



A dynamic price and supply model of the U.S. beef industry : an interfacing of the market levels
by Gary Wayne Brester

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Applied Economics

Montana State University

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Abstract:

A rational distributed lag model of prices and supplies is estimated for the feeder, slaughter, carcass, and retail levels of the U.S. beef industry. The model interfaces these levels because of their economic interactions. Marketing margins are estimated and provide the linking mechanism between the levels. The rational lags are estimated using a nonlinear least squares algorithm which allows for the estimation of nonstochastic difference equations: the latter serving the purpose of divorcing the disturbance process from the systematic portion of the regression equations. Demand and supply elasticities and price flexibilities are calculated to measure short and long term dynamic responsiveness, while interpretation and implication of the results are offered in the body. The model estimated in the thesis appears to offer an improvement over previous studies.

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Gary Wayne Bester

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April 23, 1982

A DYNAMIC PRICE AND SUPPLY MODEL OF THE U.S. BEEF

INDUSTRY: AN INTERFACING OF THE MARKET LEVELS

by

GARY WAYNE BRESTER

A thesis submitted in partial fulfillment
of the requirements for the degree

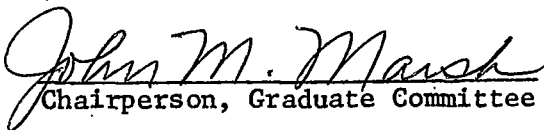
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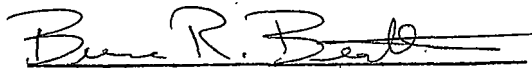
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Approved:


Chairperson, Graduate Committee


Head, Major Department


Graduate Dean

MONTANA STATE UNIVERSITY
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TABLE OF CONTENTS

Chapter		Page
	Vita.	ii
	Acknowledgements.	iii
	Table of Contents	iv
	List of Tables.	vi
	List of Figures	vii
	Abstract.	viii
1	INTRODUCTION.	1
	Introduction and General Market Structure.	1
	Statement of the Problem	4
	Objectives	5
	Procedures	5
	Review of Literature	6
2	THEORETICAL CONSIDERATIONS AND MODEL SPECIFICATION. . .	12
	Theory of the Consumer	12
	Theory of the Firm	15
	The Concept of Marketing Margins	20
	Model Specification.	24
	An Overview	24
	Retail Demand Sector.	28
	Carcass Demand Sector	31
	Slaughter Demand Sector	33
	Feeder Placement Demand Sector.	35
	Feeder Placement Supply Sector.	38
	Processing Supply Sector.	39
	Retail Supply Sector.	42
	Econometric Theory	43
	General Linear Model.	44
	Distributed Lags.	50
3	EMPIRICAL RESULTS	57
	Retail Demand Sector	57
	Carcass Demand Sector.	62
	Carcass-Retail Marketing Margin Equation.	62
	Carcass Price Equation.	63
	Slaughter Demand Sector.	66
	Farm-Carcass Marketing Margin Equation.	66
	Slaughter Price Equation.	68
	Feeder Placement Demand Sector	70
	Feeder Placement Supply Sector	72

TABLE OF CONTENTS (cont'd)

Chapter		Page
	Processing Supply Sector.	77
	Fed Beef Slaughter Supply Equation	77
	Nonfed Beef Slaughter Supply Equation.	80
4	SUMMARY AND CONCLUSIONS	84
	LITERATURE CITED	90
	APPENDICES	95

LIST OF TABLES

Table		Page
1	Regression Results of the Retail Price, Carcass Price, and Carcass-Retail Marketing Margin Equations.	58
2	Estimates of the Short and Long Run Price Flexibilities and Supply Elasticities of the Price and Supply Beef Model.	59
3	Regression Results of the Slaughter Price, Feeder Placement Demand, and Farm-Carcass Marketing Margin Equations.	67
4	Regression Results of the Feeder Placement Supply, Fed Slaughter Supply, and Nonfed Slaughter Supply Equations.	73
Appendix		
Table		
A	Original Data Used for the Price and Supply Equations . . .	96
B	Original Data Used for the Marketing Margin Equations . . .	100
C	Carcass Price Equation Using the Observed Values of the Carcass-Retail Marketing Margin.	101
D	Slaughter Price Equation Using the Observed Values of the Farm-Carcass Marketing Margin.	102
E	Regression Results of the Feeder Price and Good Slaughter Price Reduced Form Equations	103
F	Regression Results of the January 1 Inventory of Feeder Cattle Equation	104

