

Finally, the Equations (2) and (3) were combined to form the final empirical representation of the supply of slaughter cattle during the "market" period.

$$(4)\quad \hat{F}_{m_t} = -1973.5 + 243.89\, Pss_t + .17\, F_{o_t}$$

$$+ .095\, F_{o_{t-1}} - 99.3\, P_{fc_t} + 33.99\, T$$

$$\text{Combined } R^2 = .84$$

$$d^1 = 1.13$$

where

F_m = marketings of fed cattle for slaughter by quarter- 22 major feeding states

F_o = number of cattle on feed at the beginning of each quarter - 22 major beef producting states

P_{f_c} = average price per cwt. for Choice and Good grade 300-400 pound feeder steers Kansas City

T = time (1960 = 1)

d^1 = Durbin-Watson test statsitic

All of the coefficients agree with the underlying economic theory with respect to sign and all of the variables except $F_{o_{t-1}}$ are statistically significant at the 99.5 percent confidence level. The variable $F_{o_{t-1}}$ is significant at the 90 percent level.

Beef Slaughtering Industry

Operational Structure and Behavior

It is axiomatic that the competitive environment of the large, established meat packers has been significantly altered. Recent data published by the Packers and Stockyard Administration indicate that the percentage of commercial cattle slaughter accounted for by the four leading firms has dropped steadily from about 36.4 percent in 1950, to about 23.0 percent in 1969 (Table V). The next four largest firms have remained constant at approximately 8.6 percent of the total.

A variety of factors can be cited as primarily responsible for the structural change in the meat packing industry; foremost of which are: (1) the phenomenal growth in the number of cattle fed - in particular those fed in commercial lots, (2) the initiation and wide-spread acceptance of

TABLE V

PERCENT OF U. S. COMMERCIAL CATTLE SLAUGHTER BY THE FOUR RANKING FIRMS (ARMOUR, CUDAHY, SWIFT, AND WILSON)

Year	Percent	Year	Percent	Next Four Largest Percent
1950	36.4	1960	23.5	
1951	32.0	1961	24.2	6.2
1952	34.3	1962	23.7	7.1
1953	34.4	1963	22.9	7.0
1954	32.4	1964	22.6	7.9
1955	30.8	1965	23.0	7.2
1956	29.8	1966	22.4	7.8
1957	29.3	1967	22.2	7.4
1958	27.4	1968	21.5	7.3
1959	24.7	1969	23.0	8.6

Source: Annual reports of meat packers filed with the Packers and Stockyars Administration (P&SA-125)

federal grading of beef, and (3) changing technology in both the procurement and processing of slaughter cattle.

Because of rapid growth in cattle feeding new firms could enter the industry and the existing firms were able to expand their slaughtering operations without significantly reducing the number of animals available to other established firms. Generally these new plants have located in close proximity to major cattle feeding areas.

After the Korean War approximately 50 percent of the beef was graded on a voluntary basis. By 1970, however, Federal grading amounted to almost 65 percent of all beef and 85 percent of the fed beef.[8] The widespread retailer and consumer acceptance of federal grades, in particular "U. S. Choice," reduced the advantages of product differentiation previously held by the national packers. Small independent packers can supply "U. S. Choice," or other particular grades as easily as the large volume packers.

Finally, the development of modern technology in meat packing, improved transportation and lower wage rates in rural areas facilitated the entry of new firms and eliminated the need for geographically centralized slaughter plants and branch houses.

The market for fed beef products is undoubtedly a national market that can be characterized by national concentration statistics. However, *a priori* knowledge would suggest that this characterization is not relevant for analyzing the market structure at the regional and local levels. Even though the data in Table V indicate that the largest eight firms account for only 31.6 percent of the total commercial slaughter (a type II oligopoly is evident when the largest eight firms account for 33 percent of the industry)[9] the level of concentration is much higher in the local procurement areas. Generally, in most market areas three or four major packers or packer buyers purchase a substantial share of the areas total marketings; the remainder of which goes to a fringe of small competitive firms. In a recent consent decree it was found that in a ten-county area of Iowa, the Iowa Beef Processors, Inc., alone accounted for 25.4 percent of the areas total fed cattle slaughter.[10]

Short Run Demand for Slaughter Cattle

From the foregoing review it is postulated that much of the packing industry operates, at least at the regional and local level, within a framework of imperfect competition. The actions of each packer have an appreciable effect on both the competitor plants and the prices received by local fed cattle producers. Moreover, when the packers market their final product, the buying forces are also imperfectly competitive. That is, additional beef products can only be marketed by packers at successively lower prices.

By and large, the marginal productivity considerations are the fundamental determinants of the individual packers demand for slaughter cattle. On the basis of the expected final product prices (e.g. beef carcasses, primal cuts, hides and beef by-products) and on projected margins, the beef packer will determine the maximum number of cattle that will be purchased at each price level. However, since the short run supply curve of slaughter cattle is less than perfectly elastic, the final price and quantity become negotiated and is settled on the basis of the bargaining power of the opposing forces.

For example, in Figure 4, let MRP (Marginal Revenue Product) represent the net addition to the packers total revenue attributable to the purchase of each additional slaughter animal. By assuming independence between the various other inputs required in the production process, the marginal revenue product curve, MRP, represents the packers demand curve for slaughter cattle.

The short run supply curve or marginal cost curve for a particular cattle feeder, S_i (i=1,2,...n) is denoted as ss. Associated with this short run supply curve is a marginal expense curve which indicates the additions to the packer total cost resulting from the purchase of each additional animal. This curve, MSC, will always lie above the supply curve ss because the total amount paid for any level of purchase is based on the per animal price of the last animal purchased. The range of possible terms of exchange on which both the packer and feeder would be willing to deal is then bounded by p_1abcp_2, the actual exchange

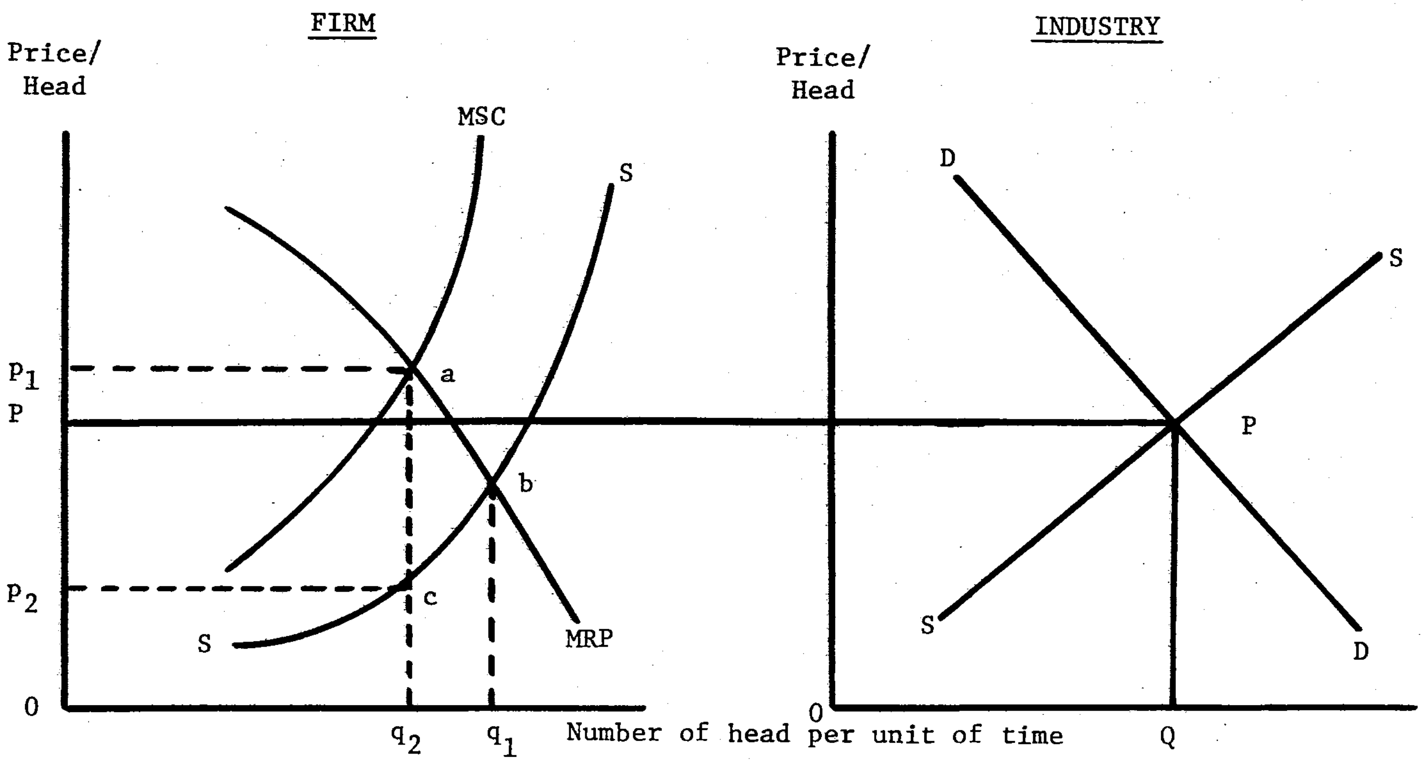

Figure 4. Market Pricing of Slaughter Cattle
Under Imperfect Competition

rate between the two parties will be determined by (1) the ability the feeder has in making the effective supply curve horizontal between Op_2 and Op_1, and (2) the ability the packer has in making MRP more inelastic.

Depending upon the available supply of slaughter cattle in the immediate marketing area, the local concentration of both packing plants and feedlots, and the degree of packer feeding, the feedlot operator can, in fact, make the effective supply of cattle curve a horizontal line at any level he wishes - at least until the horizontal line reaches the existing supply curve. This allows the feeder the option of bargaining on either price or quantity, or both.

On the other hand, the most favorable position for the packer is to establish a price of Op_2 and purchase Oq_2 head. The packers success in gaining this position is primarily determined by:

1. The available supply of slaughter cattle. "With larger supplies, the packer buys aggressively and with scarce supplies is forced to 'bid up' prices."[11]
2. The ability to capitalize on the market imperfections observed with respect to federal grading and specification and the collection and dissemination of market news prices and other marketing information.
3. The degree to which slaughter requirements can be supplemented by packer owned or packer contracted cattle.

Short Run and Market Period Equilibrium

In the short run the equilibrium price and quantity of the industry is determined by the interaction of both the aggregate supply and aggregate demand curves. If DD and SS in Figure 4 represent the collection of the demand and supply, respectively, of all firms in the industry, the short run equilibrium price is OP and OQ head are purchased. Each individual packer, depending on his relative bargaining position, purchases between Oq_1 and Oq_2 head at a price between Op_2 and Op_1.

The equilibrium price established during the market period is less difficult to analyze. Generally, once the cattle have reached the market, the supply of each feeder is essentially fixed, and can be represented by a straight line parallel to the vertical axis. The market supply curve is simply the horizontal summation of all individual supply curves. In Figure 5 the fixed quantity available for sale is $O\bar{Q}$ and the market supply curve is the straight line labeled S. If the demand is DD the equilibrium price in the market period is $O\bar{P}$. Thus, it is apparent that any weakness (strength) in demand is transformed entirely into reduced (higher) prices at the market.

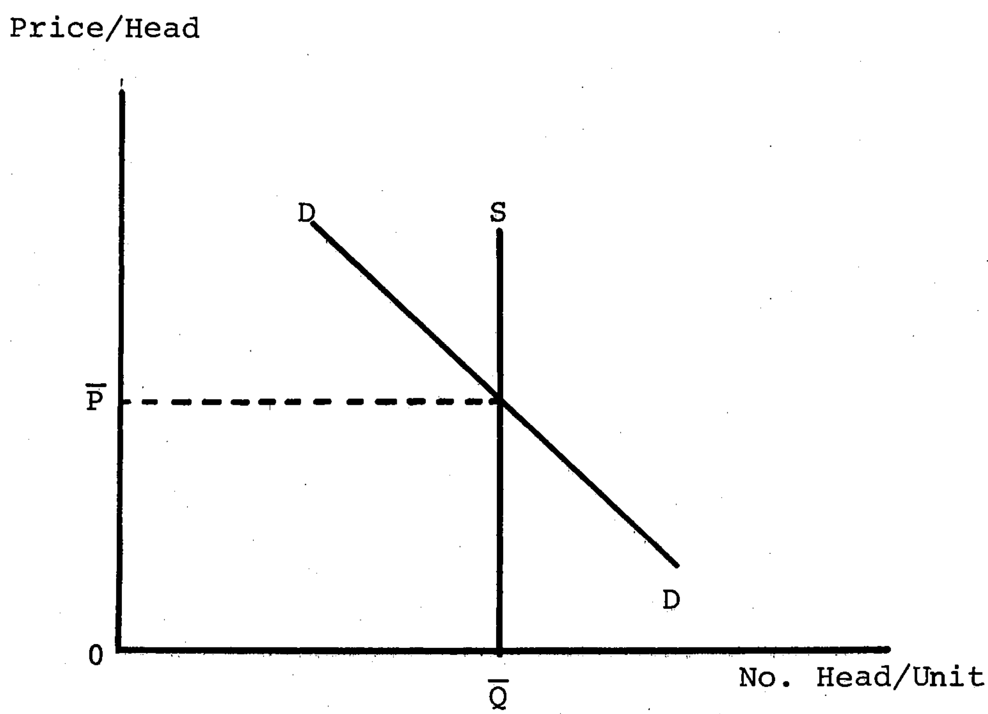

Figure 5. Price Equilibrium in the Market Period

FOOTNOTES

[1]John E. Trierweiler and Donald B. Erickson, "Structural Relationships for National and Regional Beef Cattle Production," Agricultural Experiment Station, S. Dakota Station, Technical Bulletin 25 (June, 1965), p. 14.

[2]Ronald A Gustafson and Ray N. VanArsdall, "Cattle Feeding in the United States," E.R.S., U.S. Department of Agriculture, Agricultural Economic Report No. 186 (October, 1970), p. 24.

[3]Willard F. Williams, "Structure and Conduct of the Commercial Cattle Feeding Industry," Supplemental Study No. 1 to Technical Study No. 1, "Organization and Competition in the Livestock and Meat Industry," National Commission on Food Marketing (June, 1966), p. 21.

[4]Arnold Aspelin and Gerald Engelman, "Packer Feeding of Cattle, Its Volume and Significance," Packers and Stockyards Division, C.M.&S., U.S. Department of Agriculture, Marketing Research Report No. 776 (November, 1966), p. 2.

[5]Jack H. Armstrong, "Cattle and Beef: Buying, Selling, and Pricing," Cooperative Extension Service, Purdue University (May, 1968), p. 46.

[6]J. E. Faris, "Analytical Techniques Used in Determining the Optimum Replacement Pattern," Journal of Farm Economics, No. 42 (November, 1960), pp. 755-66.

[7]Terry Lee Dunn, "Economic Implication of Interlevel Goal Conflict and Operational Inconsistency in the Beef Marketing System: The Packer-Feeder Subsector," (Master of Science thesis, Oklahoma State University, May, 1970), p. 57.

[8]Gerald Engelman, "Some Implications of Antitrust and Competitive Regulation of a Projected Vertically Integrated Pork Industry." Paper presented at the National Symposium on Vertical Coordination in the Pork Industry, Purdue University, April 16, 1971, p. 6

[9]Richard Caves, American Industry: Structure, Conduct, Performance, Second Edition, Prentice-Hall, Inc. (Englewood Cliffs, New Jersey, 1967), p. 11.

[10]U. S. vs. Iowa Beef Packers, Inc., et. al. Civil 69-C-308-W-N.D. Iowa (1970), p. 11.

[11]Dunn, p. 81.

CHAPTER IV

SPECTRAL DECOMPOSITION OF SLAUGHTER STEER PRICES

Introduction

Gaining information about the fundamental time-varying characteristics of an economic series is a central feature in the exploratory stages of model selection and specification. As illustrated in the literature review, numerous stochastic models of varying degrees of sophistication can be used in economic forecasting. The future behavior of most economic time-varying processes, in addition to being dictated by economic theory, is related to its past and present behavior. Narrowing the range of plausable model types must, therefore, depend on a combined knowledge of the industry producing the series and a statistical description of the underlying serial dependencies. The value of the much simplier and straight-forward algebraic and trigonometric models, for example, directly depend on the extent and repeatability of these underlying time patterns.

In this chapter spectral and cross-spectral analyses will be used to examine the statistical time-varying properties of both actual and deflated slaughter cattle prices. First, however, a heuristic explanation of spectral analysis and the necessary estimating procedure will be given. No attempt will be made to present the statistical properties of the spectral estimators or to discuss the hypotheses underlying the power spectrum and the cross-spectrum. An excellent survey and bibliography are found in Dhrymes' Chapters 9-12.[1]

Power Spectrum Estimate

The essence of spectral analysis is to establish the relative contribution that a number of frequency components make toward explaining the total variance of a stochastic process. In this way the spectrum conveys information in terms of frequency about the periodic or almost periodic components in a time series. Economists have traditionally been practicing a naive form of spectral analysis when they decompose a time series into "trend-cycle," "seasonal" and "irregular" movements. Spectral analysis, however, is statistically more powerful and easier to interpret graphically than the conventional moving average or correlogram.

The first step in estimating the power spectrum is to assume that the time series $\{x(t); t = 1,2,3,...n\}$ is a finite sample from a covariance stationary or near stationary generating process $\{X(t); t = -\infty...,-1,0,1,... +\infty\}$. The assumption of stationarity implies that the mean of x(t) is a constant and the autocovariance C_{xx} is a function of the interval k; k=(s-t) and not of the point in time at which x is measured. Estimators of the mean and covariance function are:

$$X_t = \frac{1}{n} \sum_{t=1}^{n} x_t$$

$$C_{xx}(k) = \frac{1}{n-k} \left[\sum_{t=1}^{n-k} X_t X_{t+k} - \frac{1}{n-k} \sum_{t=1+k}^{n} X_t \cdot \sum_{t=1}^{n-k} X_t \right]$$

where

$k = 0,1,2,\ldots m,\ldots,(n-1)$

Even though economic time varying processes are seldom, if ever, covariance stationary, the concept does permit reasonable inferences to be made about the time varying nature of the process; and as suggested by Fishman,[2] a suitable transformation can be applied that will make the process conform more closely to stationarity.

Before converting the autocovariance function into an estimate of the power spectrum, a weighting function must be specified. This function improves the statistical estimating properties of the power spectrum. In a recent article by Jenkins three different weighting schemes were suggested.[3] First, the original data can be premultiplied by a function called the "data window." Second, the autocovariance estimate may be weighted by a "lag window." Third, the autocovariance can be Fourier transformed and the raw spectrum smoothed by a "spectral window."

In the following estimation procedures the autocovariance function will be weighted by

λ_k where

$$\lambda_k \begin{cases} 1 & 0 < k < m \\ 1/2 & k = o,m \\ & m = \text{maximum lag} \end{cases}$$

From the theory of Fourier cosine transforms the weighted autocovariance function can now be represented by:

$$\hat{F}_{xx}(\omega_j) = \frac{2}{\pi} \sum_{k=1}^{T} \lambda k \, \hat{C}_{xx}(k) \cdot \mathrm{Cos}\, \frac{kj\pi}{m} + \frac{\hat{C}_{xx}(0)}{\pi}$$

for k,j = 0,1,2,... (m+1)

$\hat{F}_{xx}$ is called the raw power spectrum and is estimated over the interval (o,π) at m + 1 equi-distant points ω_j ($\omega_j = \frac{j\pi}{m}$, j = 0,1,2,...m). The quantity ω is the number of revolutions around the unit circle per time unit. If f equals the frequency in cycles per time until and P the length of time required for one complete cycle, the following relationships can be established:

$$\omega = \frac{2\pi}{P} \; ; \; P = \frac{1}{f} = \frac{2\pi}{\omega}$$

The raw estimates of the power spectrum are then smoothed by the spectral window:

$$\hat{F}_{xx}(\omega_0) = .54\, \hat{F}_{xx}(0) + .46\, \hat{F}_{xx}(\omega_1)$$

$$\hat{F}'_{xx}(\omega_j) = .23\,\hat{F}_{xx}(\omega_{j-1}) + .54\,\hat{F}(\omega_j) + .23\,\hat{F}_{xx}(\omega_{j+2}),\ 0<j<m$$

$$\hat{F}'_{xx}(\omega_m) = .54\,\hat{F}_{xx}(\omega_m) + .46\,\hat{F}_{xx}(\omega_{m-1})$$

Since $\sigma_x^2 = C_{xx}(o) = \int_{\omega=o}^{m} F_{xx}(\omega)\, d_\omega$ the power spectrum provides a decomposition of the variance of a time series in the frequency domain. That is, it describes the process in terms of the relative contribution to the overall variance of the time series of a small band of frequencies around a particular ω_j.