LIST OF FIGURES

Figure		Page
1	Illustration of Primary and Derived Functions and Marketing Margins.	22
2	Flow Diagram of the Beef Price and Supply Model	26

ABSTRACT

A rational distributed lag model of prices and supplies is estimated for the feeder, slaughter, carcass, and retail levels of the U.S. beef industry. The model interfaces these levels because of their economic interactions. Marketing margins are estimated and provide the linking mechanism between the levels. The rational lags are estimated using a nonlinear least squares algorithm which allows for the estimation of nonstochastic difference equations: the latter serving the purpose of divorcing the disturbance process from the systematic portion of the regression equations. Demand and supply elasticities and price flexibilities are calculated to measure short and long term dynamic responsiveness, while interpretation and implication of the results are offered in the body. The model estimated in the thesis appears to offer an improvement over previous studies.

Chapter 1

INTRODUCTION

Introduction and General Market Structure

The livestock and meat industry constitutes approximately one-half of all agricultural cash receipts in the United States. Total cash receipts from farm marketings of all commodities in 1980 amounted to 13.6 billion dollars. Livestock and livestock products alone accounted for 6.7 billion dollars. Over time this market has supplied increasing amounts of meats to domestic consumers. As a result, per capita consumption of all meats in the U.S. is the highest in the world.¹ About one-half of all the U.S. meats marketed and consumed is beef. Beef's importance to producers is also manifest in cash receipts; cattle and calf marketings alone totaled 3.1 billion dollars in 1980.²

The U.S. beef industry can be separated into several broad categories: (1) production of feeder calves and cattle, (2) production of fed and nonfed slaughter cattle, (3) meat slaughtering

¹1981 Handbook of Agricultural Charts, U.S. Department of Agriculture. Economic Research Service.

²U.S. Department of Agriculture. Economic Research Service. "Indicators of the Farm Sector: Income and Balance Sheet Statistics." Statistical Bulletin Number 674. Washington, D.C.: Government Printing Office. 1980 (p. 15).

and processing, and (4) consumption. Those involved in the production of feeder cattle are typically referred to as cow-calf or cow-yearling operators. These producers own breeding stock for the purpose of producing calves; however, many producers via retained ownership grow the calves out to yearlings. Generally, these feeder cattle are sold through regionally centralized auctions to either feedlots or stocker operations and sometimes directly to meat packers. In recent years there has been an increasing trend towards direct marketing of feeders from the ranch to feedlots and packers. Feedlots finish feeder calves and yearlings in confined operations using primarily high-energy feed rations. Animals fattened from this type of operation are referred to as "fed" beef.

On the other hand, stocker operators purchase feeder cattle and usually finish them in a less confined situation using roughages (range grasses or hay) as the primary feed. The steers and heifers fattened in this type of system, along with cows and bulls, are all referred to as "nonfed" beef. Vealer production of young calves is referred to as "baby beef." It is generally assumed that a high degree of competition best characterizes the market structure of these types of operations.

The next level of the marketing channel is slaughtering and processing. At this level beef animals are slaughtered and then processed into carcass halves. In the late 1960's, there was an

increasing movement in the processing sector towards further breaking of these carcasses and selling them as boxed beef (fabrication of carcasses into primal and subprimal cuts, boxed and frozen for transportation).

The processing sector has experienced a moderate increase in the level of national market concentration in recent years. For example, in 1969 the four largest packing firms commanded 29.5 percent of steer and heifer slaughter. In 1978, the four largest firms controlled 31.7 percent. The four largest firms in 1978 were, however, not the same as the four largest in 1969.

While the national four-firm concentration ratio does not appear to be extremely high, this concentration ratio is much larger when viewed on a regional basis. For instance, in 1978, 16 of the 23 major cattle feeding states had four-firm concentration ratios that exceeded 70 percent.³ Thus, viewed on a regional basis the market structure of the packing level might be characterized as an oligopoly. It is assumed that firms may be able to exert market power enabling themselves to capture short term profits.

Currently, most processing plants sell over 80 percent of their products as boxed beef to retailers with the remainder being traded as

³Packers and Stockyards Program. Concentration in the Meat Packing Industry -- National and Local Procurement Levels. Agricultural Marketing Service, U.S. Department of Agriculture, April 1980.

carcasses. Retailers further process this beef into various table cuts. Consumers purchase beef in a market structure primarily classified as monopolistic competition (Holdren, 1964) where both price and non-price competition occurs among retail outlets.

Statement of the Problem

The U.S. livestock-meat marketing system is large and complex. Throughout the 1970's there have been structural changes in both the feeding and processing of beef animals. The behavioral aspects at each level are, to say the least, difficult to model. Given the structure and conduct of the industry, both economic and non-economic variables appear to influence the decision making processes. Some of these variables can be measured while others are not observable. Many attempts have been undertaken to statistically model the beef industry with each attempt resulting in varying degrees of success.

Most of these studies have dealt with one or possibly two levels of the beef industry. However, since each market level either directly or indirectly affects all other market levels, an empirical model that does not encompass this interface could have serious shortcomings.

This study addresses the problems of the interrelationships of the different market levels in the beef industry, and attempts to link the market system through the use of price and supply equations and

marketing margins. The estimated structural parameters and the resulting price flexibilities hopefully will be useful to better understand the demand and supply determining forces in the livestock-meat industry. Such knowledge can be an asset in evaluating the impact of exogenous shocks and government policies on the beef industry, and also in conditional forecasting.

Objectives

There are two major objectives of this research. The first objective is to develop an econometric model interfacing the demand and supply structure of the retail, intermediate (processing) and producer levels in the U.S. commercial beef industry. The second objective is to calculate the short and long term price flexibility and supply elasticity coefficients for each of the three levels and interpreting the results.

Procedures

A dynamic price-quantity model specified on the basis of economic theory, knowledge of the industry and prior research fulfills the first objective. The model includes both price and supply equations for each of the levels in the marketing channel. The structural parameters are estimated using a nonlinear least squares algorithm incorporating nonstochastic difference equations and serial correlation in the error structure.

The second objective is obtained by mathematically calculating the short term and long term effects of changes in the model's exogenous variables on the endogenous price and supply variables. These calculations are made by using the estimated parameters specific to the exogenous regressors and difference equations from the final model specification.

Review of Literature

A large number of studies have focused on the problem of accurately modeling both the U.S. and Canadian livestock-meat industries. Many of these contained goals other than the specific problem of modeling the entire industry structure. This section will present a small cross-section of these previous studies.

Arzac and Wilkinson (1979) presented a quarterly econometric model of the U.S. livestock and feed grain industries. Consumers' demand for meat at the retail level was a function of both prices of meat and real disposable income. The model included a producer-to-retail marketing margin equation with the farm-to-retail price spread used as the marketing margin variable. The marketing margin was specified as a function of retail beef prices, wages in meat packing plants, and by-product allowances. The model included behavioral equations for livestock production, inventories, and supply relations. The model indicated that lags in the response of livestock

supplies to prices were cyclical. They concluded that their model was stable and could sustain cyclical behavior when coupled with external disturbances such as weather, changes in export demand, or government policy changes.

A different approach of modeling the beef industry was undertaken by Franzmann and Walker (1972). They modeled the feeder, slaughter, and wholesale markets using a time trend analysis. One of their conclusions was that the wholesale market level did not exhibit seasonality as did the other levels. This finding is probably not too surprising given the higher degree of market concentration found at the wholesale level. This type of structure results in greater short run price stability.

In "An Open Econometric Model of the Canadian Beef Cattle Sector," Kulshreshtha and Wilson (1972) developed a model which incorporated export demand. Their model contained static price and demand equations for retail beef using the retail market as primary demand. Demand for beef at the retail level was specified as a function of its own price, consumers income, and the price of pork. Of these variables, retail price had the greatest impact.

Some studies have used the assumption that primary demand for meat is located at the wholesale level. Crom (1970) argued that consumers are price takers at retail outlets and are therefore merely quantity adjusters. He contended the true interaction of the forces

of supply and demand occur at the wholesale level. Given this assumption, Crom presented a dynamic quarterly model of the U.S. beef and pork industries incorporating the wholesale and farm levels of the market.

If one is to model the beef industry, a basic understanding of price determining forces in the industry is essential. It is apparent that beef prices over time have been highly variable. Many models have assumed supplies of beef were predetermined. Breimyer (1957) emphasized this by stating that supply curves have gone largely unnoticed in explaining beef price variability but may actually be the most significant source of price fluctuations.

Langemeir and Thompson considered this phenomenon when, in 1967, they presented a simultaneous equations model using both supply and demand analysis. They estimated fed and nonfed domestic components along with an import component. Demand at the retail level was also separated into fed and nonfed sectors.