Studying a covariance stationary process in the frequency domain permits a clearer understanding of what constitutes a process than the autocovariance function does in the time domain. If all of the variance is concentrated in only one narrow frequency band, ω_j, the power spectrum will appear as a single "spike" at that frequency, Figure 6. At the other extreme, Figure 7, if all frequencies contribute equally to the total variance, the power spectrum graph will be a horizontal line. Of course, the majority of power spectrums estimated from economic data fall between these two extremes. In fact, Granger[4] found that a vast majority of economic variables have a similarly shaped power spectrum of the nature displayed in Figure 8.

In model selection and specification these three

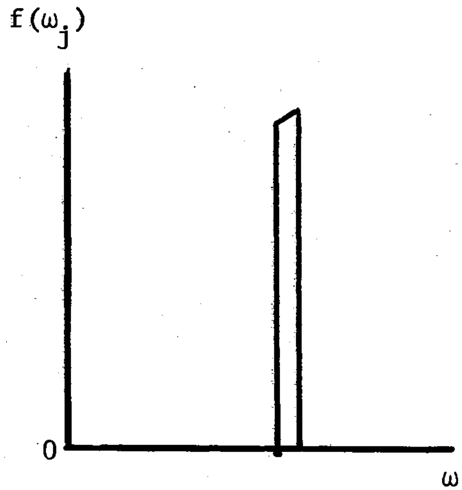

Figure 6. Spectrum of a Sine Wave

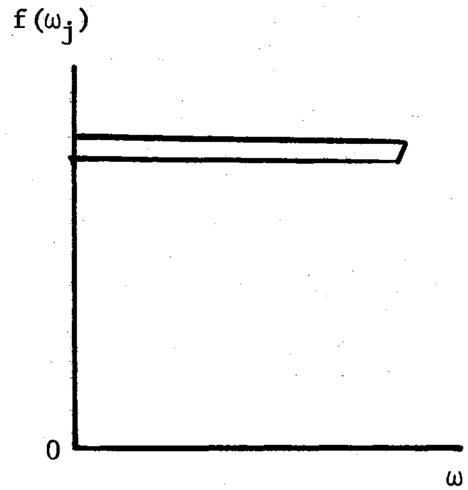

Figure 7. Spectrum of a Purely Random Series

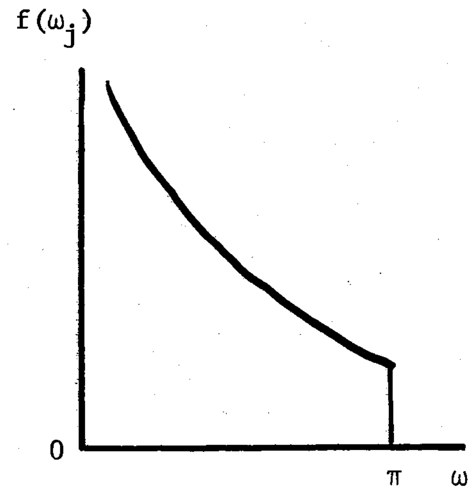

Figure 8. Typical Spectral Shape

theoretically distinct spectral characterizations have practical value.

First, the extent and repeatability of seasonal and cyclical patterns are directly related to the relative contribution of each frequecy band. The more narrow and discernable the peaks, the greater the likelihood that the series can be described by a sequence of sine and cosine waves (Figure 6). Second, a purely random series is suggested by a spectral configuration in which each frequency contributes equally to the total variance (Figure 7). This series cannot contain any cyclical, seasonal, or other deterministic components; nor can this series be expressed as a finite, linear aggregation of previous values. Third, a realization from a low-order autoregressive process is represented by a relative smooth spectrum with the predominance of power at low frequencies for a positive process and at high frequencies for a negative process (Figure 8).[5]

Cross-Spectral Estimates

Another contribution of spectral analysis to time series analysis is its capability in describing the complex interrelationships between economic variables. In oversimplified terms an empirical cross-spectrum between two series is concerned with the interactions or correlations between each pair of observations occurring over each frequency band.

Since the interpretation and estimation of the cross-spectrum have been dealt with in economic terms by both

Granger[6] and Fishman[7] only the coherency, gain, and phase statistics will be considered here.

Coherency

The coherency statistic is bounded by 0 and 1 and is similar in concept and interpretation to the coefficient of determination in standard regression analysis. The only difference is that the coherency estimate indicated the proportion of one series "explained" by the other series at each frequency component. The coherency may be computed by

$$C_{yx}^{2}(\omega_j) = \frac{\hat{F}_{yx}(\omega_j)^2}{F_{xx}(\omega_j)\,F_{yy}(\omega_j)}$$

where $F_{yx}(\omega_j)$ denotes the cross-spectrum, and $F_{xx}(\omega_j)$ and $F_{yy}(\omega_j)$ the power spectrum of the two series $_x$ and $_y$, respectively. A coherency estimate of 1 implies that, at that particular phase angle, the variances of the two series are homogeneous; whereas two series that are totally unlike (incoherent) have a coherency of 0.

Gain

The gain statistic is essentially the scalar by which the amplitude of one series at each frequency must be multiplied to produce the amplitude at the same frequency in another series, i.e. a rough analogue to a regression coefficient at each frequency component. In fact, Nerlove[8] suggested that the least squares estimate of the simple regression equation can be thought of as a weighted average of the regression or gain coefficient at each frequency ω_j. The gain statistic will be:

$$G_{yx}(\omega_j) = \frac{F_{yx}(\omega_j)}{F_{xx}(\omega_j)}$$

Phase-Shift

Finally, the phase-shift statistic simply provides an estimate of the average lead or lag of one series over another which maximizes the coherency at each frequency band

$$\pm \Phi_{yx}(\omega_j) = \tan^{-1} \cdot \frac{\text{Im}[F_{yx}(\omega_j)]}{\text{Re}[F_{yx}(\omega_j)]}$$

where Im [·] and Re [·] denote the imaginary and real parts of the complex valued cross-spectrum density function. The phase angle is measured in radians and can be converted into a calendar-time unit by computing $\gamma(\omega_j)$; where

$$\gamma(\omega_j) = \frac{\Phi_{yx}(\omega_j)}{2\pi\ \omega_j} \qquad j = 0,1,\ldots m$$

When $\gamma(\omega_j)$ is positive the input series leads the output series; otherwise, the output series leads.

Empirical Results

Frequent and irregular variations are characteristic of slaughter steer prices. As indicated in a recent article by Franzmann,[9] historical investigation of the cattle cycle has concentrated on providing a system of logic to explain why a cycle could or even should exist. Fundamental to this research is the notion that (1) a regular, current long term cattle cycle does exist; (2) the average periodicty of the cycle is 10 to 16 years; and (3) either the transitory forces outside the cattle industry or the behavior of the producer within the industry is the underlying economic mechanism responsible for the cycle.

In order to place the investigation of the time varying characteristics of cattle prices on a more rigorous foundation, the power spectrum was estimated for monthly slaughter steer prices, Chicago basis, from January 1920 through December 1970. Since it is generally advisable to use as many time lags k as possible - only so long as k does not exceed one-third of the total observations -- 199 lags were used.[10]

The most noticeable characteristic of the logarithm of the estimated power spectrum, Figure 9, is the importance of the low frequency components. Despite attempting several trend removing transformations, the frequency bands between 0 and .013 cycles per month still contributed a significant portion of the total variance. Granger[11] argues that even though a trend removal procedure has been applied, a characteristic of the estimated procedure known as leakage will still cause biases in the low frequency

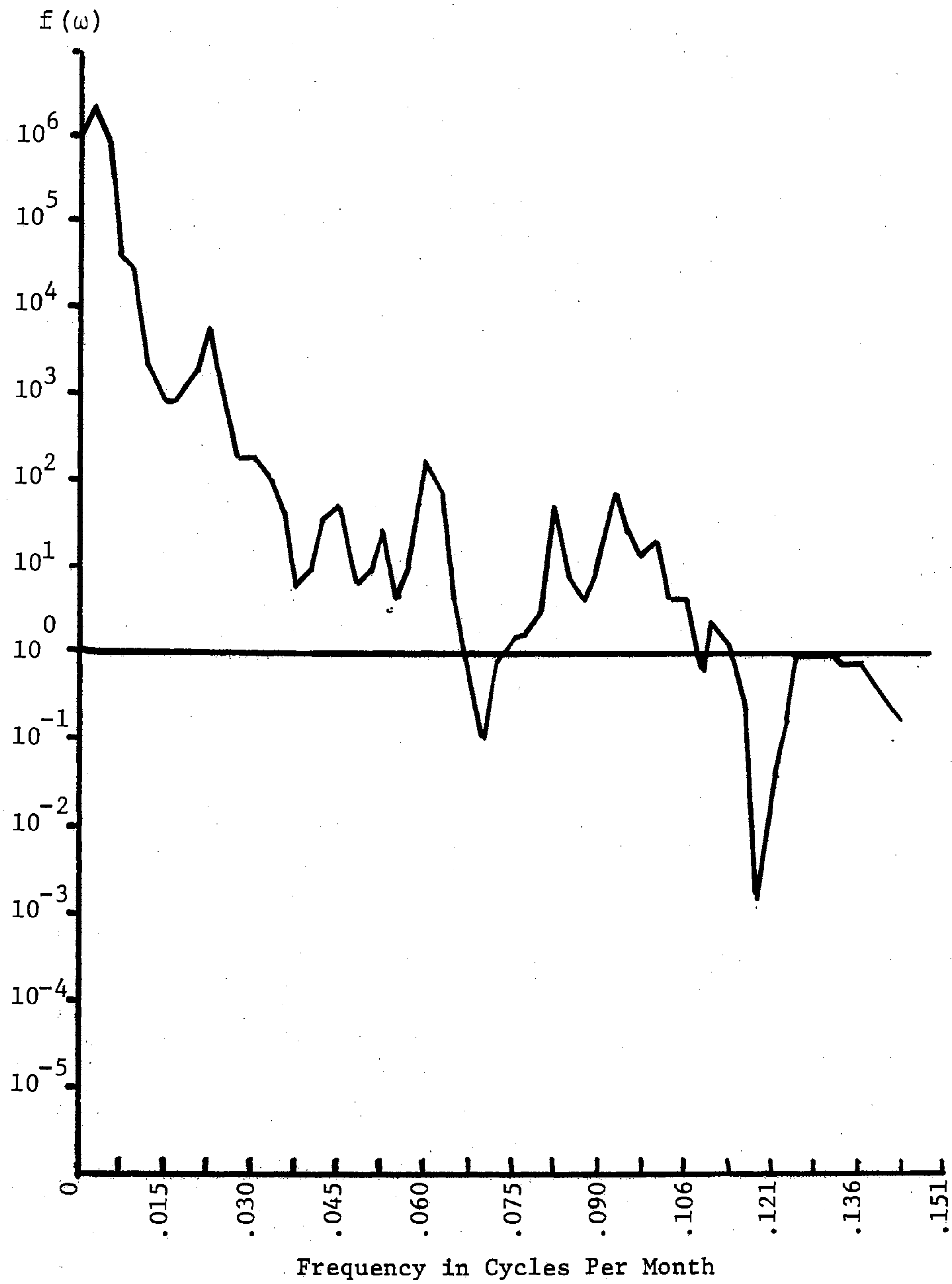

Figure 9. Log of Estimated Spectral Density Function Slaughter Cattle Prices

estimates. Granger further notes that this bias is found regardless of the length of the data base and the size of the truncation point used in the estimation procedure. Nevertheless, the failure of the estimated power spectrum to form a significant "spike" at these low frequency bands provides strong evidence for rejecting the hypothesis that actual slaughter cattle prices are characterized by a long-term cyclical component.

The power spectrum estimate does evidence the existence of a minor price cycle with a periodicity of approximately four years duration (frequency of .021 cycles per month). A formal explanation of this cycle is partially advanced by the theory of self-generation.[12] A coherency estimate of .56, Table VI, between the price of slaughter cattle and the number of cattle slaughtered each month establishes that each phase in the cycle partially generates its succeeding phase. Influences outside the cattle industry, such as feed supply, weather, other livestock products, and the demand for beef are additional explanations for this cycle.

There is some evidence that both hog prices and the number of hogs slaughtered vary cyclically with a periodicity of four years.[13] A relatively low coherency estimate between each of these series and the cattle price series, however, suggests that the four-year hog cycle is not being translated into the behavior of the four-year cattle cycle.

The power spectrum estimate of slaughter cattle prices

TABLE VI

COHERENCY AND PHASE-SHIFT BETWEEN CHICAGO SLAUGHTER STEER PRICES AND COMMERCIAL CATTLE SLAUGHTER - U.S.

Frequency Cycles/Mo. (ω_j)	Coherency Square $C^2yx(\omega_j)$	Phase-Shift $\phi yx(\omega_j)$
.0025	.58	.53
.0050	.24	.56
.0075	.67	.55
.0101	.93	.56
.0126	.13	.27
.0151	.20	.16
.0176	.07	.21
.0201	.18	.52
.0226	.33	.61
.0251	.56	.76
.0276	.37	.78
.0302	.28	.60
.0327	.15	.54
.0352	.74	.84
.0377	.41	.57
.0402	.42	.65
.0427	1.00	.31
.0452	.44	.39
.0477	.08	.36
.0503	.15	.19
.0528	1.00	.26
.0553	.89	.24
.0578	.09	.24
.0603	.71	.70
.0628	.25	.64
.0653	.68	.50
.0678	.74	.44
.0704	.00	.69
.0729	.68	.39
.0754	.84	.44
.0779	1.00	.39
.0804	.22	.13
.0829	.75	.03
.0855	.98	.08

is also characterized by a series of peaks corresponding to a period of 16 months and its harmonics. These peaks, although contributing little to the total variance of the series, are indicative of a slowly changing but stochastic seasonal pattern. As manifested by a coherency estimate of .98 at .085 cycles per month, Table VI, there is an extremely close correlation between the seasonality in cattle prices and cattle slaughter. This relationship is attributed to the seasonality in feeder cattle marketing. On the average, during the past 11 years 59 percent of the feeder cattle have been marketed, or placed on feed, during the October-December quarter (Table VII).

Deflated Slaughter Cattle Prices

A possible explanation for the long run irregularity of slaughter steer prices is the intermittent influence of inflation, deflation, wars, weather, etc. Breimyer[14] has suggested that "actual prices in dollars conform only roughly to cycles because they reflect not only the supply of cattle but also the general level of all commodity prices" and "to produce cyclical curves of some regularity it is necessary to deflate the report prices."

Recently, Franzmann empirically validated Breimyer's suggestion when he estimated a harmonic function over the period 1921-1969.[15] His results provided strong support for the conclusion that deflated prices of all cattle varies cyclically with a uniform period of ten years.

TABLE VII

CATTLE AND CALVES PLACED ON FEED, 22 STATES, DURING SPECIFIC QUARTERS
(1,000 Head)

Year	January - March	April - June	July - September	October - December
1960	2,732	2,164	2,732	5,458
1961	2,793	2,279	3,226	5,708
1962	2,938	2,515	3,675	6,470
1963	2,949	2,868	3,905	6,193
1964	3,591	2,878	4,232	6,600
1965	3,742	3,429	4,295	6,885
1966	4,602	3,660	4,529	7,333
1967	4,567	3,818	5,024	7,548
1968	5,043	4,407	5,744	8,180
1969	5,070	5,186	5,752	8,431
1970	5,099	5,231	6,127	7,952
Average	3,920	3,494	4,476	6,978

Source: Cattle On Feed, E.R.S., U.S.D.A.

In order to examine the possibility that outside forces are obscuring the true cyclical nature of slaughter steer prices, a spectral analysis was estimated with the deflated series. The Index of Prices Received by Farmers for all Farm Products, 1910-14 = 100, was used as the deflator. Figure 10 illustrates the estimated power spectra for both the deflated and undeflated price series. The spectra of the undeflated series is represented by the solid line and the deflated series by the dashed line.

The most striking finding is the presence of a highly significant ten-year cycle in the deflated price series. The peak at .008 cycles per month completely substantiates the hypothesis that the time path of deflated slaughter steer prices follow a relatively stable cycle that repeats itself at ten year intervals.

The spectral evidence of a significant long term cattle price cycle emits three important questions. First, is the undeflated price series actually characterized by an unobserved ten-year cycle that is only being obscured by the transitory factors mentioned by Breimyer? Second, in the process of deflating, is the deflator introducing a spurious cyclical component on the original series? Third, and most important, what inferences can be advanced concerning the applicability to forecasting of the deflated series?

Question I: A reconciliation of the first question is offered insofar as a ten-year cycle in cattle prices can

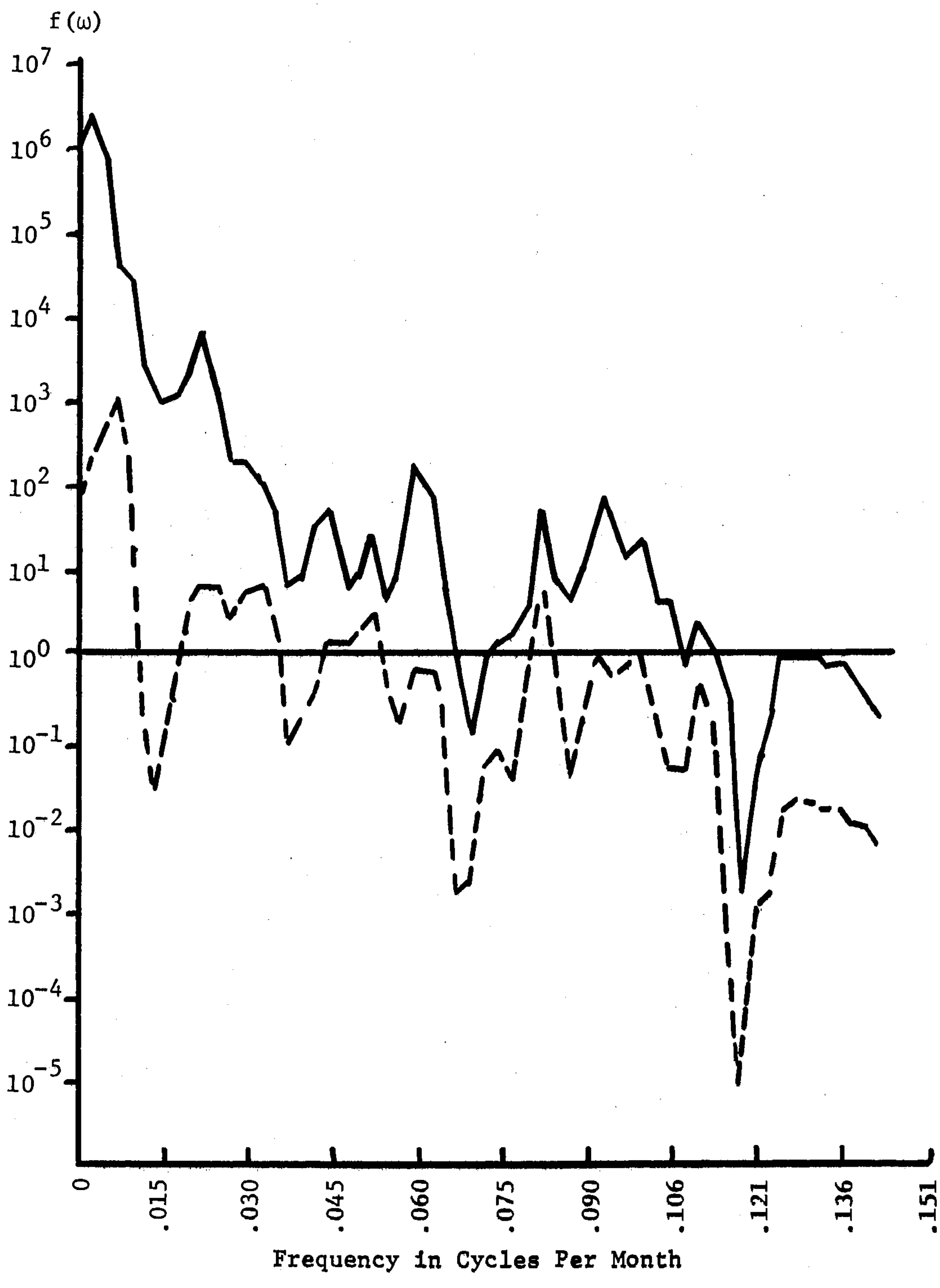

Figure 10. Log of Estimated Spectral Density Function Actual and Deflated Slaughter Cattle Prices

be linked internally to the self-generating forces within the livestock industry. For instance, Ezekiel[16] stressed that cattle cycles were a function of the variability in production caused by intermittent over-response first to high and then to low prices. Since a coherency statistic is similar in concept and interpretation to the coefficient of determination in standard regression analysis the coherency estimate of .67 at .008 cycles per month does establish a correlation between cattle prices and the supply of slaughter cattle.

Question II: The coherency, gain and phase-shift statistics between the original and deflated series can provide the type of information necessary for investigating the possibility that the deflator is inadvertently influencing the low frequency components.[17] Accordingly, these three statistics were computed for the undeflated slaughter cattle price series in relation to the deflated series. Once again, 600 observations were included and 199 was the maximum lag.