Breimyer (1957) stated that another source of price variability may be that marketing margins have not reacted to market conditions as one might expect. More specifically, meat margins have increased when supplies of beef have increased and decreased when supplies have decreased. This is especially the case in the short run before a sufficient time for adjustment has passed. Since this was not the action Breimyer expected, he was obviously assuming the meat packing

industry to be a decreasing cost industry.

Freeman (1966) found that farm-price changes were unrelated to changes in marketing margins in the short run. However, he noted that it is possible changes in marketings could result in farm-price changes that do not reflect costs of production. He, like Breimyer, further suggested that supply factors account for changes in farm prices.

There are a number of studies which relate the influence of market structure upon price determination and resulting distribution effects. Multop and Helmuth's (1980) study concluded that increased market concentration in the meat packing sector has had a significant impact on beef prices at the farm, wholesale, and retail levels. They continue that this concentration has also affected the carcass-to-retail marketing margin. However, Ward and Bullock's (1980) review of that study reported that it appeared to suffer from errors in economic logic as well as methodology.

Ward (1980) presented a study which included variables representing market concentration. In that study, he found that increased market concentration has not caused increases or decreases in beef prices at any level. Furthermore, increased market concentration has had no effect on the farm-to-carcass marketing margin.

Gardner (1975) expounds on the issue of market concentration. He

discusses the methods which apparently are used by marketing firms to set prices. He adds that price markups must change with either a shift in demand or supply in order to establish market equilibrium. A problem occurs because markups change differently depending upon whether price movements originate from a change in retail demand or farm supply. Also, if the demand for food increases, the farm-retail price ratio (and percentage of the marketing margin) will be reduced if marketing inputs are more elastic in supply than farm products. Obviously, both cases have implications for farm policies (which form farm-price ceilings and/or price floors) with respect to changes in the farmers' share of the food dollar.

Breimyer (1957) noted that consideration of utility analysis and consumer behavior have dominated price and market theory. Inherent in this theory has been the assumption of perfect competition. He continues that even the classical textbook case of perfect competition, farm production, has been continually moving from centralized markets (especially in the beef industry) to direct markets.

Duewer (1978) noted that, in market models, equivalent amounts of a product should be priced at each level to accurately analyze price spreads. Thus, conversion factors are used and have recently been updated because of changes in both animal types and industry practices. Currently it takes 2.40 lbs. of live cattle to equal 1 lb.

of retail beef for the farm-retail conversion. The farm-carcass conversion is 1.63 lbs. and the carcass-retail conversion is 1.48 lbs. Use of the conversion factors tends to reduce bias in a model when explicitly measuring the impact of margins on prices and quantities.

Chapter 2

THEORETICAL CONSIDERATIONS AND MODEL SPECIFICATION

This chapter is separated into five specific categories: (1) the theory of consumer behavior, (2) the theory of the firm, (3) the nature of marketing margins, (4) model specification, and (5) econometric theory. The first three sections provide the foundation for the development of the fourth section, model specification. The fifth section discusses the econometric theory used to estimate the equations supported by the maintained hypothesis. Although model specification is dependent upon received economic theory, common knowledge of the latter necessitates only treating these subjects here in a brief manner.

Theory of Consumer Behavior

The assumption of consumer rationality is the basis upon which consumer theory is developed. A rational consumer is one who ranks various alternatives in order of their preference. This ranking procedure can be expressed mathematically by a utility function. A consumer's utility function is unique except for a monotonic transformation and is confined to a specific time period. In this sense, the function is static. Utility functions are continuous with continuous first- and second-order partial derivatives. These partials are positive indicating that a consumer prefers more of all

goods to less. In addition, the function is strictly quasi-concave.

A rational consumer desires to maximize utility by purchasing an optimal combination of goods subject to an income constraint.

Mathematically,

$$U = f\left(\sum_{i=1}^n x_i\right)$$

represents an ordinal utility function where the x_i are the quantities of goods X_i consumed. A typical income constraint may take the form

$$Y = \sum_{i=1}^n p_i x_i$$

where p_i represents the prices of goods x_i . For reasons of simplicity, a utility function incorporating two goods will be used for the remainder of this section. However, it is recognized that the function can and may contain more than two goods.