Examination of the coherency function in Figure 11a illustrates that the deflator does preserve the overall movement and general appearance of the original series at fequencies corresponding to the ten-year cycle, four-year cycle, and the seasonal and its harmonics. The gain estimate in Figure 11b also indicates that the deflator is not, at low frequencies, abnormally attenuating

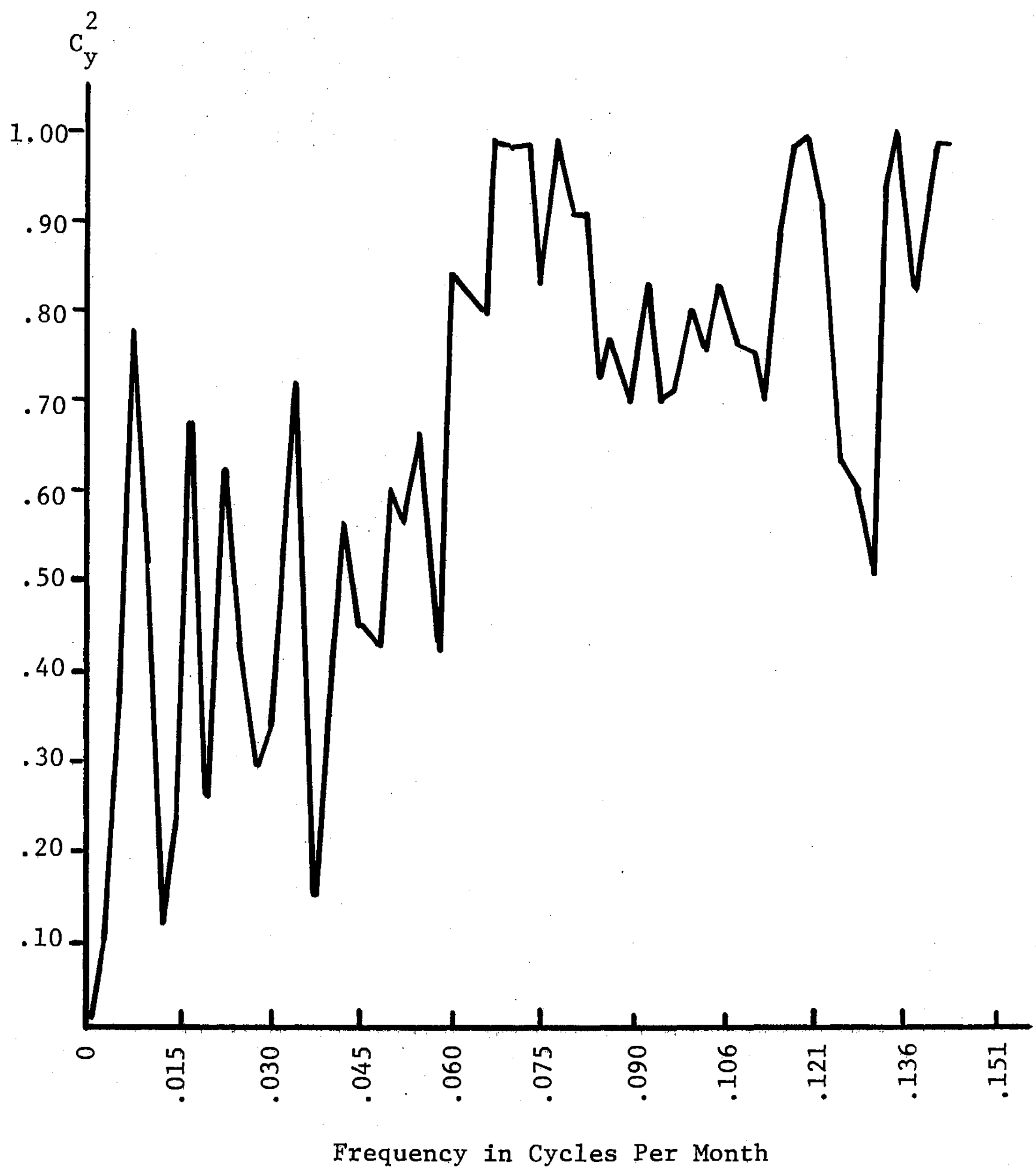

Figure 11a. Coherency Function of Actual Slaughter Cattle Prices and Deflated Slaughter Cattle Prices

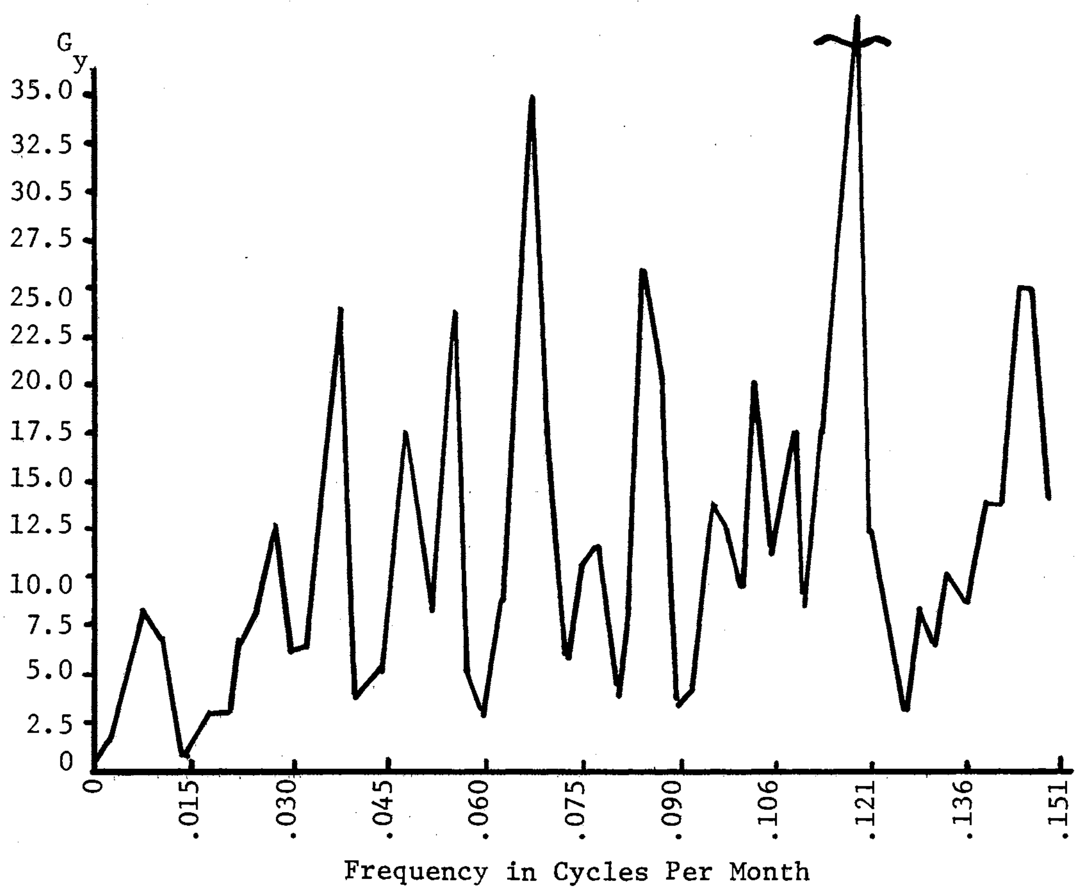

Figure 11b. Gain Diagram for Actual Slaughter Cattle Prices and Deflected Slaughter Cattle Prices

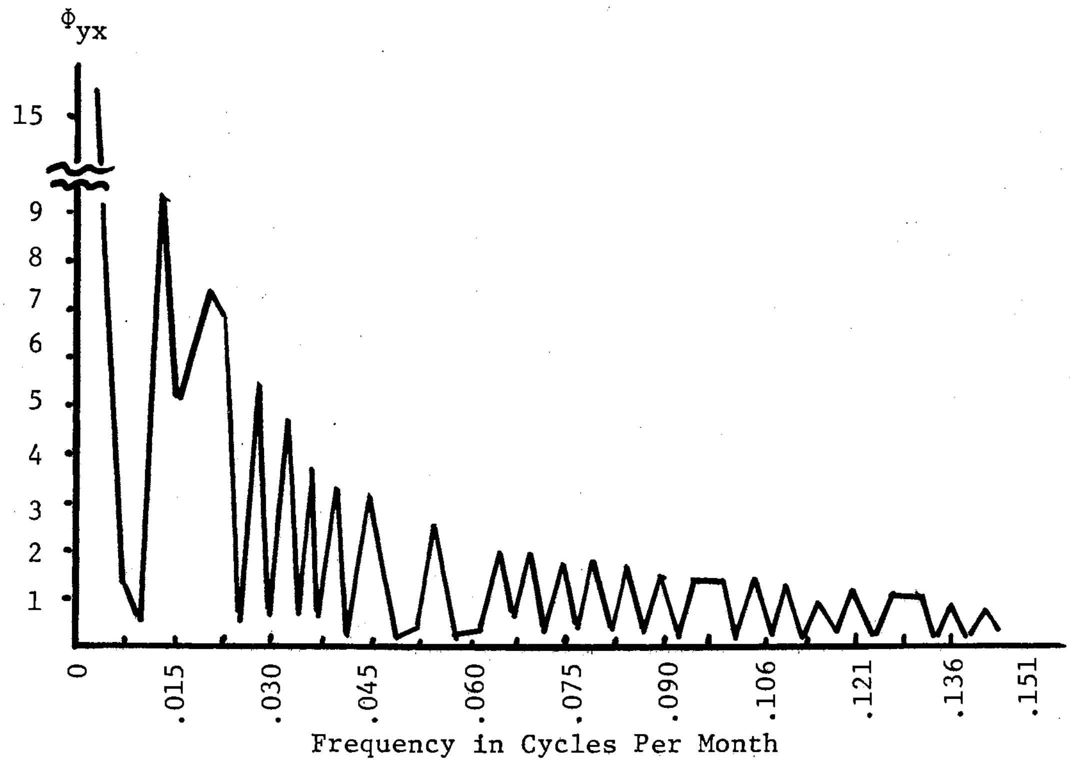

Figure 11c. Phase-shift Diagram for Actual Slaughter Cattle Prices and Deflected Slaughter Cattle Prices

the amplitude of the original series. In fact, only an insignificant amount of dampening is recorded at .008 cycles per month. Finally, although rather violent phase-shifts were observed at extremley low frequencies, the deflator does not abnormally influence the remainder of the power spectrum. Since the coherency is extremely low at frequencies less than .008, the significance of the phase shifts in these frequency bounds is limited.

Question III: On the strength of the statistical evidence presented thus far it must be concluded that the slaughter cattle price series is characterized by an unobservable long-term cycle with a periodicity of ten years. Even so, the real value of this cycle must be assessed in terms of its contribution to describing and forecasting cattle prices. Franzmann[18] demonstrated that the time path of the average price of all slaughter cattle can be described by a mathematical function comprised of a ten-year cyclical component and a seasonal component fluctuating about a linear trend. He then concluded that "the stability of the period of the estimated cyclical variation holds forth the promise of increased forecasting reliability over rather long periods of time."[19]

Over a short planning horizon, however, consideration of a long-term cyclical component only adds to the dimensionality of the problem. First, as demonstrated in the following mathematical model, where the deflated prices of of 900-1,100 pound Choice steers are used as the dependent variable, only 64 percent of the total variance in the series can be explained:

$$\hat{Y}_t = \underset{}{.073} + \underset{(.000008)}{.00006T} + \underset{(.0006)}{.008 \cos 3t^{\circ}} - \underset{(.0006)}{.00095 \sin 7.5t^{\circ}}$$

$$+ \underset{(.0009)}{.0024 \cos 7.5t^{\circ}} - \underset{(.0006)}{.0024 \sin 30t^{\circ}} - \underset{(.001)}{.0016 \cos 30t^{\circ}}$$

$$R^2 = .64$$

Y = deflated, 900-1,100 pound Choice grade slaughter steer prices - Chicago

T = trend (1920 = 1)

Second, since the management problem considered in this dissertation requires forecasts of the undeflated series, it necessarily follows that future values of the deflator must be known or at least forecastable. The errors associated with forecasting future values of the deflator and converting the deflated series into estimates of the actual series would probably transcend the errors from a similar model using the undeflated series as the dependent variable.

Concluding Inferences

The major objective of this chapter is to seek fundamental regularities in the price series for slaughter cattle that could have practical model selection and/or predictive value. As visually portrayed by the log of the estimated power spectrum the second movement time varying properties of the slaughter steer price series is characterized by: (1) an extremely irregular long-term fluctuation in the original series; (2) a highly regular long-term cycle of 10 years duration in the deflated series; (3) a slightly significant minor price cycle with a regular periodicity of approximately four years; and (4) nonconforming (trending) seasonal patterns.

In general the nature of the time patterns in the original price series is such that doubt is cast on the possibility of using a simple unobserved components model for forecasting future price movement. If data are not readily available on the underlying economic mechanism which generates the four-year cycle, however, it may be possible to include a sinusoidal function with a duration of four years in a behavioral model.

Some support was advanced for the possibility that, since outside forces are obscuring the true cyclical nature of the original series, a price deflator should be entertained. By deflating the original series, the task of estimation could be greatly simplified. However, the problems inherent in estimating the deflator makes it questionably acceptable for short-term forecasting.

Finally, it can be argued that apart from the irregular long-term cyclical behavior and the somewhat important minor cycle, the seasonal component may contain useful information about possible forecasting techniques. As previously indicated, a process having a relatively smooth spectral shape with a preponderance of power concentrated at either extreme can be explained by a low-order autoregressive model. Classic examples would be moving average models, first difference models, distributed lag models and exponential smoothing techniques.

FOOTNOTES

[1]P. J. Dhrymes, Econometrics, Harper & Row (New York, New York, 1970), Chapters 9-12.

[2]G. S. Fishman, Spectral Methods in Econometrics, Harvard University Press (Cambridge, Massachusetts, 1969).

[3]G. M. Jenkins, "General Considerations in the Analysis of Spectra," Technometrics, Vol. 3 No. 2: 133-165 (May, 1961).

[4]C. W. J. Granger, in association with M. Hatanaka, Spectral Analysis of Economic Time Series, Princeton University Press (Princeton, New Jersey, 1964).

[5]C. W. J. Granger, "The Typical Spectral Shape of an Economic Variable," Econometrica, 34: 150-161 (January, 1966).

[6]Granger and Hatanaka, pp. 20-21.

[7]Fishman, pp. 19-20.

[8]M. Nerlove, "Spectral Analysis of Seasonal Adjustment Procedures," Econometrica, 32: 241-286 (July, 1964), p. 273.

[9]John R. Franzmann, "Cattle Cycles Revisited," Journal Article 2207 of the Oklahoma Agricultural Experiment Station, presented to the Southern Agricultural Economics Association, Jacksonville, Florida, February 1-2, 1971, pp. 1-20.

[10]Granger and Hatanaka, p. 22.

[11]Granger, p. 152

[12]H. F. Breimyer, "Observations on the Cattle Cycle," Agricultural Economics Research, Vol. VII, No. 1: 1-11 (January, 1955).

[13]Arnold B. Larson, "The Hog Cycle as Harmonic Motion," Journal of Farm Economics, Vol. 46, No. 2 (May, 1964), pp. 375-386.

[14]Breimyer, pp. 4-11.

[15]Franzmann, pp. 1-20.

[16]Mordecai Ezekiel, "The Cobweb Theorem," Quarterly Journal of Economics, 52: 255-280, 1938.

[17]Dhrymes, Chapter 10.

[18]Franzmann, pp. 1-20.

[19]Ibid.

CHAPTER V

MATHEMATICAL FORMULATION OF THE MODEL

Model Selection

During the past quarter century economists have produced a multiple of econometric and statistical techniques that can be used in model specification and estimation. The use of simultaneous equation procedures and its emphasis on model building, for example; or, fitting procedures using recursive models, two and three stage least squares, harmonic analysis, and distributed lag models, have all been upheld as developments which will aid in decision making.

The review of literature and the estimated power spectrum are helpful in narrowing this range of plausable model types. The work by Schmitz and Watts on forecasting wheat yields and the harmonic analysis approach by Waugh and Miller illustrated that if a series is characterized by significant seasonal or cyclical patterns a simplified unobserved components technique could produce acceptable forecasts. The suggestion by Fisher that a forecasting model must account for both the inter-relationships within the system and the dynamic adjustment process followed as variables more from one equilibrium to another is given primary consideration.

As visually indicated by the estimated power spectrum, the slaughter cattle price series not only resembles the power spectrum typically observed in most economic series but also is void of any visually significant underlying periodic components. This suggests that the direct application of mathematical models be eliminated from consideration and that further investigation concentrate on the on the difficult behavioral representations.

Mathematically derived in this chapter is a low-order autoregressive model that will hopefully account for the multiperiodic nature of the beef producing process and the uncertainty about future beef prices. As indicated in Chapter III, beef production is not instantaneous and thus time and price expectations are important restrictions on significant changes in output. Even in the absence of uncertainty the relevant criteria for production decisions are the discounted future product prices.

The Lag Distribution Problem

By using the very specific definition of dynamics given by Baumol,[1] "A system is dynamical if its behavior over time is determined by functional equations in which variables at different points in time are involved in an essential way," the following explicit functional form can be given:

$$P_t = f\ (X_{it}, X_{it-1}, X_{it-2} \ldots, X_{jt}, X_{jt-1}, X_{jt-2} \ldots, X_{gt})$$

This system takes on dynamic properties through the introduction of exogenous (or at least predetermined) variables that have both an immediate influence on P_t as well as a lagged effect. A more exact representation would be:

$$(1) \quad P_t = a_o + \sum_{i=1}^{n-1} \{B_{i1} X_{it} + B_{i2} X_{it-1} + B_{i3} X_{it-2} + \ldots\}$$

$$+ \sum_{j=n}^{m-1} \{B_{j1} X_{jt} + B_{j2} X_{jt-1} + B_{j3} X_{jt-2} + \ldots\}$$

$$+ \sum_{g=m}^{r} \{B_q X_{qt}\} + w_t \; ; \; r < \infty$$

Where the current value of the endogenous variable P_t is determined by the present and past values of a finite number of exogenous variables X_i and X_j and the current value of a number of exogenous variables X_g. This representation implies that the time form of the underlying lag scheme characterizing X_i is significantly different from that of X_j.

A Finite Lag Structure as Probabilities

For the moment assume that w_t is a stationary random variable with mean zero and a fixed covariance structure that may or may not be serially correlated. Clearly, without restricting the sequences $\{B_{ik}, B_{jk}; k = 1,2,3,\ldots\}$ of unknown parameters the problem of estimating these parameters cannot be defined. That is, Equation (1) requires that an infinite number of functionally unrelated parameters be estimated from a finite set of observation. It is natural to first impose the restrictions that all the $\{B_i$'s$\}$ and $\{B_j$'s$\}$ have a finite sum, i.e.

$$\sum_{k=1}^{\infty} B_{ik} = M \qquad -\infty < M < +\infty$$

$$\sum_{k=1}^{\infty} B_{jk} = M$$

In economic terms this restriction implies that a finite change in the values of the independent variables $\{X_i\}$ and $\{X_j\}$ which persist indefinitely, along with the present level of $\{X_g\}$ result in a finite change in the dependent variable P_t.

Second, in some applications the requirement that all the $\{B_{ik}$'s$\}$ and $\{B_{jk}$'s$\}$ are of the same sign is imposed. This allows Equation (1) to be rewritten as:

$$(2)\ P_t = a_o + \sum_{i=1}^{n-1} \{B_i \ (\omega_o X_{it} + \omega_1 X_{it-1} + \omega_2 X_{it-2} + \ldots)\}$$

$$+ \sum_{j=n}^{m-1} \{B_j \ (\partial_o X_{jt} + \partial_1 X_{jt-1} + \partial_2 X_{jt-2} + \ldots)\}$$

$$+ \sum_{g=m}^{r} (B_g X_{gt}) + w_t$$

where now the sequences ω_p and ∂_p are all non-negative and sum to unity, that is:

$$\omega_p \geqq 0 \qquad\qquad (p = o,1,2,\ldots),$$

$$p \geqq 0$$

and

$$\sum_{p=0}^{\infty} \omega_p = 1 \quad ; \quad \sum_{p=0}^{\infty} \partial_p = 1$$

Note also that

$$\omega_p = \frac{B_{ip}}{\sum_k B_{ik}} \qquad \text{and} \qquad \partial_p = \frac{B_{jp}}{\sum_k B_{jk}}$$

This is a rather strong restriction; nevertheless, since the ω's and ∂'s are non-negative and sum to one, they can be identified, formally with probabilities defined over the set of non-negative integers (0,1,2,3,...∞). The sequences of ω's and ∂'s describe the shape and time form of different lagged values on the dependent variable.

For convenience consider a backward shift operator L which is defined by:

$$L\, X_t = X_{t-1} \;;\; L^2\, X_t = X_{t-2} \;..\; L^m\, X_m = X_{t-m}$$

For the index of variables in Equation (2)

$$L\, X_{it} = X_{it-1} \;;\; L^2\, X_{it} = X_{it-2} \;;\; \text{and so forth}$$

$$L\, X_{jt} = X_{jt-1} \;;\; L^2\, X_{jt} = X_{jt-2} \;;\; \text{and so forth}$$

Equation (2) can now be rewritten as:

$$P_t = a_o + \sum_{i=1}^{n-1} \{B_i \ (\omega_o + \omega_1 L + \omega_2 L^2 + \omega_3 L^3 + \ldots)X_{it}\}$$

$$+ \sum_{j=n}^{m-1} \{B_j \ (\partial_o + \partial_1 L + \partial_2 L^2 + \partial_3 L^3 + \ldots)X_{jt}\}$$

$$+ \sum_{g=m}^{r} \{B_g \ X_{gt}\} + w_t$$

and finally as:

$$(3) \quad P_t = a_o + \sum_{i=1}^{n-1} \{B_i \ W(L)X_{it}\} + \sum_{j=n}^{m-1} \{B_j \ A(L)X_t\}$$

$$+ \sum_{g=m}^{r} \{B_g \ X_{gt}\} + w_t$$

Where W(L) and A(L) can be interpreted as either power series or polynominal in the lag operator L, or as lag generating functions.[2]

General Lag Structures

By varying the functions W(L) and A(L) time paths of different forms can be produced. For example, Fisher[3] suggested that the initial effect of a change in an exogenous variable is small, but as time passes the cumulative effect of the change becomes greater. Fisher's assumption would indicate that the weights W(L) and A(L) should follow a logarithmic normal distribution, such as that shown in Figure 12.

Because of the difficulty in estimating the coefficients in Fisher's model, Koyck recommended that a single parameter geometrically declining probability (lag) distribution be used to approximate the underlying true form of the lag. This distribution assumes that the biggest response occurs immediately at the beginning of the adjustment period and then tapers off for each successive time unit. By allowing several separate early terms in the sequences ω's and ∂'s before starting the geometric decline the geometric distribution can be considered a short-cut approximation to Fisher's logarithmic normal distribution.

A somewhat more inclusive assumption about the shape of the distributed lag structure was proposed by Solow.[4] In the article "On a Family of Lag Distributions" Solow advanced the two-parameter Pascal distribution as a general form for lag distributions. As illustrated in Figure 14, depending on the value of λ and r, both the theoretical underpinnings and the physical lag characteristics of the Pascal distribution are similar to the distribution outlined by Fisher. Moreover, in the special case where the parameter r=1 the Pascal distribution reduces to the geometric distribution reduces the geometric distribution.[5]

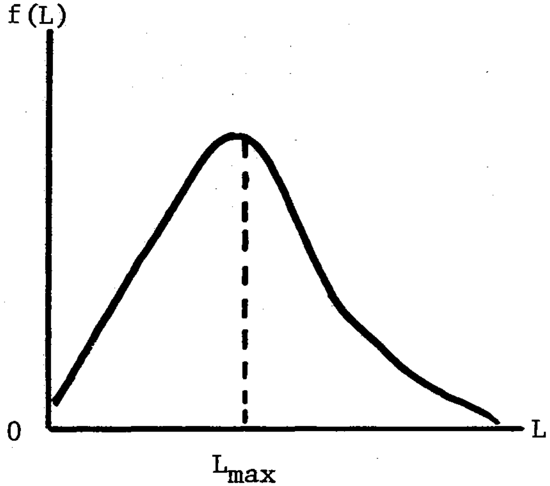

Figure 12. Fisher's Logarithmic Normal (Lag) Distribution

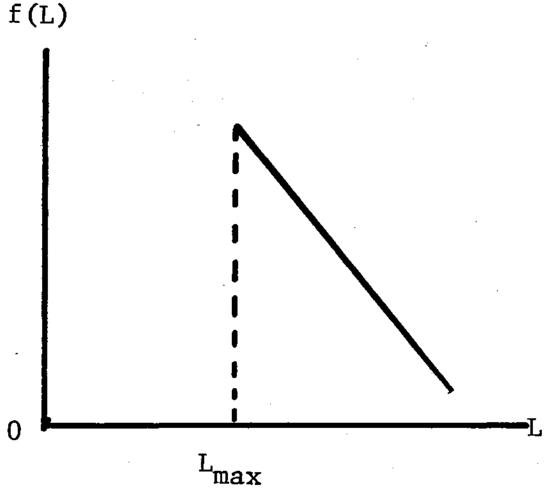

Figure 13. Koyck's Geometrically Declining Distributed Lag Function

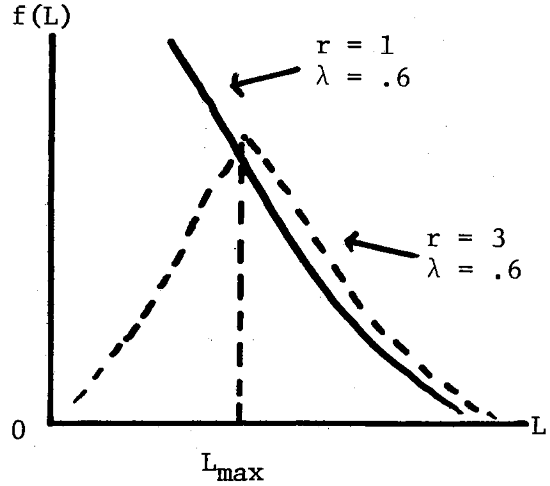

Figure 14. Pascal Distributions with Parameter $\lambda = .6$ and Parameter $r = 1$ and 3

Finally, Cagan[6] and later Nerlove[7] strongly suggested that the form of the lag should be derived from the implications of a particular behavioral hypothesis rather than assumed *a priori*. This approach yields a specific distribution of lag only incidentally. The difference between this approach and that proposed by Fisher and Koyck is strictly conceptual. Both approaches have widely different implication at the underlying structures that generate the lag; however, the final reduced form of both Cagan's "adaptive expectations model" and Nerlove's "partial adjustments model" implies a geometrically declining lag scheme.

Geometric Lag Generating Function

Because of the ease with which the geometrically declining lag form can be estimated (everything depends on only one additional parameter) and since it is consistent with several expectation and partial adjustment models, assume that the lag coefficients (ω_k) and (∂_k) decay geometrically with k beginning at 1. That is,

$$\omega_k = \lambda^k \qquad 0 \leq \lambda < 1$$

$$\partial_k = \mu^k \qquad 0 \leq \lambda < 1$$

and the generating function simplifies to [8]

$$W(L) = \frac{1}{1-\lambda L}$$

$$A(L) = \frac{1}{1-\mu L}$$

This allows Equation (3) to be rewritten as:

$$(4) \quad P_t = a_o + \frac{\sum_{i=1}^{n-1} B_i X_{it}}{(1-\lambda L)} + \frac{\sum_{j=n}^{m-1} B_j X_{jt}}{(1-\mu L)}$$

$$+ \sum_{g=m}^{r} B_g X_{gt} + Wt$$

By observing that W(L) and A(L) have formal inverses $W(L)^{-1}$ and $A(L)^{-1}$ Equation (4) can be solved or reduced by multiplying through by $(1-\lambda L)$ $(1-\mu L)$ to get $(1-\lambda L)$ $(1-\mu L)$ $Y_t = (1-\lambda L)$ $(1-\mu L)$ $a_o + B_i$ $(1-\mu L)$ $X_{it} + B_j$ $(1-\lambda L)$ $X_{jt} + (1-\lambda L)$ $(1-\mu L)$ W_t

or

$$(5) \quad P_t = \delta\ a_o + \sum_{i=1}^{n-1} B_i X_{it} - \mu \sum_{i=1}^{n-1} B_i X_{it-1}$$

$$+ \sum_{j=n}^{m-1} B_j X_{jt} - \lambda \sum_{j=n}^{m-1} B_j X_{jt-1}$$

$$+ \delta \sum_{g=m}^{r} B_g X_{gt} + (\lambda+\mu) P_{t-1} + \lambda\mu P_{t-2} + U_t$$

Where $\delta = (1-\lambda-\mu+\lambda\mu)$

$$U_t = W_t - (\lambda+\mu)\ W_{t-1} + \lambda\mu\ W_{t-2}$$

Model Estimation

Several problems are involved in the straight-forward estimation of the unknown parameters in Equation (5). The first, and most critical, is the problem of autocorrelation in the residuals U_t. The second is the nonlinear way in which λ and μ enter the specification. Each of these problems are handled in turn.

Autocorrelated Error Terms

At the outset it was assumed that U_t follows a stationary random process with a constant covariance function. Although U_t is independent of X_t i,j,g it is an oversimplification to assume that it is independent of P_{t-1}. In fact, since P_{t-1} is itself a weighted average of past U's it will almost always be highly correlated with U_t.

Griliches[9] referenced several additional sources of serial correlation in this particular lag model. Even if the original distribution (W_t) in Equation (3) is not serially correlated, the reduction procedure may induce it.

If the W_t's in

$$P_t = a_o + \sum_{i=1}^{n-1} B_i\ W(L)\ X_{it} + \sum_{j=n}^{m-1} B_j\ A(L)\ X_j$$

$$+ \sum_{g=m}^{r} B_g\ X_{gt} + W_t$$

are serially correlated, the U_t's in

$$W(L)^{-1}\ A(L)^{-1}\ P_t = \ldots + U_t$$

will be serially correlated, since $U_t = W(L)^{-1}\ A(L)^{-1}\ W_t$. Alternatively, if the W_t's are uncorrelated, the U_t's must be correlated.

Regardless of whether or not autocorrelation is superimposed by the reduction procedure the likelihood of serial correlation in the true distribution arising from errors in specification should be suspect. Ignoring this would alone result in biased and inconsistent estimates of the coefficient.[10]

One approach to the problem of serial correlation is to assume a particular form for the interdependency and estimate its parameters jointly with the others. Thus, assume that the time dependency of the U's can be adequately represented by a first order Markov process of the form

$$U_t = \beta U_{t-1} + e_t \quad ; \quad |\beta|<1.$$

where β is the autocorrelation coefficient and the deviates

e_t are mutually independent with constant variance σ_e^2 and 0 mean.

Solving Equation (5) for U_t and lagging each term one time period gives:

$$(6) \quad -U_{t-1} = \delta a_o + \sum_{i=1}^{n-1} B_i X_{it-1} - \mu \sum_{i=1}^{n-1} B_i X_{it-1} + \sum_{j=n}^{m-1} B_j X_{jt-1} - \lambda \sum_{j=n}^{m-1} B_j X_{jt-2} + \delta \sum_{g=m}^{r} B_q X_{qt-1} - P_{t-1} + (\lambda+\mu) P_{t-2} + \lambda\mu P_{t-3}$$

By multiplying this equation through by β substituting into $- U_t + e_t = \beta U_{t-1}$ and subtracting this from Equation (5) produces the final equation:

$$(7) \quad P_t = \delta a_o + \sum_{i=1}^{n-1} B_i X_{it} - (\mu+\beta) \sum_{i=1}^{n-1} B_i X_{it-1} + \mu\beta \sum_{i=1}^{n-1} B_i X_{it-2} + \sum_{j=n}^{m-1} B_j X_{jt} - (\lambda+\beta) \sum_{j=n}^{m-1} B_j X_{jt-1} + \lambda\beta \sum_{j=n}^{m-1} B_j X_{jt-2} + \delta \sum_{g=m}^{r} B_g X_{gt} + (\lambda+\mu+\beta) P_{t-1}$$

$$- \quad (\lambda+\mu)\ \beta+\lambda\mu \qquad P_{t-2} + \lambda\mu\beta \quad P_{t-3}$$

(Note that $\sum_{g=m}^{r} X_{gt-1} = 0$)

Nonlinear λ and μ Coefficients

Another difficulty with estimating Equation (5) is that even if λ and μ were known the nonlinear nature of λ and μ prevents, at least superficially, estimation of the necessary parameters. Fuller and Martin,[11] however, have theorized that by bounding the admissible range of λ and μ an iterative estimating procedure can be applied that will yield estimates which possess the large sample properties of consistency and asymptotic normality. Moreover, if the likelihood function is unimodal these estimates will be efficient, and, therefore, provide a maximum likelihood solution. In *Computer Algorithms For Estimating The Parameters of Selected Classes of Nonlinear Single Equation Models*, Martin [12] provides a complete computer procedure that can, after slight alterations, be used to estimate the parameters in Equation (7).

The "Naive" Model

A close inspection of Equation (7) indicates that if $\lambda=\mu=\beta=0$ the equation reduces to a simple linear equation with r independent variables or

$$(8)\quad P_t = a_o + \sum_{i=1}^{r} b_i X_{it} + U_t$$

where the predetermined variables X_i exert a determining influence on P_t instantaneously. If (1) the X_i's can be measured with certainty and are totally independent of the U_t's and (2) the U_t's are normally distributed with 0 mean and constant variance this equation will produce best linear unbiased estimates of $\hat{P}_t$.

The forthcoming chapter will consider the exact nature of the variables to be included in Equation (7) and the direct application of the empirical data base to estimate its parameters. As an alternative hypothesis for testing the forecasting ability of the implicit form of Equation (7), Equation (8) will also be fitted using similar explanatory variables.

FOOTNOTES

[1]W. J. Baumol, Economic Dynamics, The MacMillan Company (New York, 1951), p. 5.

[2]Zvi Griliches, "Distributed Lags: A Survey," Econometricia, Vol. 35, No. 1: 16-49 (January, 1967), p. 18.

[3]Irving Fisher, "Our Unstable Dollar and the So-called Business Cycle," Journal of the American Statistical Association, Vol. 20: 179-202, (1925).

[4]Robert M. Solow, "On a Family of Lag Distributions," Econometrica, Vol. 28, No. 2 (April, 1960), p. 393.

[5]Ibid, p. 395

[6]P. Cagan, "The Monetary Dynamics of Hyper-Inflation," in Friedman Ed., Studies in the Quantity Theory of Money, University of Chicago Press (Chicago, Illinoi, 1956).

[7]M. Nerlove, Distributed Lags and Demand Analysis for Agricultural and Other Commodities, U.S. Department of Agriculture, Agricultural Marketing Service, Agricultural Handbook No. 141 (Washington, 1958).

[8]Griliches, p. 19.

[9]Zvi Griliches, "A Note on Serial Correlation Bias in Estimates of Distributed Lags," Econometrica, Vol. 29: 65-73 (1961).

[10]Ibid

[11]W. A. Fuller and J. E. Martin, "The Effect of Auto-correlated Errors on the Statistical Estimation of Distributed Lag Models," Journal of Farm Economics, Vol. 43: 71-82 (1961).

[12]James E. Martin, Computer Algorithms for Estimating the Parameters of Selected Classes of Nonlinear, Single Equation Models, Oklahoma State University, Processed Series P-585 (May, 1968).

CHAPTER VI

MODEL SPECIFICATION AND ESTIMATION

Introduction

The model to be derived in this chapter will serve as basis for quantitative estimation and is intended to yield forecasts at least six months in advance that will assist management in evaluating available production and purchasing alternatives. From the economic theory of the industry, the statistical characteristics of the data series and the statistical estimating procedure presented in the foregoing chapter, the basic supply and pricing equations will be developed.

Since the number of the exogenous or predetermined variables that enter the final equation must be estimated, additional equations are specified; that is, several of the behavioral variables that occur as exogenous in the final price equation are treated as endogenous in preceding equations. In this way the system is developed recursively, step-by-step, from the basic production relation to the final forecasting equation.

In keeping within the ultimate objective stated at the outset (i.e. predicting future slaughter steer prices), the choice concerning the algebraic form of the relations, the time interval to which the observations refer, and the inclusion or exclusion of variables is made primarily on grounds of simplicity and data availability. Economic and statistical considerations will be used in assessing the relative value of a variable and eliminating unnecessary theoretical possibilities. The final choices, however, are resolved by estimation and re-estimation, intuition and judgment.

Commercial Beef Supply

A number of potentially relevant and readily available data series can be considered in specifying beef supplies on a monthly basis. For instance, the U. S. Department of Agriculture provides information on the number, weight, and grade classification of all cattle slaughtered in both federally inspected and non-inspected plants, by state and by region. Detailed information is also available on the number of confirmed direct slaughter cattle sales in the primary beef producing states and the receipts of slaughter cattle at major stockyards.

Trial runs of the forthcoming price forecasting equation indicate that the most promising results are obtained when total commercial cattle slaughter is admitted an an explanatory variable. Commercial cattle slaughter includes the number of feedlot marketings, non-fed steers and heifers, and cull breeding stock.

According to the theory expressed in Chapter III, an aggregation of the number of cattle and calves placed on feed by each individual feeder represents the available short-run supplies of <u>feedlot cattle</u>. Once resources have been committed to cattle feeding monthly slaughter supply becomes extremely inelastic and are directly related to the actual duration of the feeding period. Adjustments in this inventory, although uncommon, are primarily attributed to the movement of light-weight calves out of the feedlot as changes are observed in price expectations and pasture conditions.

Non-fed or grass-fed steers and heifers are not reported as such by the Department of Agriculture. These cattle are commonly regarded to be the less "fleshy" standard and utility grade animals that have not been exposed to high concentrate rations. Cow slaughter consists mainly of the cull or grass-fat cows that have been eliminated from breeding herds. Range conditions, present and anticipated profit levels, and psychological motivation are the major determinants of non-fed marketings and cow slaughter.

In the following forecasting equation the total supplies of slaughter cattle are regarded as primarily determined by the number of animals on feed, the price of replacement cattle six months previous, and a 12-month seasonal cycle:

$$(1)\quad Q_{ct} = \underset{(1.62)}{125.2 + .009\, Inv_{ct-6}} - \underset{(-2.97)}{12.2\, P_{ft-6}}$$

$$- \underset{(5.67)}{82.46 \sin 30t^{o}} + \underset{(6.05)}{.374\, Q_{ct-12}} + \underset{(3.6)}{3.4\, T} + 387\, WD_t$$

R^2 = .87
Se = 77 thousand head
d = 1.4

where

Q_c = Monthly commercial cattle slaughter - U. S., thousand head

Inv_c = Cattle and calves on feed beginning of nearest quarter by weight distribution - 23 states, thousand head

P_f = Average price of Choice and Good, 300-400 pound feeder steers - Kansas City

WD = Number of fully utilized slaughter weeks

t = Month

T = Time (January 1963 = 1)

d = Durbin-Watson test statistic

(·) = t - statistic

In general the least squares regression coefficients agree with economic theory with respect to the direction of influence and all are statistically different from zero at the 5 percent level (i.e. the coefficient has a 95 percent probability of being different from zero and five chances out of 100 that it is not different from zero). The Durbin-Watson statistic of 1.4 for measuring serial correlation in the disturbances is inconclusive.

With only slight modification the procedure outlined by Hayenga and Hacklander[1] is followed for translating the quarterly "on feed" information into an estimate of subsequent monthly slaughter figures. Briefly, by assuming that the normal weight for steers and heifers is 1,100 pounds and 900 pounds, respectively, and that steers gain an average of 2.5 pounds per day and heifers 2.0 pounds per day, a matrix indicating the weight categories that contribute significantly to total slaughter each month is derived. As an example, the data published each quarter in Cattle on Feed are classified into steers and heifers and into five weight ranges. Those cattle in the heavier weight categories, 900 pounds and above, will be marketed soon after the report becomes available; whereas the lighter weight groups, less than 900 pounds, are marketed in subsequent months. There is not statistical advantage to be gained by distinguishing between steers and heifers.

A statistical inspection of the data (Table IV, Page 33) illustrates that although the variation in monthly cattle slaughter can be regarded as stationary, from 1960 to 1968 total slaughter increased at an average annual rate of 4 percent. Since 1968, however, the mean slaughter level has remained relatively constant at approximately three million head per month. Adjustments in the structure of the cattle feeding industry (Chapter III), and improvements in feeding practices and feeding efficiency that have enabled feeders to decrease the fattening period are primarily responsible for this growth. In order to account for this phenomenon, several possibilities - both statistical and behavioral - were examined in the initial specification of the equation.

The admission of the number of cattle and calves placed on feed each quarter as an explanatory variable will account for major long term adjustments in the cattle feeding industry. In order to explain the year-to-year variations, the number of cattle slaughtered in the corresponding month one year previous was included and found to be statistically significant. Because of the declining or flattening tendency of the growth rate, a trial regression was made on the logarithm of time; from the statistical results it was found, however, that a linear trend term is more significant.

Both the lagged price of feeder calves and the 12-month seasonal cycle (represented by sin 30°)* are believed to represent the variation in cow slaughter and grass-fed

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*Because of the loss of a degree of freedom it is not always necessary to include trigonometric terms as reciprocal pairs. By applying the trigonometric identity

$$\text{Cos } \frac{360^{\circ}(t+t_o)}{k} = A \text{ Cos } \frac{360^{\circ}t_o}{k} - B \text{ Sin } \frac{360^{\circ}t_o}{k}$$

where

$$A = \alpha \text{ Cos } \frac{360^{\circ}t}{k} \qquad B = \alpha \text{ Sin } \frac{360^{\circ}t}{k}$$

$$\alpha = \sqrt{A^2 + B^2} = \text{amplitude} \qquad k = \text{period}$$

$$t = \text{month}$$

slaughter. Because of the importance of range conditions on maintaining breeding stock, most herds are seasonally reduced during the late fall months and built back up during early spring. Correspondingly lower grade grass-fed cattle are primarily marketed in late fall.