The maximization of a constrained utility function is performed using a Lagrangean multiplier function. Given the two-good utility function,

$$U = f(x_1, x_2)$$

subject to the income constraint,

$$Y = p_1 x_1 + p_2 x_2$$

the Lagrangean function becomes,

$$L = f(x_1, x_2) + \lambda(Y - p_1 x_1 - p_2 x_2)$$

where λ is some undetermined Lagrangean multiplier.⁴

The solution to this system is referred to as the first-order, or necessary condition for a maximum. It is determined by setting the first partial derivatives of the Lagrangean function with respect to x_1 , x_2 , and λ equal to zero and solving:

$$\begin{aligned}\frac{\partial L}{\partial x_1} &= f_1 - \lambda p_1 = 0 \\ \frac{\partial L}{\partial x_2} &= f_2 - \lambda p_2 = 0 \\ \frac{\partial L}{\partial \lambda} &= Y - p_1 x_1 - p_2 x_2 = 0.\end{aligned}$$

For total utility to be maximized, the ratio of the marginal utilities of each good must equal the ratio of their prices irrespective of the choice of a utility index.

$$\frac{f_1}{f_2} = \frac{p_1}{p_2}$$

The true maximum for the system is found by solving for the second-order, or sufficient condition. This procedure requires that the relevant bordered Hessian determinant be positive.⁵

Consumer demand functions are then derived from first-order conditions for constrained utility maximization. The system contains,

⁴It can be shown that the Lagrange multiplier can be interpreted as the marginal utility of income. See Henderson and Quandt (1980, p. 14).

⁵See Chiang (1974) for a detailed discussion for the solving of bordered Hessian determinants.

in this example, three equations and three unknowns. The system is solved for x_1 and x_2 , which indicates quantities consumed of X_1 and X_2 are single-value functions of prices and income.⁶ Thus, we obtain the classical demand functions incorporating the direct and indirect effects of prices and the income effects.

Theory of the Firm

A firm is defined as a technical unit that uses inputs to produce outputs. The mathematical expression for this process is the firm's production function. The production function describes the technical relationship between quantities of inputs and quantities of outputs with a given state of technology and resource constraints. Thus, firm theory is somewhat analogous to consumer theory in that a consumer purchases inputs to "produce" utility (or output) via a utility function. This discussion concerns itself only with continuous production functions possessing continuous first- and second-order partial derivatives.

Consider a simple production function with two variable inputs, one or more fixed inputs, and a single output:

$$q = g(x_1, x_2)$$

where q is the quantity of output produced and x_1 and x_2 are the

⁶See Henderson and Quandt (1980, pp. 18-33) for a detailed discussion of the derivation of demand curves.

quantities of the variable inputs used in the production process. The production function is only defined for positive values of x_1 , x_2 , and q . The equation shows that an infinite number of quantities are possible given different combinations of the inputs.

Of course, a rational producer desires to maximize output in the most economically efficient manner. This optimizing procedure is accomplished in either one of two ways: (a) by maximizing output subject to a given cost constraint, or (b) by minimizing costs subject to a given output constraint.

Consider the first case where two inputs are purchased in a perfectly competitive market at constant prices. The cost equation then appears as

$$C = r_1x_1 + r_2x_2 + b$$

where r_1 and r_2 are the unit prices of x_1 and x_2 , respectively, and b is the cost of one or more fixed inputs. As in the case of consumer utility maximization, the optimization of output is performed using a Lagrangean function. Given the above production and cost functions, the Lagrangean appears as,

$$L' = g(x_1, x_2) + \delta(C' - r_1x_1 - r_2x_2 - b)$$

where δ is some undetermined Lagrangean multiplier⁷ and C' is some

⁷It can be shown that the Lagrange multiplier can be interpreted as the derivative of output with respect to costs, prices constant and quantities being variable. (Henderson and Quandt, 1980, p. 75.)

given level of cost. The first-order conditions for constrained output maximization are obtained by setting the first-order partial derivatives of L' with respect to x_1 , x_2 , and δ equal to zero.

$$\frac{\partial L'}{\partial x_1} = g_1 + \delta r_1 = 0$$

$$\frac{\partial L'}{\partial x_2} = g_2 + \delta r_2 = 0$$

$$\frac{\partial L'}{\partial \delta} = C' - r_1 x_1 - r_2 x_2 - b = 0.$$

The first-order condition for constrained output maximization states that the ratio of the marginal products of the inputs must be equal to the ratio of their respective prices. This can be accomplished by dividing the first equation by the second and transferring the price terms to the right-hand side, yielding

$$\frac{g_1}{g_2} = \frac{r_1}{r_2}$$

The second-order conditions must also be met to insure the maximum level of output has been obtained. This condition is fulfilled if the relevant bordered Hessian determinant is positive (Chiang, 1974).