Finally, since the number of days available for slaughter operations vary from month-to-month and from year-to-year, a proxy variable was designed to account for the number of holidays, week days, and weekends in each month. An index of the "fully-utilized" slaughter weeks within each month was developed by weighting normal week days as 1, Saturdays as 1/3, weekday holidays as 1/2, Saturday and Monday holidays as 0, and Sunday as 0.[2]

Demand for Slaughter Cattle and Market Price

Demand for Beef

From a conventional economic theory, the market demand for a product is a function of its prices, the price of

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$$t_o = \frac{k}{360^o} \arctan \frac{B}{A} = \text{phase angle}$$

and if the least squares estimates of either $\hat{A}$ or $\hat{B}$ are found to be insignificant, then $t_o = 0$ or $\frac{k}{2}$ and the equation can be reduced to either

$$\alpha \text{ Cos } \frac{360^o t}{k} \qquad \text{or} \qquad -\alpha \text{ Sin } \frac{360^o t}{k}$$

substitute commodities, the price of complementary commodities (in consumption), the price of all other consumer goods, population, personal income, and consumer tastes and preferences. The intersection of the demand function with the supply schedule gives the equilibrium price for the product, i.e. the price and quantities where economic forces are balanced so that the quantity supplied equals quantity demanded and there is no inducement to change.[3]

Breimyer[4] in his pioneering work on "The Demand and Price for Meat - Factors Influencing Their Historical Development" empirically demonstrated the importance of these factors in explaining aggregate beef prices. For the 13-year period, 1948-60, Breimyer found that the following five factors will explain 98 percent of the total variation in retail beef prices: (1) per capita beef production, (2) per capita pork production, (3) deflated disposable personal income per person, (4) consumer price index, and (5) a linear trend.

<u>Slaughter Steer Prices</u>

Even though slaughter cattle prices at the farm level are not synchronized exactly with retail prices, the major price making forces are similar. In fact, the farm level demand for beef arises because commercial meat packers market carcasses and beef by-products to wholesalers and retailers.

In Chapter III it was postulated that marginal productivity considerations were the fundamental determinants of individual packer demand for slaughter cattle. On the basis of expected final product prices and on projected profit margins, the commercial packer will determine the maximum number of cattle that will be purchased at different price levels. However, since (1) the short-run supply curve for slaughter cattle is not perfectly elastic, (2) most of the packing industry operates within a framework of imperfect competition, and (3) slaughter cattle are not homogenous, final price and quantity become negotiated.

In formulating an offer price packers-buyers will, at least theoretically, respond to the number of animals required to maintain normal slaughter schedules, the availability and quality of slaughter animals (including packer owned supplies), and expected final product prices. Feedlot operations, on the other hand, must simultaneously form an expectation about current prices and the current quantity demanded by buyers. In the short run feeders are afforded some flexibility in marketing as sales can be adjusted one to two weeks earlier (later). This flexibility diminishes, of course, as the animals approach peak slaughter weight and must be marketed.

The Price Forecasting Equation

The geometric distributed lag equation as previously developed in Chapter V (see Equation 7, Page 90) was fitted to the average price of Choice grade slaughter steers - Chicago basis from January 1963 through December 1970. The following variables were included in the final specification: commercial cattle slaughter per fully utilized work week, average slaughter weight, year-to-year change in commercial hog slaughter per fully utilized slaughter week, and a linear trend term. The first two variables exert a determining influence both instantaneously and with lag structures λ and μ, respectively. The remaining two variables are found to have their impact only during the current time period.

All of the variables are presumed to be linear in actual numbers. While a non-linear (e.g. logarithmic) approach is traditionally used, the statistical properties of the equation were not significantly improved which made it advisable to adopt linearity. The estimated price forecasting equation is as follows:

$$(2)\quad \hat{P}_{ct} = 14.7 - \underset{(1.8)}{.006}\ Q_{ct}/WD_t + .003\ Q_{ct-1}/WD_{t-1}$$

$$- .004\ Q_{ct-2}/WD_{t-2} - \underset{(3.6)}{.037}\ SW_{ct} + .032\ SW_{ct-1}$$

$$+ \underset{(3.3)}{.02}\ T + 1.2\ P_{ct-1} - .42\ P_{ct-2} + .04\ P_{ct-3}$$

$$R^2 = .93$$
$$Se = \$.57$$
$$d = 1.94$$

where

P_c = Average price of Choice 900-1,100 pound steers -

\$/cwt. Chicago

Q_h = Monthly commercial barrow and gilt slaughter - U. S. thousand head

SW_c = Average commercial slaughter weight - live pounds U. S.

The internal statistical estimating properties of this equation are promising. The coefficient of determination indicates that the equation will explain 93 percent of the total variation in monthly slaughter steer prices and the estimate of the standard deviation of the equation is only \$.57 per hundredweight or 2 percent of the average price during the period of estimation. All of the coefficients are consistent with the economic theory and significant at the 90th percentile of the t-statistic.

Even though cattle receipts at individual markets conform in general direction to national supplies, there is some question concerning the validity of concentrating on national figures as the major price determing force. Prices at major stockyards may be more sensitive to local slaughter supplies. Trial results using both the number of cattle marketed and the number of cattle slaughtered in Chicago did not, however, substantiate this hypothesis.

Recent empirical evidence suggests that the demand function for beef should be regarded as irreversible.[5] The common procedure in this situation is to adjust the price series for inflation, convert the supply variables to a per capita basis and use real income as the per capita demand shifter. In the preliminary stages it was found that these practices have limitations for predicting. Even though deflating slaughter steer prices by the Index of Prices Received by Farmers for all Farm Products does preserve the time varying properties of the series, there are problems involved in estimating future values of the deflator. Also, since population and real income are fairly constant growth factors, it is logical to let their determining influence be reflected by a linear trend variable.

Theoretically, the consumption of a commodity depends not only upon its own price, but also upon prices and supplies of all competing products. The year-to-year change in the number of hogs slaughtered each month was, therefore, used in the equation as a final consumer demand shifter. Supplies of other meat and fish are believed to be relatively unimportant in affecting the quantity of beef consumed.

There are wide variations in both the demand for and the supply of various grade and weight groups of slaughter cattle. This might be particularly true in late fall as the composition of market supplies turns in favor of grass-fat steers, heifers, and cows. In order to acccount for this variability, several series were completed and tested in the equation. For example, commercial cattle slaughter was split into three groups - steer slaughter, heifer slaughter, and cow slaughter - and include both actual and percentage terms. In general, the results were disappointing. By adding the additional variables the coefficient of determination was increased but the mean squared error was simultaneously increased. The average slaughter weight was found to be important, however, and therefore, accepted as a determinant of Choice steer prices.

The price commercial packers received for hide, tallow, and other by-products can be considered another important variable on *a priori* grounds. The value of offal from a 1,000 pound slaughter steer will average $20.00 to $30.00 and is commonly regarded as sufficient to cover variable killing or slaughter costs. By including this variable in the regression, the statistical estimating properties of the equation were greatly improved. It was found, however, that because of the influence that international trade has on by-product prices, its future values could not be successfully forecasted. This series was, therefore, excluded from the equation.

Additional Equations

The number of hogs slaughtered each month and the average slaughter weight of live cattle which are expressed as predetermined variables in the forecasting equation are, in fact, variables of unknown magnitude. Thus, two additional equations are needed to obtain estimates of Q_h and SW_c during time (t+6).

Hog Supply

The operational behavior of hog producers is found to be similar to that observed in cattle production. By including the number of hogs on farms in a previous time period, the number of fully utilized slaughter weeks, and a six-month and 12-month seasonal cycle in the following multiple regression equation, satisfactory forecasts can be made for commercial hog slaughter.

$$(3)\quad \hat{Q}_{ht} = -\,4766 + \underset{(5.8)}{.078\,Inv_{h1t-6}} + \underset{(10.6)}{.55\,Inv_{h2t-6}}$$

$$+ \underset{(4.5)}{.123\,Inv_{h3t-6}} + \underset{(12.3)}{1.4\,Inv_{h4t-6}} + \underset{(4.8)}{49.4\,P_{ht-12}}$$

$$+ \underset{(3.5)}{243.7\,Sin\,30t^{o}} - \underset{(-3.5)}{394\,Cos\,30t^{o}} - \underset{(-4.25)}{247.4\,Sin\,60t^{o}}$$

$$+ \underset{(4.3)}{1042\,WD_{t}}$$

R^2 = .83
Se = 352 head
d = 1.56

where

Inv_{hi} (i=1,2,3,4) = Barrow and gilt inventory by weight classification for slaughter market - 10 states, thousand head

P_h = Average price of all barrows and gilts - dollars per hundredweights, seven markets

All coefficients are significant at the .05 level and have the expected sign. For a complete analysis of the pork industry the reader is encouraged to consult the U.S.D.A. Technical Bulletin, Factors Affecting the Price and Supply of Hogs, by Harlow.[6]

<u>Average Commercial Slaughter Weight</u>

The month-to-month variations in average slaughter weights are postulated to be directly influenced by the duration of the feeding period and the composition of total slaughter. Witholding actions by feeders in response to changes in price expectations or weather conditions, for example, will quickly increase the weight at which cattle are slaughtered. The relative composition of total commercial slaughter figures will also affect average slaughter weights. Grass-fed steers and heifers are marketed at relatively light weights, whereas slaughter cows are marketed at extremely heavy weights.

From a behavioral standpoint no satisfactory method is found to account for the variation in slaughter weights. However, due to the somewhat regular, recurring seasonal variation a good predictor of monthly average slaughter weight is found to be:

$$(4) \quad \hat{SW}_t = \underset{}{352.5} + \underset{(9.17)}{17.1} \text{ Sin } 30t^o + \underset{(11.8)}{24.6} \text{ Cos } 30t^o + \underset{(6.92)}{.65}\, SW_{t-6}$$

$$R^2 = .95$$
$$\hat{S}e = 10.1$$
$$d = .27$$

The least squares regression coefficients are all statistically different from 0 at the 10 percent level and all have the expected signs. The Durbin-Watson statistic of .27 indicates extreme positive autocorrelation in the residuals.

This is not surprising and is attributed almost entirely to the failure to find behavioral variables that were significant and could be forecasted.

The Final "Naive" Equation

The most noticeable characteristic of Equation (2) is the overpowering way in which previous observations of the dependent variable influence current values. By holding the exogeneous variables constant at their mean, a 10 cent change in prices during period t-1 is positively associated with a 12 cent change in current prices. Whether or not this phenomenon will interfere with making advanced forecasts is difficult to assess *a priori*. For the purpose of analyzing this problem and also for providing a meaningful way in which to evaluate the equation an additional forecasting equation that does not necessitate lagging the dependent variable is specified.

In Chapter V it was demonstrated that by assuming $\lambda=\mu=\beta=0$ (i.e. the explanatory variables exert their determining influence only during the current period) the distributed lag model reduces to a simplified linear equation that can be estimated by least squares.

Correspondingly, the following equation was estimated by the least squares procedure and includes commercial cattle slaughter and the year-to-year change in commercial hog slaughter as the major explanatory variables.

$$(5)\quad \hat{P}_{ct} = 90.2 - \underset{(3.2)}{.015}\, Q_{ct}/WD_t - \underset{(5.43)}{.0049}\, [Q_{ht}/WD_t - Q_{ht-12}/WD_{t-12}] - \underset{(6.99)}{.059}\, SW_{ct} + \underset{(15.5)}{.13}\, T$$

$$R^2 = .85$$
$$Se = \$1.11$$
$$d = .78$$

All of the estimates are in agreement with _a priori_ reasoning and all were statistically significant at the 95^{th} percentile of the t-distribution. The equation has an R^2 of .85 with an estimated standard error at the mean of $1.11 per hundredweight.

As was to be expected the Durbin-Watson d-Statistic of .78 indicates extreme positive serial correlation in the residuals. In general, since the disturbance term represents the influence of omitted variables the extreme correlation in this equation is attributed to the effect of explanatory variables not included in the analysis. Of major importance is the intentional omission of beef prices at either the wholesale or retail level as a determining factor. If the analyst knew these prices with certainty, slaughter cattle prices could simply be derived from them. Some improvement is observed by replacing the linear trend term with different combinations of national income, disposable consumer income, and population. However, it was found that the errors involved in estimating future values of these demand factors transcended their additional contribution to reducing the standard error of the question.

The data base used in estimating the equations in this chapter are to be found in Appendix A, pages 152 through 160. In the following chapter a comparison of the estimating and predictive properties of the two price forecasting equations will be initiated. For simplicity, Equation (2) will be referred to as Model I and Equation (5) as Model II.

FOOTNOTES

[1]Marvin Hayenga and Duane Hacklander, "Short Run Livestock Price Predicting Models," Research Bulletin 25, Michigan State University (1970).

[2]Ibid, p. 8

[3]Richard H. Leftwich, <u>The Price System and Resource Allocation</u>, Holt, Reinehart and Winston (1955, 1960, 1966), p. 31.

[4]Harold F. Breimyer, "Demand and Prices for Meat, Factors Influencing Their Historical Development," Technical Bulletin No. 1253, U.S. Department of Agriculture, (December, 1961).

[5]John W. Goodwin, Reuven Andorn, and James E. Martin, "The Irreversible Demand Function for Beef," Technical Bulletin No. T-127, Oklahoma State University (June, 1968).

[6]Arthur A. Harlow, "Factors Affecting the Price and Supply of Hogs," Technical Bulletin No. 1274, E.R.S., U.S. Department of Agriculture (December, 1962).

CHAPTER VII

EMPIRICAL EVALUATION

Introduction

The purpose of this chapter is to historically assess the predictive performance of the two models presented in the foregoing chapter. This is not an easy task and since there is no consensus on the best procedure a great deal of judgment and intution is required. Economists and statistitions, for instance, have made available an extensive body of information relating to the measurement and interpretation of the theoretical estimating properties underlying an econometric model. However, the econometric problem in which the model is specified is seldom encountered in empirical applications. In practical forecasting situations not only are true values of the exogenous or lagged endogenous variables not known at the time the predictions are made, but the data, after publication, are subject to substantial revisions. Before presenting the results it is important, therefore, to briefly consider the methods which will be utilized in evaluating the models.

Evaluation Procedure and Techniques

The first distinction to be made is between the summary statistics that relate to the internal estimating properties of the fitted equations and those that relate to the model's predictive performance.

Internal summary statistics apply to the empirical bias and precision of the model in simulating the economy and depend crucially on the theoretical distribution of the error terms. The reason for this is that the residual errors (i.e. the difference between the observed value of the dependent variable and the estimated value) indicate the extent of the movement in the dependent variable that is not explained by the explanatory variables. If the errors are small relative to the total movement in the dependent variable, a major portion of the movement has been accounted for. Accordingly, the most common of these summary statistics is the coefficient of determination (R^2) for measuring the portion of the movement in the dependent variable that is explained by the independent variables, the estimated standard error ($\hat{S}_e$) for assessing the "precision" of the estimation procedure, and the Durbin-Watson d-statistic for determining the degree of serial correlation in the residuals.

Although these statistics are necessary for gaining confidence in the predictive procedure, they are not sufficient for producing the "best" forecasts. In a pragmatic fashion Goldberger[1] demonstrated that in several cases a best linear unbiased predictor is not equivalent to the best linear unbiased estimator. Additional statistics are, therefore, necessary for judging the performance of the model beyond the period of estimation. In this respect the following summary statistics are found to be important in assessing the relative predictive value of the models:

(1) the residual forecasting variance, $V_\ell(\mu)$

(2) the forecasting coefficient of determination $\bar{R}_\ell^2$

(3) and Theil's inequality coefficient, U.

By taking into consideration information about the degrees of freedom, a measure of a model's forecasting precision can be derived. The residual forecasting variance is computed by observing the variance of the residuals for each time period forecasted ahead and then correcting for both the number of constraints imposed on the model and the lead periods ℓ. Formally the residual forecasting variance is defined as:

$$V_\ell(\mu) = \frac{\Sigma(\mu_t - \bar{\mu})^2}{n - k + \ell}$$

where n is the total number of observations, k is the number of constraints and ℓ is the length of time into the future for which the forecasts are made. The larger the forecast variance, the more widespread the error distribution, and the smaller the precision of the projection.

A forecasting statistic analogous to the R^2 can be defined on the basis of the residual forecasting variance by

$$\bar{R}_\ell{}^2 = 1 - \frac{V_\ell\ (\mu)}{V(Y)}$$

where V(Y) is the variance of the dependent variable and is defined as $V(Y) = \Sigma\ (Y_t - \bar{Y})^2 / (n-1)$. The objective is to select the model with the smallest $V_\ell\ (\mu)$ and the largest $\bar{R}_\ell{}^2$. First preference is given to a low residual forecasting variance.

The degree to which the forecast change corresponds to the direction and extent of the observed change is also of value. It is inappropriate, however, to merely count the number of true turning points forecast correctly. A model which predicts "a miniscule advance" when "a miniscule decline" occurs cannot be judged as completely wrong; the extent of the error matters. A method which utilized information about the absolute discrepancy between the forecasted and observed change is Theil's[2] inequality coefficient:

$$U_\ell = \frac{\sqrt{\Sigma\ (Y_{t+\ell} - \hat{Y}_{t+\ell})^2}}{\sqrt{\Sigma Y_{t+\ell}^2}\ \sqrt{\Sigma \hat{Y}_{t+\ell}^2}}$$

where $Y_{t+\ell}$ and $\hat{Y}_{t+\ell}$ are the actual and predictive values for each lead time ℓ, respectively. The coefficient U is confined to the interval $0 \leq \mu \leq 1$ with a value of 0 indicating perfect prediction and a value of 1 showing perfect inequality. No rigorous tests, however, have been developed to judge whether the difference between two U coefficients is statistically significant.

Finally, the principal motivation for this dissertation is the development of a model that will assist management in evaluating production and marketing alternatives. Therefore, a detailed discussion will be given on the success of the selected model in identifying opportunities for hedging or forward coverage with live beef future contracts.

Empirical Results

Estimating Performance

As evidenced by the summary statistics included in Table VIII, the internal statistical estimating properties of Model I are clearly superior to those of Model II. By using a geometric distributed lag specification, 92 percent of the total variation in slaughter steer prices between January 1963 and December 1970 is accounted for. This compares to the 85 percent explained by the multiple regression equation - Model II.

TABLE VIII

INTERNAL SUMMARY STATISTICS

	R^2	S_e	D. W.
Model I:	.92	.57	1.94
Model II:	.85	1.11	.78

The estimated standard error of the residuals ($\hat{S}_e$) corresponding to Model I is $.57 per hundredweight or 2 percent of the average price reported for Choice grade slaughter steers during the period of estimation; whereas the estimated standard error for Model II is $1.11 per hundredweight or 4 percent of the average price.

Because of the inclusion of a first order Markov process in the initial specification of Model I, the error terms from this model are absent of any serial dependency. However, as indicated by the Durbin-Watson ratio of .78 the error terms in Model II are serially correlated. Thus, straightforward interpretation of its estimating statistics is no longer valid; i.e. with serially correlated errors, understated variances and inefficient estimates are likely to be obtained.[3]

Forecasting Performance

In order to compare the predictive performance of each model *ex post* forecasts (i.e. observed values of the predetermined variables are assumed to be known at the time the forecast is made) were calculated for the 48-month period beginning January 1967. Future values of the lagged dependent variables are not assumed to be known and thus must be estimated.

It can be argued that if *ex ante* forecasts were used, more confidence could be placed in the ability of the model to predict. It is necessary, however, to utilize the *ex* post approach to properly evaluate a model. In this way, any error which results can be attributed to the model itself and not from incorrect data projections.

In the final reduced form of Model I each estimate $\hat{P}_{ct}$ is a linear function of the lagged values of the dependent variable and both current and previous values of the predetermined variables. Since lagged dependent variables are treated as unknowns, advanced price forecasts from this model must be generated recursively.

For instance, at any origin t the projected value for say $\hat{P}_{ct+3}$ is a direct function of the previously estimated values of $\hat{P}_{ct+2}$ and $\hat{P}_{ct+1}$, the current value P_{ct} and the observed exogenous variables X_{it}, X_{it-1}, X_{it-2}, or

$$\hat{P}_{ct} = f\ (P_{ct-1}, P_{ct-2}, P_{ct-3}, X_{it}, X_{it-1}, X_{it-2})$$

$$\hat{P}_{ct+1} = f\ (P_{ct}, P_{ct-1}, P_{ct-2}, X_{it+1}, X_{it}, X_{it-1})$$

$$\hat{P}_{ct+2} = f\ (\hat{P}_{ct+1}, P_{ct}, P_{ct-1}, X_{it+2}, X_{it+1}, X_{it})$$

$$\hat{P}_{ct+3} = f\ (\hat{P}_{ct+2}, \hat{P}_{ct+1}, P_{ct}, X_{it+3}, X_{it+2}, X_{it+1})$$

$$\vdots$$

$$\hat{P}_{ct+} = f\ (\hat{P}_{ct+\ell-1}, \hat{P}_{ct+\ell-2}, \hat{P}_{ct+\ell-3}, X_{it+\ell}, X_{it+\ell-1}, X_{it+\ell-2})$$

The actual price forecasts that are built up in this fashion with Model I are presented in Columns 3 through 8 in Table XVIII of Appendix B. Column 2 of this table gives the average price reported each month for Choice 900-1,100 pound slaughter steers at Chicago. The forecasts from Model II are dependent only on the observed values of the independent variables and are presented in Column 9.

Although the statistics in Table IX substantiate the previous findings that the estimating properties of Model I are more acceptable, the predictive ability of Model II is clearly superior. For the <u>ex post</u> estimates made at the origin and one month in advance (i.e. during this period actual values of the lagged dependent variables are known) the residual forecasting variance of .015 and the corrected coefficient of determination of .862 compares to .031 and only .716, respectively, for Model II.

For successive lead times, however, the summary statistics differ markedly in favor of Model II.

TABLE IX:

FORECASTING SUMMARY STATISTICS

Lead Time (ℓ)	Degrees of Freedom		V_ℓ (ℓ)		R_ℓ^2		U	
	Model I	Model II	Model I	Model II	Model I	Model II	Model I	Model II
0,1	41	44	.015	.031	.862	.716	.014	.02
2	42	45	.033	.030	.697	.725	.021	.02
3	43	46	.040	.029	.633	.734	.024	.02
4	44	47	.043	.028	.606	.743	.026	.02
5	45	48	.046	.029	.578	.743	.027	.02
6	46	49	.046	.027	.578	.752	.028	.02

The residual forecasting variance for the projections made six months in advance for Model I was .046 and for Model II, .027. The corrected forecasting coefficient of determination of .578 for Model I is substantially below the .752 for Model II. These results are further confirmed when the U-test is applied to the forecasted and actual values. For the predictions made six months in advance the inequality coefficient for Model I was .028, whereas the U coefficient for Model II was estimated at only .02.

From a close examination of the way in which the projections from Model I must be built up one from the other, a partial explanation of the discrepancy between the estimating properties of this model and its predictive performance emerges. While it is true that the forecasts made one month in advance have no common components, projections made for successive periods are dependent, to a great extent, on the previous estimates. Therefore, the error terms observed at higher forecast levels are serially correlated with those committed at lower levels. For instance, the errors observed when computing the three step ahead forecasts are associated with the errors in the one and two step projections. As illustrated in Table XVIII, the consequence of this is a tendency for the forecast to lie wholly above or below the actual value before it is eventually observed.

Practical Application

The final test is to generate the *ex ante* predictions for Model II and examine its ability to recognize hedging or long coverage opportunities in live future contracts. The data assigned to the predetermined variables are those calculated *directly* from the equations in Chapter VI and are presented, along with the actual values for comparison, in Figures 18, 19, and 20 of Appendix B. Before turning to the analysis it will be useful to first define the three idealized types of hedging positions that are commonly established in live beef futures.

The *short hedge* position occurs when spot feeder cattle are purchased and an equivalent amount of future contracts are sold. This position entails being long cash (spot) and short futures. As the average feeding period is five to six months in duration, short hedge positions are generally established in the deferred options. The *long hedge* or coverage position involves hedging the expected future requirements of live beef by buying future contracts. The firm may or may not simultaneously sell an equivalent forward cash contract. The *unhedged* position is defined as being "hand to mouth" or void of a forward commitment - either cash contracts or futures.

Assume that at the beginning of each month an *ex ante* prediction is generated for the average price of slaughter steers at Chicago that will be realized six months hence.

Simultaneously, the close of the live beef futures option that will terminate during month (t+6) for even-numbered months and (t+7) for odd months, is observed.

A simplified decision rule to follow is that whenever the forecasted cash price is greater than the futures quotation, it is recommended that commercial packers establish coverage for that month's slaughter requirements by buying an equivalent amount of futures contracts. Conversely, whenever the calculated cash price is less than the future price it is recommended that packers remain "hand-to-mouth" and that feedlot operators initiate short hedge positions by selling the equivalent production in future contracts. This information is presented in Figure 15 and in Table XIX of Appendix B.

The predicted cash price, made six months previous, is plotted as a dashed line in Figure 15. For comparison the actual cash price for Choice slaughter steers is plotted as a solid line. Also represented on the same figure by the horizontal bars is the live beef future quotation on the day the forecast is made or t-6.

Example 1: On August 1, 1966, the February 1967 live beef futures contract closed at $27.75. The forecasted average slaughter steer price for January 1967 was $23.60 per hundredweight; an expected <u>decrease</u> of $4.15 per hundredweight.

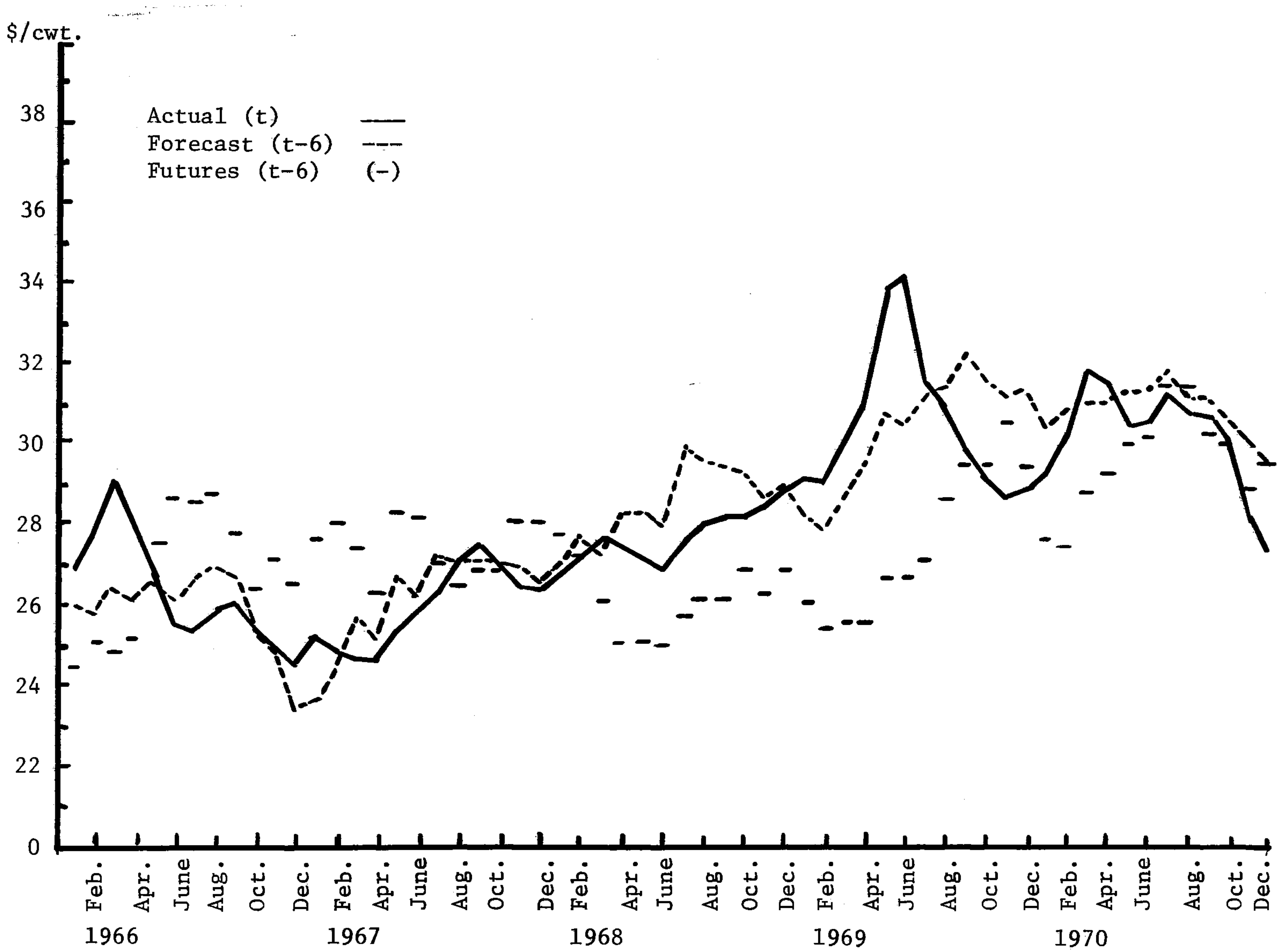

Figure 15. Historical Performance of Model II

On the basis of Model II alone an expected price decline of this magnitude would suggest that feedlot operators hedge all of the cattle that will reach market weight during January by selling February 1967 futures. On the other hand, commercial meat packers would be advised to maintain a non-hedge or "hand-to-mouth" position for their January requirements.

On January 15, 1967, the February 1967 live beef option closed at $26.00 for the actual decrease of $1.75 per hundredweight. Observe from Figure 15 that although the actual price forecasting error was $1.75 per hundredweight ($25.25 actual vs. $23.60 forecasted) the model did succeed in identifying the correct hedging alternative.

Example 2: On December 1, 1968, the June 1969 live beef futures contract closed at $26.70. The predicted cash price for May 1969 was $30.80 per hundredweight; an expected increase of $4.10 per hundredweight.

On the basis of this forecast, commercial meat packers would be advised to establish long hedged (coverage) positions for their May requirements by buying June 1969 future contracts. Simultaneously, on the basis of an expected $4.10 per hundredweight increase in slaughter cattle price, cattle feeders would be prompted to maintain unhedged positions on all animals that will reach market weight during May 1969.

This example provides an ideal illustration of making correct decisions based on a statistical model though the predicted price and the actual price differ greatly. The average price observed during May 1969 was $33.85 per hundredweight for an actual absolute forecasting error or $3.05 per hundredweight. Observe, however, that on May 15, 1969, the June 1969 live beef futures option closed at $32.85; an actual savings to the commercial packer of $6.15 per hundredweight ($32.85 - $26.70 = $6.15 per hundredweight).

A comparison of the anticipated and actual savings for the 60 month period, January 1966 through December 1970, indicate that the model had only four serious failures (see Table XIX, Page 169). The downswing in October, November, and December of 1969 was badly overestimated, and as a result, long hedge positions were strongly recommended. In December 1970 the model failed to sufficiently account for the sharp break in prices that began in early October and thus short hedge positions were not recommended for December production. Short positions were, however, correctly suggested for September through November. In addition, modest errors were also made in July 1967 and July 1970.

Two exogenous variables were understated in the *ex ante* forecasts during the period April 1968 through September 1968, thus producing substantial overestimates of slaughter prices. For instance, the *ex ante* estimates for July 1968 cattle and hog slaughter were 2,945 thousand

and 5,754 thousand head, respectively. Actual slaughter numbers totalled 3,048 and 6,209 thousand head, respectively. Nevertheless, six months prior to the April 1968 period, the futures market was extremely bearish and as demonstrated in Figure 15, live beef contracts were trading in the $25.50 - $26.50 range; the model correctly suggested that long coverage positions be established.

The major underestimates observed during April - May 1969 and the overestimates during August 1969 through January 1970 are not the result of errors in forecasting the exogenous variables. The sharp increase in slaughter cattle prices during second quarter 1969 is attributed to the combination of reduced red meat production, unusually low unemployment rates, and sharply increasing personal income (see Figures 16 and 17). Since the model is responsive to changes in meat production, long positions were correctly recommended.

The model overestimated the sharp break that developed during late third quarter and early fourth quarter 1969. Although the model did account for the increase in cattle and hog slaughter observed during that period it was unable to adjust for the corresponding decline in the general economic conditions. As illustrated in Figures 16 and 17 the seasonal adjusted rate of unemployment advanced from a January 1969 low of 3.3 percent to 4.0 percent in September. In terms of real value per capita, disposable income rose noticeably through third quarter only to turn sharply

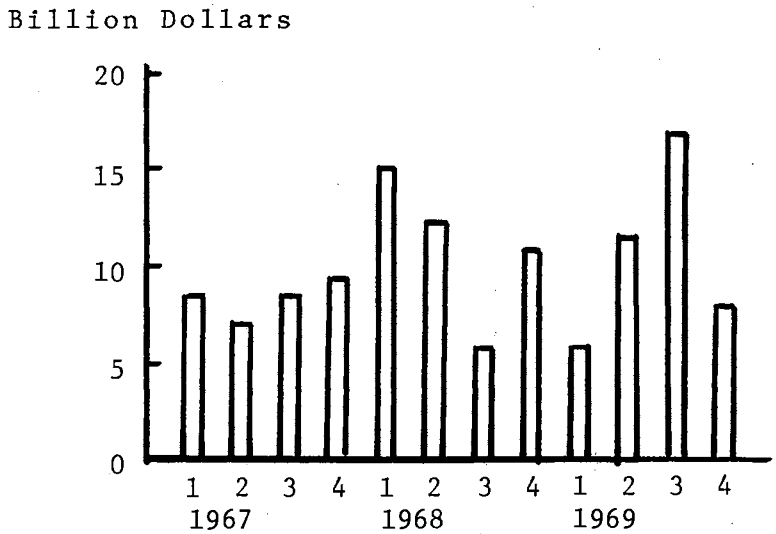

Figure 16. Disposable Personal Income - Change From Previous Quarter

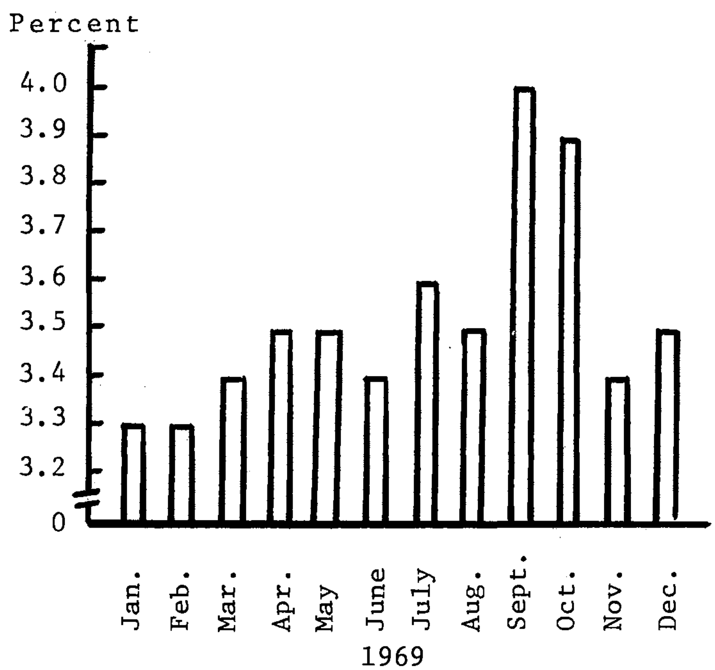

Figure 17. Seasonally Adjusted Unemployment Rate, by Month

Source: <u>Survey of Current Business</u>, U. S. Department of Commerce, Vol. 50, No. 1

lower in fourth quarter.

Concluding Remarks

The most disappointing finding was the failure of the geometric distributed lag model to adequately predict slaughter steer prices. As the lead time increased and previously estimated values of the lagged dependent variables enter the model the predictive ability of Model I decreased significantly. The forecasting coefficient of determination for indicating the extent of the movement in the dependent variable that is predicted by the independent variables decreased from .862 at the origin to .578 for the estimates made six months in advance. The "precision" of the predictions, as measured by the residual forecasting variance, decreased from .015 at lead time $\ell = 1$ to .046 at $\ell = 6$.

Because of the success this model had in explaining the variation in cattle prices during the estimation period, its failure as a forecasting instrument cannot be attributed to the improper specification of the lag distribution scheme. The inclusion of either a logarithmic normal distribution or a Pascal distribution function would not likely improve the R^2 of .92 and the estimated standard error of 57 cents per hundredweight observed by using the geometric lag distribution. The problem lies with the way in which the estimates of the lagged dependent variable compound the forecasting errors as the lead time increases. It may be theoretically sound to ignore this problem when the researcher is only interested in explaining the current movement of the dependent variable. In this model, however, serial correlation tends to be so strong that the lagged endogenous variable cannot legitimately be considered as predetermined.

The practical performance of the "naive" multiple regression model (Model II) was promising. Even though the estimating properties of this model are not impressive, it is successful in providing the type of information required by decision makers. For example, during the moderate down trend that began in mid-1966 the model unmistakenly recommended short hedged positions be maintained by cattle feeders. Though cash prices began a slow uptrend in early 1967, opportunities for covering future slaughter steer requirements did not occur until March 1969. This information was particularly profitable during the sharp increase in March - June 1969. By establishing long positions six months in advance, savings of $5.35, $4.90, and $6.15 per hundredweight, respectively, could have been realized.

By adhering to the assumption that all future positions are established at the beginning of each month and subsequently terminated on the 15th of the sixth month, over the 60 month period beginning January 1, 1966, total savings to commercial packers were $81.70 per hundredweight. In terms of a single 40,000 pound futures contract, this savings amount to $32,680. Conversely, savings to feedlot operators from establishing short hedge positions total \$34.90 per hundredweight or \$13,960 per contract. There were no losses observed from taking short positions, however, total losses of \$4.05 per hundredweight (\$1,620 per contract) were observed on the long side.

FOOTNOTES

[1]Arthur Goldberger, "Best Linear Unbiased Prediction in the Generalized Linear Regression Model," American Statistical Association Journal, Vol. II (June, 1962), pp. 369-375.

[2]H. Theil, Economic Forecasting and Policy, Amsterdam (1961), pp. 32-35.

[3]J. Johnston, Econometric Methods, McGraw-Hill Book Company, Inc., (New York, 1963) p. 179.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Introduction

During the past half century knowledge on measuring and interpreting the economic and statistical properties of parameters occurring in theoretical equation systems has broadened considerably. The outgrowth of this research has been the development of numerous techniques for price analysis and price forecasting. The use of simultaneous equation processes and its concurrent emphasis on model building, fitting procedures using recursive models, two and three stage least squares, distributed lag models and in recent years spectral analysis, have all been upheld as new developments which will aid in decision making. However, their usefulness in agricultural price analysis by farmers and business firms has been almost imperceptible.[1] Three basic reasons can be cited for this failure: First, researchers have failed to clearly define specific, real world problems of importance before undertaking analysis; second, the preoccupation with estimating supply and demand relationships and interpreting their practical significance in terms of flexibilities or elasticities has led only incidentally to useful price forecasting; finally, by establishing structural estimation as the major goal and price analysis the subordinate, there is an inclination to overlook pertinent information or exclude results that appear inconsistent with conventional statistical practices. The general purpose of this dissertation is, therefore, to outline a specific pricing problem and apply a composite of techniques plus subjective judgment in developing an objective price forecasting model.

The first part of this chapter details the objectives of the study and the economic and statistical procedures employed in fulfilling these objectives, the second section presents the highlights of the empirical findings, and the final part draws some conclusions on the practical usefulness of the empirical results and outlines areas for additional research.

Objectives and Procedures

The major objectives of this study are: (1) to outline a practical management problem involving significant price uncertainty, (2) to develop the research methodology necessary for specifying a "workable" price forecasting model, (3) to empirically estimate the proposed model or models, and (4) to critically evaluate the selected models performance in reducing the uncertainty outlined in the management problem.

Variations in the prioe of slaughter cattle are typical of those observed in most agricultural commodities. For instance, during the past two decades the average monthly price of Choice slaughter steers at Chicago ranged from a high of $36.93 per hundredweight to a low of $18.88 per hundredweight. During this period the average price of a Choice grade 1,000 pound animal was $269.00. The average price deviation from this mean was $37.00 per animal.

Absolute price movement and the variations of price about their mean are of concern to both cattle producers and commercial meat packers. It is believed, however, that these decision makers are more interested in knowing where cattle prices will be at some future date and what, if any, production of purchasing alternatives are available for reducing the exposure to an unfavorable price move.

Now that an established cattle futures market exists which permits hedging opportunities, the problem is further reduced to one of developing a six-month forecasting model and evaluating its success in identifying hedging and forward coverage possibilities.

Methodological experts do not agree on the analysis that will result in the emergence of the "best" forecasts. Therefore, in order to gain an idea of a representational model worthy of further investigation the first section of this study concentrates on: (a) reviewing the available literature on statistical and economic techniques, (b) gaining an understanding the economic structure and conduct of the beef cattle industry, and (c) developing an understanding of the time varying properties of the slaughter steer price series itself.

Numerous stochastic models of varying degrees of sophistication can be used in economic price forecasting. Reviewing the types of problems and techniques that have attracted the attention of price researchers is, therefore, a central feature in the exploratory stages of model selection and specification.

Before relevant relationships can be displayed in an econometric model, some familarity with the economic reality of the industry is necessary. Specifically, the economic concentration, regional location, and general ownership of the firms within each production activity (i.e. feeder calf production, slaughter cattle production, and beef packing) are reviewed. In addition, the procedures followed by the primary operators in interpreting and initiating fundamental decision rules are theoretically and empirically analysed.

The future behavior of most economic time-varying processes, in addition to being dictated by economic theory, is related to its past and present statistical behavior. Narrowing the range of plausable model types must, therefore, depend on a statistical description of the underlying serial dependencies of the price series itself. This is done by spectral analysis. Although the power spectrum is not a forecasting technique itself, in an exploratory capacity the spectral estimate permits a clearer understanding of what constitutes a significant pattern than the conventional moving average, correlogram, or periodogram.

The second part of the study concentrates on the difficult task of (a) selecting and mathematically deriving the estimating equations, (b) choosing the exact nature of the variables to be admitted in the model, and (c) applying the empirical data base to estimating the required parameters.

From the economic theory of the cattle industry and from the spectral decomposition of the price series, the explicit functional form of the relationship between slaughter steer prices and the underlying causal factors is specified. Because of the randomness inherent in observing economic phenomenon and the difficulty in obtaining structures that are estimable, economic and statistical assumptions are introduced. Also, since an econometric forecast is a hypothesis, an alternative forecasting model is specified.

In specifying the variables to include in the forecasting models, economic and statistical arguments are weighed with intuition and judgment. Summary statistics and economic insights are helpful in assessing the relative value of a variable and eliminating unnecessary theoretical possibilities. Questions concerning the years to be included in the analysis, the use of actual data or first differences, and the use of logarithmic variables or other transformations are, however, only resolved through estimation, adjustment, and re-estimation.

In the final section the results of confronting the models with the data via estimating procedures and their predictive ability are presented. On the basis of (1) the internal statistical estimators of each model and (2) their *ex post* forecasting performance, the "best" model is selected for further investigation. Final consideration is given to the success the selected model has in identifying opportunities for hedging or forward coverage with live beef future contracts.

Findings and Conclusions

The literature review, although not exposing an objective choice criterion for specifying a price forecasting model did provide information of the type of techniques that should be given special attention. Simultaneous equation systems, although extremely useful for understanding the economics of a market structure, were not found to be significantly better than the simplified multiple regression models in forecasting future events.

Several studies pointed out the importance of knowing, at the outset, the statistical properties of a given time series process. If the series is characterized by significant seasonal or cyclical patterns, an elementary unobserved components technique could manifest acceptable forecasts.

Because of the multiperiodic nature of the beef production process and the uncertainty about future beef prices, the work by Fisher[2] on expectation models is important. That is, a forecasting model must account for both the time dependencies within the operational environment and the dynamic adjustment process followed a variables move from one equilibrium to another.

From the nature of the time varying patterns in slaughter steer prices doubt is cast on the possibility of using a simplified unobserved components model for forecasting future slaughter steer price movements. As visually portrayed by the estimated power spectrum the time varying properties of steer prices are characterized by: (1) an extremely irregular long-term fluctuation in the original price series, (2) a highly regular long-term cycle of 10 years duration in the deflated series, (3) a slightly significant minor price cycle with a regular periodicity of approximately four years, and (4) non-conforming (trending) seasonal patterns. These findings suggest the direct application of mathematical models be eliminated from consideration and that further investigation concentrate on the difficult behavioral representations; in particular the low-order autoregressive models.

The slaughter cattle industry in the United States is highly complex and characterized mainly by pure competition at the production level and imperfect competition at the processing or packing level. From conventional economic theory the factors that make up the market demand for a product and the quantities that producers are willing to put on the market are the primary determinants of market price.

By and large, the number of cattle and calves placed in Corn Belt, West Coast, and Southwest feedlots represent the major available short run supply of slaughter cattle. The remaining slaughter supplies, roughly 25 percent of the total, consists of cull cows and non-fed steers and heifers. Once resources have been committed to cattle feeding, monthly slaughter supply becomes extremely inelastic and is directly related to the actual duration of the feeding period. This is particularly true as the animals approach peak market weight and must be slaughtered.

Marginal productivity considerations are the fundamental determinants of individual packer demand for slaughter cattle. On the basis of expected final product prices and a projected profit margin, it is postulated that the commercial packer will determine the maximum number of cattle that will be purchased at different price levels. However, since (1) the short run supply curve for slaughter cattle is not perfectly elastic, (2) much of the packing industry operates within a framework of imperfect competition, and (3) slaughter cattle are not homogeneous, final price and quantity becomes negotiated. The major factors considered by packers in formulating an offer price are hypothesized to be (1) the number of animals required to maintain slaughter schedules, (2) the availability and quantity of total meat supplies in market channels, and (3) expectations about final product prices, i.e. carcass prices, prices of primal beef cuts, variety meat prices, and prices of hides and inedible offal.

The following four equations were found to provide the most satisfactory forecasts, at least six months in advance, of average Choice steer prices at Chicago:

$$(1)\ \hat{Q}_{ct} = 125.2 + .009\ Inv_{ct-6} - 12.2\ P_{ft-6} - 82.46\ \text{Sin}\ 30_t{}^o + .374\ Q_{ct-12} + 3.4T + 387\ WD_t$$

$$R^2 = .87$$

$$(2)\ \hat{Q}_{ht} = -\ 4766 + .078\ Inv_{h1t-6} + 55\ Inv_{h2t-6} + .123\ Inv_{h3t-6} + 1.4\ Inv_{h4t-6} + 49.4\ P_{ht-12} + 243.7\ \text{Sin}\ 30t^o - 394\ \text{Cos}\ 30t^o - 247.4\ \text{Sin}\ 60t^o + 1042\ WD_t$$

$$R^2 = .83$$

$$(3)\ \hat{SW}_t = 352.5 + 17.1\ \text{Sin}\ 30t^o + 24.6\ \text{Cos}\ 30t^o + .65\ SW_{t-6}$$

$$R^2 = .95$$

<u>Model</u> <u>II</u>

$$(4)\ \hat{P}_{ct} = 90.2 - .015\ Q_{ct}/WD_t - .0049\ [Q_{ht}/WD_t - Q_{ht-12}/WD_{t-12}] - .059\ SW_{ct} + .13\ T$$

$$R^2 = .85$$
$$S_e = \$1.11$$

The variables used in the final equation are:

Q_c = Monthly commercial cattle slaughter - U.S.

Q_h = Monthly commercial barrow and gilt slaughter - U.S.

SW_c = Average commercial slaughter weight

P_c = Average price of Choice slaughter steers - Chicago

In general, the results of the estimating process were satisfactory. All structural coefficients exhibit signs consistent with a priori economic theory and evidence. The determining influence of either a lagged price scheme (a proxy for final product prices) or a final product price is omitted from Equation (4). As a result, the residuals are highly serially correlated. No serial correlation is indicated in the other equations.

Statistical theory has proven that least squares estimation of the structural relations in this system will result in unbiased estimates of the parameters. This is so because none of the endogenous variables have been treated as independent in any equation in the same period. Therefore, the disturbances between equations are not correlated.

For the forecasts made six months in advance the statistical performance of this model was found to be clearly superior to that of a complex geometric distributed lag model which enabled the estimation of two possible types of lagged adjustments. Because of the overpowering way in which the lagged dependent variant entered the lag model, this variable could not legitimately be treated as predetermined. As a result there was a tendency for the calculated predictions to lie either wholly above or below the observed prices when they eventually came to hand.

Despite the fact that the statistical estimating properties of Model II suffered from extreme serial correlation, its *ex ante* forecasting performance and ability to identify opportunities for hedging or forward coverage are promising.

In oversimpliefied terms, by following the decision rule that whenever the predicted price is above the futures option, long positions are established and, conversely, whenever the calculated price is below the relevant contract price, short positions are initiated.

Over the 60 month period beginning January 1, 1966, a total savings of $81.70 per hundredweight could have been realized by commercial beef packers. Conversely, savings to feedlot operators for establishing short hedge positions totalled $34.90 per hundredweight. Total losses from taking long positions amounted to only $4.05 per hundredweight; no losses are observed on the short side.

Limitations and Recommendations for Additional Research

Statistical representation of real world problems necessitate some degree of simplicity. The limitations of this study stem almost entirely from the gap that exists between the theoretical and practical application of econometric theory. In practical forecasting situations not only are true values of exogenous or lagged endogeneous variables not known at the time the predictions are made, but the published data are also subject to revision. Even though a variable is known to be important in the sample period, if the series is not known long enough in advance and cannot be estimated, it is not of direct use in the model. In fact, the major problem with Model II is the inability of the linear trend term to sufficiently account for sharp movements in general economic indicators. Acceptable forecasts of the economic indicator have yet to be made public.

Fundamental to practical applications is the assumption that the economics outside the period of estimation will be the same as those during the time the model was estimated. This can be partially overcome by sufficiently understanding the factors that influence price and updating the model as new information becomes available. The researcher should also be aware of the factors not included in the model which can change. Changes in weather, war, and government policy, for example, may cause the forecast to be in error.

Forecasting techniques are not exact and, therefore, it is not always necessary or even desirable to use the estimates directly from the model. Only those variables that have a consistent and continuous effect on price are included in statistical models; the net impact of additional determinants must, therefore, come from the subject knowledge and judgment of the researcher. Readily available information would include: (1) the magnitude of the most recent errors; have they been consistently high or low? (2) Are the values of the independent variables outside the range observed during the sample period? (3) What costs are involved with committing an error; are overestimates more hazardous than underestimates?

Once an acceptable price forecast is reached the only remaining task for management is the derivation of individual "decision rules." These decision rules should relate specifically to the working policy of the feedlot or packing operation. For instance, after gaining experience and confidence with a price forecasting model probability ranges and "buffer" levels between the predicted price and the futures price can be established.

FOOTNOTES

[1]William A. Cromarty, Paper presented at the A.A.E.A. Annual Meetings, University of Missouri, August 10, 1970.

[2]Irving Fisher, "Note on a Short-Cut Method for Calculating Distributed Lags," International Statistical Institutional Bulletin, Vol. 29 (1937), pp. 323-327.

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APPENDIX A

DATA BASE FOR ESTIMATING THE MODELS

TABLE X

AVERAGE PRICE FOR ALL SLAUGHTER BARROW
AND GILTS - 7 MARKETS COMBINED
($/cwt.)

Month	1964	1965	1966	1967	1968	1969	1970
January	14.70	16.06	27.93	19.46	18.31	19.77	27.40
February	14.70	17.01	27.80	19.38	19.41	20.41	28.25
March	14.48	16.98	24.41	18.43	19.07	20.69	25.97
April	14.16	17.63	22.26	17.62	19.00	20.38	24.05
May	14.84	20.29	23.16	21.83	18.88	23.14	23.53
June	15.83	23.38	24.72	22.29	20.43	25.16	24.04
July	17.11	24.27	25.09	22.58	21.48	26.05	25.13
August	17.05	24.67	25.75	21.04	20.08	26.91	22.12
September	16.76	22.92	23.16	19.46	19.93	25.94	20.35
October	15.39	23.36	21.57	18.16	18.29	25.53	17.91
November	14.43	24.33	19.87	17.36	17.92	25.77	16.59
December	15.55	28.07	19.67	17.29	18.76	26.93	16.91

TABLE XI

AVERAGE PRICES OF CHOICE AND GOOD FEEDER CALVES AT KANSAS CITY ($/cwt.)

Month	1964	1965	1966	1967	1968	1969	1970
January	24.50	21.30	26.38	27.74	26.70	29.22	34.04
February	24.58	21.44	28.53	27.70	27.69	30.26	35.72
March	24.75	22.20	29.86	27.84	28.38	32.01	37.35
April	23.72	23.49	28.92	27.73	28.81	33.72	37.45
May	22.74	24.12	29.46	28.60	30.36	36.62	38.63
June	22.60	24.58	28.78	28.62	30.14	36.01	39.43
July	21.86	24.40	27.42	28.44	30.12	33.36	39.02
August	21.32	23.93	28.23	29.00	29.92	33.31	37.48
September	21.56	24.64	28.90	28.82	29.42	33.19	36.28
October	21.12	24.61	28.57	27.98	28.94	32.94	36.40
November	21.24	24.46	27.94	27.00	29.25	32.34	34.67
December	20.80	25.30	27.54	27.08	29.46	32.83	33.53

TABLE XII

DATA BASE FOR ESTIMATING STEERS AND HEIFERS ON FEED - 23 STATES

Month	1964	1965	1966	1967	1968	1969	1970
January	4,935	4,785	5,490	6,108	5,839	6,388	7,518
February	2,588	2,514	2,865	3,048	2,979	3,399	3,883
March	3,828	3,944	4,370	4,689	4,778	5,581	6,186
April	4,359	4,440	4,846	5,193	5,457	6,301	6,853
May	2,655	2,790	3,171	3,563	3,436	3,826	3,915
June	4,929	5,231	5,824	6,164	6,304	7,105	7,313
July	6,596	7,045	7,568	7,944	8,088	8,955	9,327
August	2,623	2,450	3,182	3,139	3,256	3,404	3,461
September	5,485	5,748	6,582	6,666	6,856	7,417	7,470
October	6,095	6,402	7,352	7,339	7,633	8,212	8,326
November	3,172	3,541	3,808	3,597	3,981	4,591	4,541
December	4,553	5,230	5,795	5,446	5,941	7,042	7,001

TABLE XIII

MARKET HOGS AND PIGS ON FARMS BY WEIGHT GROUPS
(Thousand Head)

Date	Under 60 Pounds	60 - 119 Pounds	120 - 179 Pounds	180 - 219 Pounds
1964:				
March 1	11,741	7,574	8,232	4,776
June 1	21,957	8,805	5,361	3,007
Sept. 1	14,412	11,616	10,095	946
Dec. 1	12,731	10,312	8,246	5,239
1965:				
March 1	10,689	6,805	7,752	4,556
June 1	19,276	8,033	5,173	2,750
Sept. 1	12,692	10,038	8,729	4,788
Dec. 1	12,197	9,270	7,157	4,453
1966:				
March 1	10,876	6,162	7,169	3,985
June 1	20,536	8,384	5,144	2,658
Sept. 1	13,357	10,739	9,328	4,871
Dec. 1	12,534	9,707	7,540	4,723
1967:				
March 1	11,627	6,754	7,728	4,470
June 1	20,179	9,165	5,486	3,053
Sept. 1	13,802	10,332	9,562	5,130
Dec. 1	13,150	10,080	7,566	4,977
1968:				
March 1	11,945	7,030	8,040	4,550
June 1	20,681	8,946	5,789	3,161
Sept. 1	15,014	10,687	9,693	5,249
Dec. 1	13,973	10,865	8,294	5,101
1969:				
March 1	12,230	7,135	8,103	4,632
June 1	18,528	8,942	5,743	3,324
Sept. 1	14,351	9,600	8,569	4,980
Dec. 1	12,883	9,883	7,357	4,572
1970:				
March 1	12,618	7,100	7,682	4,421
June 1	21,040	9,653	6,061	3,371
Sept. 1	16,670	11,224	9,494	5,188
Dec. 1	15,745	11,809	8,782	5,566

TABLE XIV

COMMERCIAL INSPECTED HOG SLAUGHTER - U.S.
(thousand head)

Month	1964	1965	1966	1967	1968	1969	1970
January	8,006	6,996	5,533	7,304	7,567	7,704	6,824
February	6,829	6,162	5,408	6,581	6,633	7,004	6,073
March	7,410	7,526	6,717	7,689	7,130	7,526	7,023
April	7,442	6,691	6,139	6,768	7,367	7,551	7,297
May	6,356	5,514	5,720	6,205	7,264	6,684	6,422
June	5,933	5,479	5,481	6,010	5,872	6,184	6,259
July	5,798	5,142	4,944	5,536	6,210	6,355	6,364
August	5,708	5,529	5,943	6,732	6,724	6,284	6,616
September	6,563	6,341	6,751	7,009	7,123	7,229	7,658
October	7,797	6,255	6,944	7,676	8,300	7,772	8,339
November	7,486	6,335	7,175	7,481	7,423	6,462	8,083
December	7,691	5,814	7,255	7,132	7,547	7,084	8,819

TABLE XV

AVERAGE SLAUGHTER WEIGHT:
ALL CATTLE

Month	1964	1965	1966	1967	1968	1969	1970
January	1,043	1,023	1,023	1,036	1,028	1,025	1,053
February	1,054	1,021	1,019	1,035	1,030	1,021	1,052
March	1,052	1,012	1,012	1,030	1,028	1,015	1,048
April	1,042	1,007	1,011	1,029	1,024	1,018	1,040
May	1,035	1,001	1,011	1,027	1,021	1,013	1,037
June	1,022	991	1,007	1,019	1,008	1,013	1,031
July	1,005	985	995	1,008	1,005	1,001	1,019
August	992	976	996	998	995	996	1,017
September	988	978	996	1,004	995	1,009	1,019
October	997	986	1,005	1,008	1,004	1,014	1,024
November	1,006	1,000	1,021	1,016	1,012	1,027	1,036
December	1,020	1,017	1,035	1,030	1,021	1,043	1,050

TABLE XVI

COMMERCIAL CATTLE SLAUGHTER - U.S.
(thousand head)

Month	1964	1965	1966	1967	1968	1969	1970
January	2,515	2,637	2,870	2,902	3,031	3,127	3,033
February	2,120	2,342	2,549	2,578	2,735	2,738	2,651
March	2,320	2,716	2,792	2,849	2,711	2,809	2,829
April	2,508	2,476	2,606	2,661	2,745	2,808	2,899
May	2,513	2,501	2,764	2,942	3,007	2,840	2,818
June	2,683	2,705	2,934	2,934	2,779	2,812	2,956
July	2,660	2,719	2,725	2,719	3,048	3,001	2,996
August	2,611	2,836	3,036	2,999	3,087	2,980	2,873
September	2,725	2,934	2,980	2,838	2,976	3,124	3,097
October	2,875	2,891	2,880	2,975	3,291	3,316	3,144
November	2,571	2,813	2,827	2,781	2,833	2,735	2,775
December	2,718	2,780	2,763	2,692	2,784	2,948	2,971

TABLE XVII

FULLY UTILIZED WORK WEEKS

Month	1964	1965	1966	1967	1968	1969	1970
January	4.4	4.0	4.2	4.2	4.4	4.4	4.2
February	4.0	4.0	4.0	4.0	4.2	4.0	4.0
March	4.4	4.6	4.6	4.6	4.2	4.2	4.4
April	4.4	4.4	4.2	4.0	4.4	4.4	4.4
May	4.2	4.1	4.2	4.4	4.5	4.3	4.2
June	4.4	4.4	4.4	4.4	4.1	4.2	4.4
July	4.6	4.3	4.0	4.1	4.4	4.4	4.5
August	4.2	4.4	4.6	4.6	4.4	4.2	4.2
September	4.3	4.3	4.2	4.1	4.0	4.2	4.2
October	4.4	4.2	4.2	4.4	4.6	4.6	4.4
November	4.1	4.3	4.3	4.3	4.1	3.8	4.0
December	4.4	4.3	4.2	4.0	4.2	4.4	4.4

APPENDIX B

DATA FOR MEASURING THE PREDICTIVE PERFORMANCE OF THE MODELS

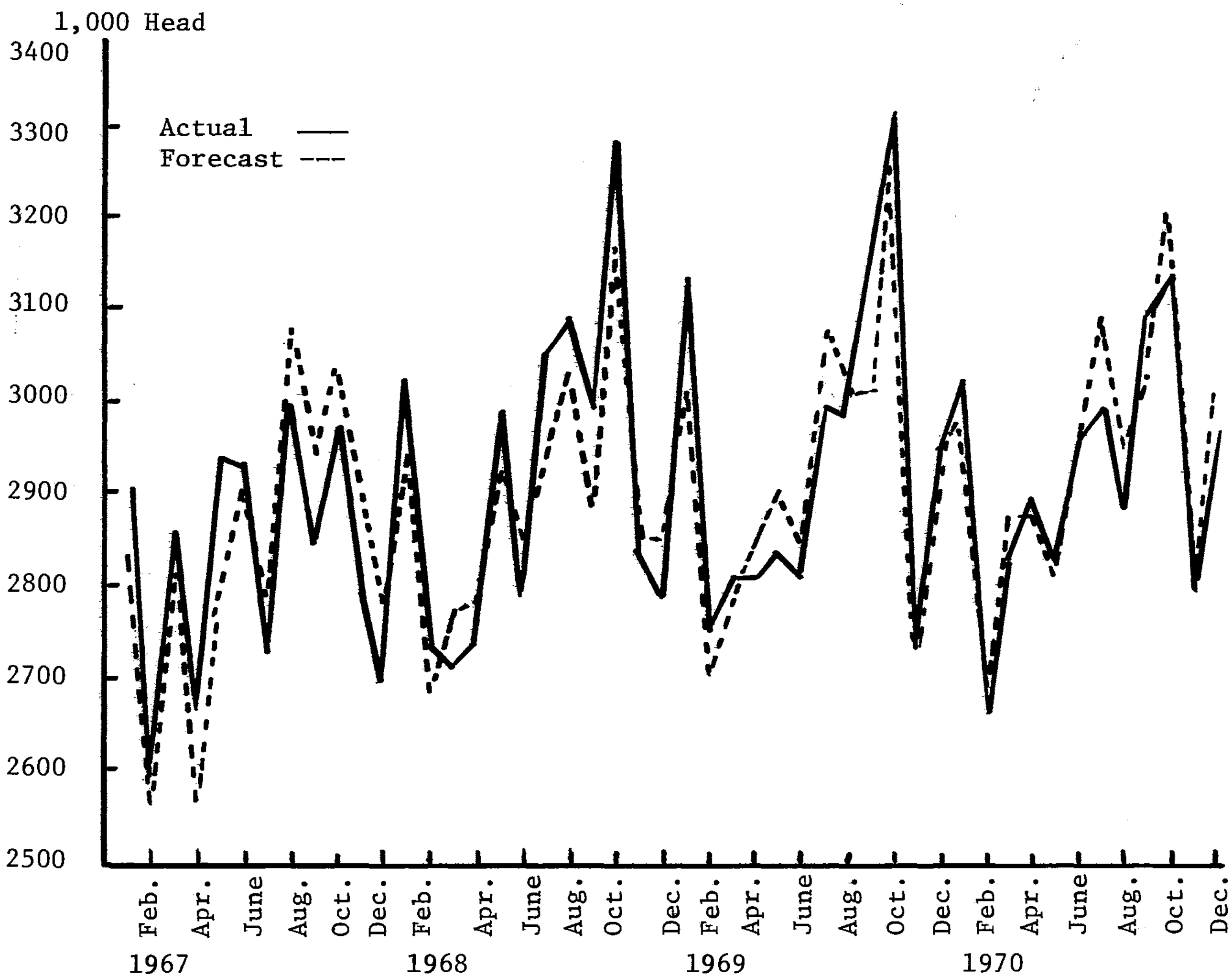

Figure 18. Commercial Cattle Slaughter - U. S.

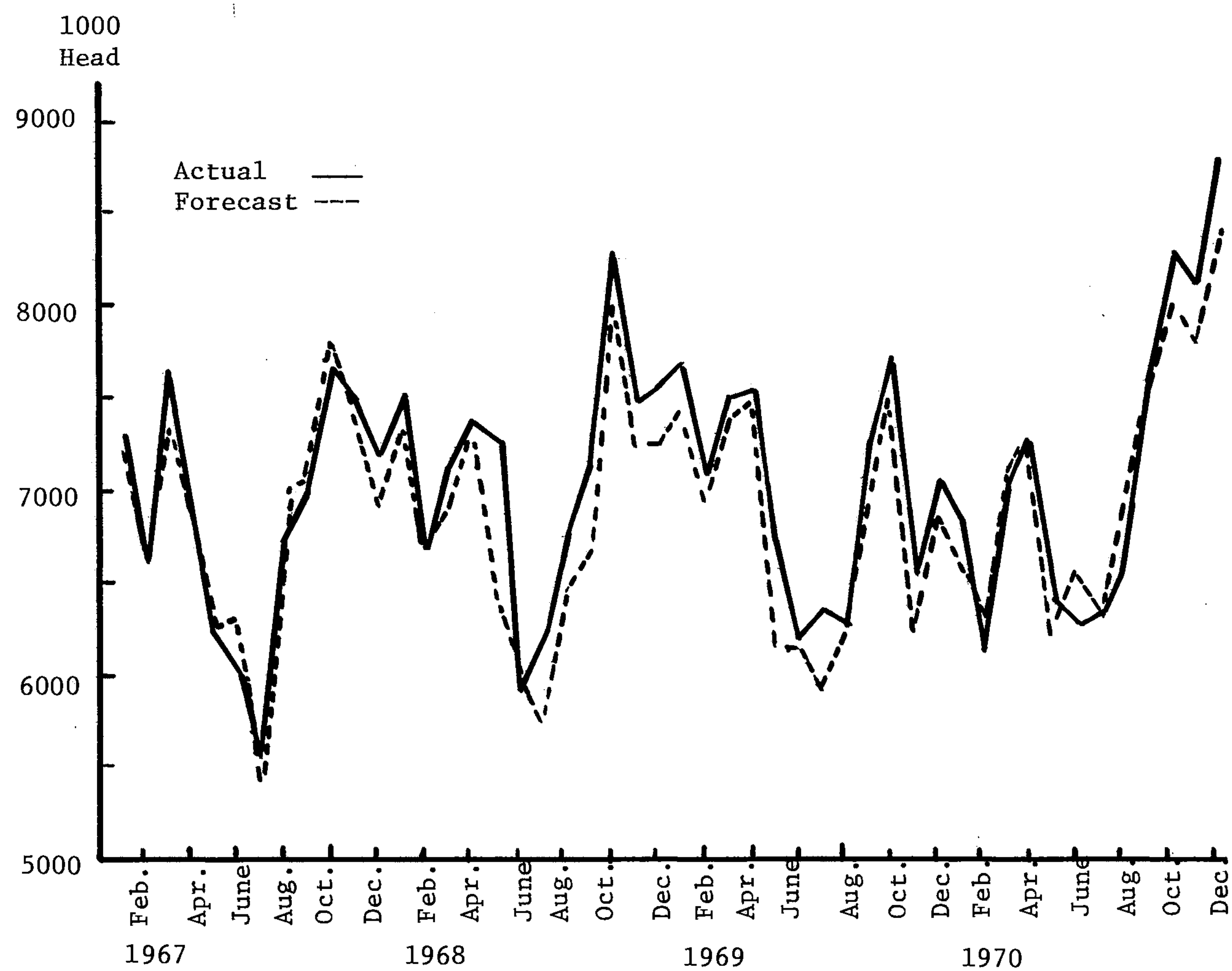

Figure 19. Commercial Barrow and Gilt Slaughter - U. S.

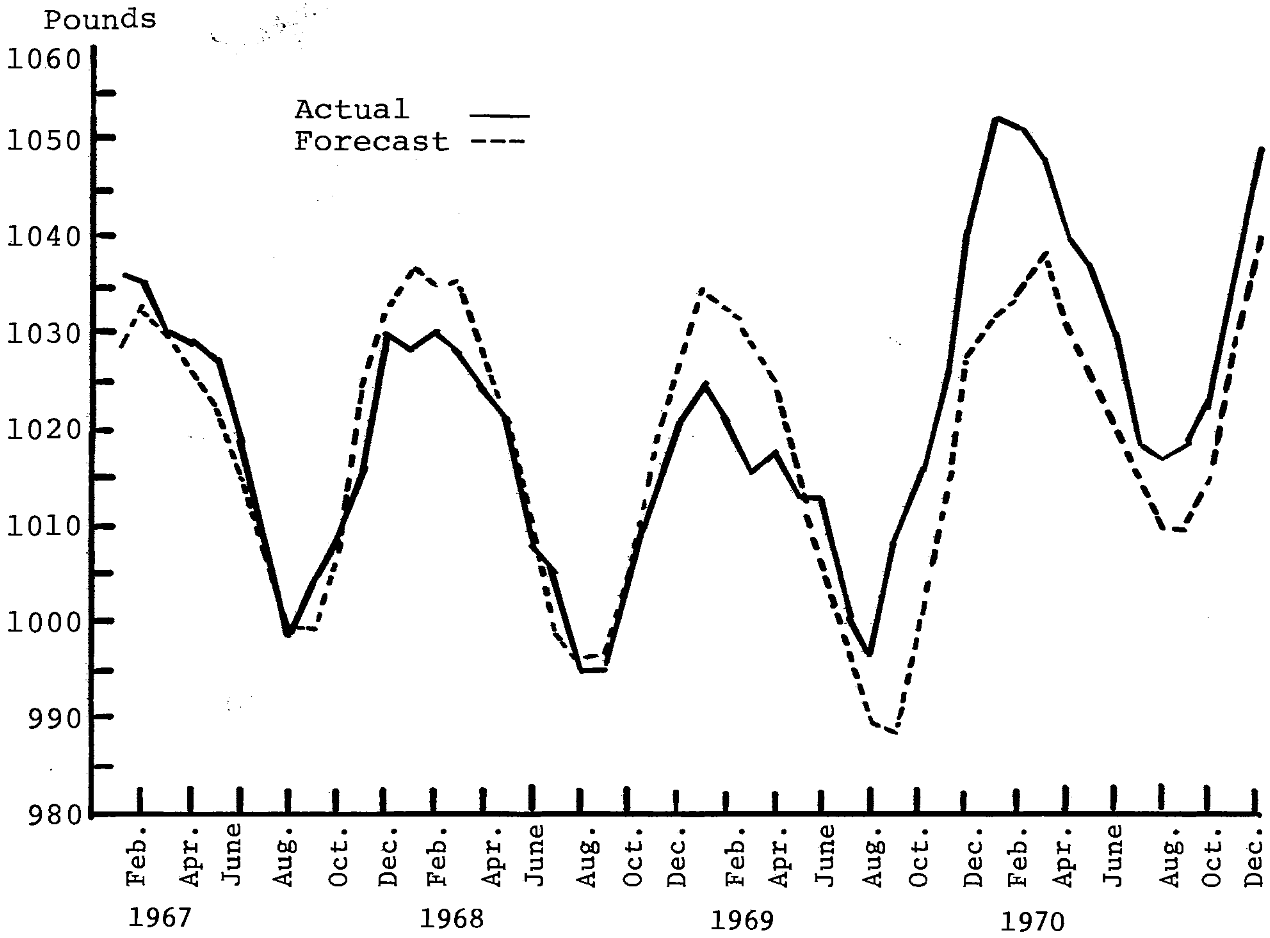

Figure 20. Average Commercial Slaughter Weight - U. S.

TABLE XVIII

ACTUAL AND PREDICTED PRICE OF CHOICE STEERS AT CHICAGO

Date	Actual	Lead Time One Month	Two Months	Three Months	Four Months	Five Months	Six Months	Six Months
		Model I						Model II
1967:								
January	25.25	23.92	23.61	23.73	24.23	24.12	24.13	23.07
February	24.92	25.61	24.05	23.78	23.87	24.23	24.16	24.55
March	24.64	25.17	25.98	24.62	24.41	24.48	24.73	25.61
April	24.66	24.50	25.09	25.79	24.73	24.58	24.63	25.09
May	25.46	24.96	24.76	25.28	25.83	25.06	24.95	26.11
June	25.89	26.11	25.52	25.35	25.75	26.15	25.61	26.36
July	26.40	26.60	26.85	26.34	26.21	26.50	26.78	27.27
August	27.22	27.19	27.42	27.64	27.24	27.15	27.35	27.89
September	27.62	27.30	27.23	27.43	27.61	27.32	27.25	27.39
October	26.97	27.76	27.35	27.31	27.47	27.60	27.39	27.57
November	26.51	26.85	27.78	27.42	27.39	27.51	27.59	27.80
December	26.45	25.93	25.88	26.28	26.71	27.35	27.37	26.75

TABLE XVIII (Continued)

Date	Actual	One Month	Two Months	Three Months	Four Months	Five Months	Six Months	Six Months
		Lead Time						
		Model I						Model II
1968:								
January	26.87	26.48	25.88	26.23	26.85	26.65	26.64	27.04
February	27.34	27.26	26.81	26.28	26.55	27.01	26.86	27.84
March	27.75	27.61	27.52	27.13	26.71	26.91	27.23	27.78
April	27.49	28.20	28.04	27.96	27.65	27.35	27.49	28.55
May	27.16	28.18	27.01	27.87	27.81	27.58	27.37	27.17
June	26.89	27.55	27.56	28.29	28.18	28.14	27.98	28.63
July	27.65	27.09	27.86	27.87	28.44	28.36	28.33	28.67
August	28.01	28.37	27.71	28.38	28.39	28.81	28.75	29.24
September	28.20	28.03	28.46	27.88	28.40	28.41	28.70	28.69
October	28.21	28.21	28.01	28.39	27.94	28.32	28.32	28.74
November	28.46	28.14	28.15	27.97	28.26	27.93	28.20	28.69
December	28.88	28.47	28.10	28.10	27.97	28.18	27.95	28.99

TABLE XVIII (Continued)

Date	Actual	One Month	Two Months	Three Months	Four Months	Five Months	Six Months	Six Months
		Lead Time						
		Model I						Model II
1969:								
January	29.23	28.47	27.98	27.66	27.66	27.56	27.71	28.06
February	29.11	29.25	28.35	27.93	27.67	27.68	27.61	28.17
March	30.19	29.19	29.35	28.57	28.24	28.06	28.06	29.23
April	30.98	30.49	29.32	29.46	28.85	28.61	28.48	29.90
May	33.85	31.11	30.54	29.51	29.62	29.18	29.01	30.49
June	34.23	34.04	30.83	30.33	29.53	29.61	29.30	30.00
July	31.49	33.89	33.67	30.86	30.47	29.89	29.95	30.73
August	30.94	30.38	33.19	33.00	30.82	30.54	30.13	31.03
September	29.75	30.01	29.35	31.82	31.67	30.08	29.88	29.98
October	29.02	29.29	29.60	29.02	30.94	30.83	29.71	30.43
November	28.66	28.42	28.74	29.01	28.56	29.96	29.88	29.82
December	28.89	28.41	28.13	28.41	28.62	28.30	29.27	30.06

TABLE XVIII (Continued)

Date	Actual	Lead Time: One Month (Model I)	Two Months (Model I)	Three Months (Model I)	Four Months (Model I)	Five Months (Model I)	Six Months (Model I)	Six Months (Model II)
1970:								
January	29.31	28.18	27.62	27.38	27.60	27.75	27.52	28.55
February	30.26	29.62	28.31	27.82	27.63	27.79	27.89	30.14
March	31.93	30.61	29.87	28.71	28.33	28.20	28.31	30.70
April	31.56	32.14	30.59	29.94	29.05	28.77	28.67	30.47
May	30.39	31.01	31.70	30.34	29.84	29.19	28.99	30.43
June	30.62	30.01	30.75	31.35	30.30	29.93	29.47	31.07
July	31.39	30.04	30.33	30.97	31.44	30.67	30.41	31.91
August	30.81	31.42	31.01	30.39	30.89	31.22	30.69	31.39
September	30.75	30.03	30.75	29.39	30.91	30.27	30.51	30.51
October	30.16	30.35	29.50	30.13	29.85	29.50	29.75	30.21
November	28.24	29.31	29.55	28.81	29.30	29.09	28.85	29.42
December	27.42	28.00	28.34	28.53	27.96	28.31	28.17	28.66

TABLE XIX

DATA BASE FOR EVALUATING MODEL II

Date	I[a] Actual (t)	II Predicted (t-6)	III[b] Futures (t-6) 1st of month	IV[b] Futures (t) 15th of month	V Absolute Error (I-II)	VI[c] Expected Savings L=(II-III) S=(III-II)		VII Actual Savings (Loss*) (III-IV) or (IV-III)
	($)	($)	($)	($)	($)		($)	($)
1966								
1	26.87	26.02	24.50	27.10	.85	L	1.52	2.60
2	27.79	25.81	25.05	27.55	1.98	L	.76	2.50
3	29.22	26.51	24.85	28.20	2.71	L	1.66	3.33
4	27.98	26.15	25.20	28.00	1.83	L	.96	2.80
5	26.75	26.68	27.60	26.10	.07	S	.92	1.50
6	25.49	26.18	28.60	25.50	.69	S	2.42	3.10
7	25.41	26.47	28.60	25.55	1.33	S	1.86	3.05
8	25.85	26.99	28.75	26.15	1.14	S	1.76	2.60
9	26.11	26.66	27.80	26.45	.55	S	1.14	1.35
10	25.50	25.49	26.45	25.70	.01	S	.96	.75
11	24.94	24.78	27.15	25.30	.16	S	2.37	1.85
12	24.50	23.40	26.55	24.30	1.10	S	3.15	2.25
1967								
1	25.25	23.60	27.75	26.00	1.62	S	4.15	1.75
2	24.92	24.40	28.00	25.20	.48	S	3.60	2.80
3	24.67	25.80	27.45	25.40	1.13	S	1.65	2.05
4	24.66	25.15	26.25	25.00	.49	S	1.10	1.25
5	25.46	26.80	28.30	26.55	1.35	S	1.50	1.75
6	25.89	26.20	28.20	25.50	.34	S	2.00	2.70

TABLE XIX (Continued)

Date	I[a] Actual (t)	II Predicted (t-6)	III[b] Futures (t-6) 1st of month	IV[b] Futures (t) 15th of month	V Absolute Error (I-II)	VI[c] Expected Savings L=(II-III) S=(III-II)		VII Actual Savings (Loss*) (III-IV) or (IV-III)
	($)	($)	($)	($)	($)		($)	($)
1967								
7	26.40	27.30	27.15	27.10	.92	L	.15	.05*
8	27.22	27.15	26.50	27.10	.07	L	.65	.60
9	27.62	27.20	26.90	27.00	.41	L	.30	.10
10	26.97	27.10	26.85	26.25	.09	L	.25	.60
11	26.51	27.00	28.10	26.10	.46	S	1.10	2.00
12	26.45	26.55	28.10	26.30	.10	S	1.55	1.80
1968								
1	26.87	27.05	27.70	26.00	.19	L	.65	1.70
2	27.34	27.80	27.25	27.65	.46	L	.55	.40
3	27.75	27.30	26.00	26.95	.45	L	1.30	.95
4	27.49	28.30	25.10	27.15	.80	L	3.20	2.05
5	27.16	28.40	25.10	26.60	1.27	L	3.30	1.50
6	26.89	27.90	25.00	27.30	1.02	L	2.90	2.30
7	27.65	29.95	25.70	27.30	2.30	L	4.25	1.60
8	28.01	29.70	26.15	27.50	1.71	L	3.55	1.35
9	28.20	29.58	26.10	26.95	1.35	L	3.45	.85
10	28.21	29.40	26.85	27.90	1.21	L	2.55	1.05
11	28.46	28.60	26.25	27.70	.17	L	2.35	1.50
12	28.88	29.00	26.85	29.85	.12	L	2.15	3.00

TABLE XIX (Continued)

Date	I[a] Actual (t)	II Predicted (t-6)	III[b] Futures (t-6) 1st of month	IV[b] Futures (t-6) 15th of month	V Absolute Error (I-II)	VI[c] Expected Savings L=(II-III) S=(III-II)		VII Actual Savings (Loss*) (III-IV) or (IV-III)
	($)	($)	($)	($)	($)		($)	($)
1969								
1	29.23	28.25	26.00	28.40	.98	L	2.25	2.40
2	29.11	27.85	25.50	30.00	1.26	L	2.35	4.50
3	30.19	28.80	25.16	31.00	1.39	L	3.64	5.35
4	30.98	29.50	25.60	30.50	1.48	L	3.90	4.90
5	33.85	30.80	26.70	32.85	3.05	L	3.60	6.15
6	34.23	30.50	26.70	35.00	3.77	L	3.80	8.30
7	31.49	31.25	27.15	29.50	.24	L	4.10	2.35
8	30.94	31.55	28.60	30.30	- .61	L	2.95	1.70
9	29.75	32.35	28.85	28.50	2.60	L	3.50	.35
10	29.02	31.60	29.50	28.50	2.58	L	2.10	1.00 *
11	28.66	31.15	30.50	29.25	2.49	L	.65	1.25 *
12	28.89	31.40	29.40	28.75	2.51	L	2.00	.65 *
1970								
1	29.30	30.40	27.70	29.60	1.10	L	2.70	1.90
2	30.26	30.95	27.50	31.00	.70	L	3.45	3.50
3	31.93	31.10	28.80	33.15	.80	L	2.30	4.35
4	31.56	31.10	29.25	31.95	.47	L	1.85	2.70
5	30.39	31.40	30.05	30.70	1.04	L	1.35	.65
6	30.62	31.35	30.20	31.30	.75	L	1.15	1.10

TABLE XIX (Continued)

Date	I[a] Actual (t)	II Predicted (t-6)	III[b] Futures (t-6) 1st of month	IV[b] Futures (t-6) 15th of month	V Absolute Error (I-II)	VI[c] Expected Savings L=(II-III) S=(III-II)	VII Actual Savings (Loss*) (III-IV) or (IV-III)
	($)	($)	($)	($)	($)	($)	($)
1970							
7	31.39	31.85	31.50	31.30	.47	L .35	.20 *
8	30.81	31.10	31.50	30.65	.31	S .40	.85
9	30.75	31.20	30.20	29.50	.46	L 1.00	.70
10	30.16	30.65	30.00	30.10	.50	L .65	.10
11	29.24	30.05	28.90	28.00	1.81	L 1.15	.90 *
12	27.42	29.50	29.60	28.10	2.12	S .10	1.50

[a] Actual 900-1100 Choice steers, Chicago

[b] Live beef futures; Chicago Mercantile Exchange, first of month for t-1
15th of month for t

[c] S = Short hedge
L = Long hedge

VITA

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