The second optimization procedure, constrained cost minimization, minimizes input costs subject to an output constraint. Using the above production and cost functions, a Lagrangean function can be formed

$$L'' = r_1 x_1 + r_2 x_2 + b + \gamma(q' - g(x_1, x_2)),$$

where γ is some undetermined Lagrangean multiplier⁸ and q' is some fixed level of output. The first-order conditions for constrained cost minimization are found by setting the first-order partial derivatives of L'' with respect to x_1 , x_2 , and γ equal to zero.

$$\frac{\partial L''}{\partial x_1} = r_1 + \gamma g_1 = 0$$

$$\frac{\partial L''}{\partial x_2} = r_2 + \gamma g_2 = 0$$

$$\frac{\partial L''}{\partial \gamma} = q' - g(x_1, x_2) = 0.$$

The second-order condition for this case requires that the relevant bordered Hessian determinant be negative (Chiang, 1974).

Normally a producer varies both the input costs and levels of output. Therefore, his goal is neither one of constrained output maximization nor one of constrained cost minimization, but rather the goal of profit maximization. A profit function takes the form

$$\pi = pq - C$$

where π represents profit, p is the unit price of output q , and C is total cost. Substituting the above production and cost functions for q and C , respectively, the profit function becomes

$$\pi = pg(x_1, x_2) - r_1 x_1 - r_2 x_2 - b.$$

Profit is maximized when the first- and second-order conditions are met. The first-order condition is found by setting the

⁸ γ equals the reciprocal meaning of δ given in footnote 7.

first-order partial derivatives of π with respect to x_1 and x_2 equal to zero.

$$\frac{\partial \pi}{\partial x_1} = pg_1 - r_1 = 0$$

$$\frac{\partial \pi}{\partial x_2} = pg_2 - r_2 = 0.$$

The first-order condition requires that the quantity of each input be used to the point where its marginal value product equals its price, or that the ratio of the marginal products equal the ratio of the input prices.

$$pg_1 = r_1$$

$$pg_2 = r_2.$$

The second-order conditions for profit maximization require that the principal minors of the relevant Hessian determinant alternate in sign (Chiang, 1974).

The supply function for a firm is then obtained from the first-order condition for profit maximization.⁹ An aggregate supply curve is derived from the horizontal summation of all the individual supply curves, which relates the level of output supplied to a schedule of output prices.

⁹See Henderson and Quandt (1980) for a detailed discussion of the derivation of supply curves.

The Concept of Marketing Margins

The market demand and supply curves derived from the respective theories of the consumer and the firm are considered primary functions. Thus, these are the curves from which all other market demand and supply curves in the marketing channel are derived.

Primary demand, can be considered a joint demand curve for all inputs used to produce a specific commodity. These inputs consist of the raw farm product plus marketing services in the time (storage), space (transportation), and form (processing) dimensions. Derived demand at any marketing level, i.e. processing or farm can be obtained from the primary demand curve by subtracting the appropriate marketing costs, assuming that the supply function for marketing inputs is static and that the final product is produced from fixed input proportions.¹⁰ Therefore, the difference between any two derived demand curves, is given by the appropriate marketing margin.

The concept of derived supply curves is similar to that of derived demand curves with one exception - the primary supply curve occurs at the producer level. Therefore, the derived supply curves can be obtained from the primary supply curve by adding an appropriate

¹⁰The "fixed proportions" assumption is a simplifying, although realistic assumption. Gardner (1975) provides a more general mathematical model as an alternative to the assumption of fixed proportions.

marketing margin.

Tomek and Robinson (1981) define these marketing margins as (1) the difference between the price paid by consumers and the price received by producers, or as (2) the price of a collection of marketing services determined by the demand for and the supply of such services. The former is easy to conceptualize, however, the latter definition is important for the determination of the variables which influence the size of margins. It is used in the thesis for the purpose of model specification, i.e. identifying the different costs that account for the spread.

An example of marketing margins is given in Figure 1. Prices are determined at the retail, processing, and producer levels by the intersection of the appropriate supply and demand curves. Price at the retail level, P_r , is established at the point of intersection between the primary demand curve, PD_r , and retail-level derived supply curve, DS_r . Price at the carcass (processing) level, P_c , is established at the point of intersection between the derived demand curve, DD_p , and the derived supply curve, DS_p . Likewise, the price at the farm level, P_f , is established at the point of intersection between the farm-level primary supply curve, PS_f , and the farm-level derived demand curve, DD_f . It can be seen then that the carcass-to-retail marketing margin M_1 is the difference between P_r and P_c . The farm-to-carcass marketing margin M_2 is the difference between

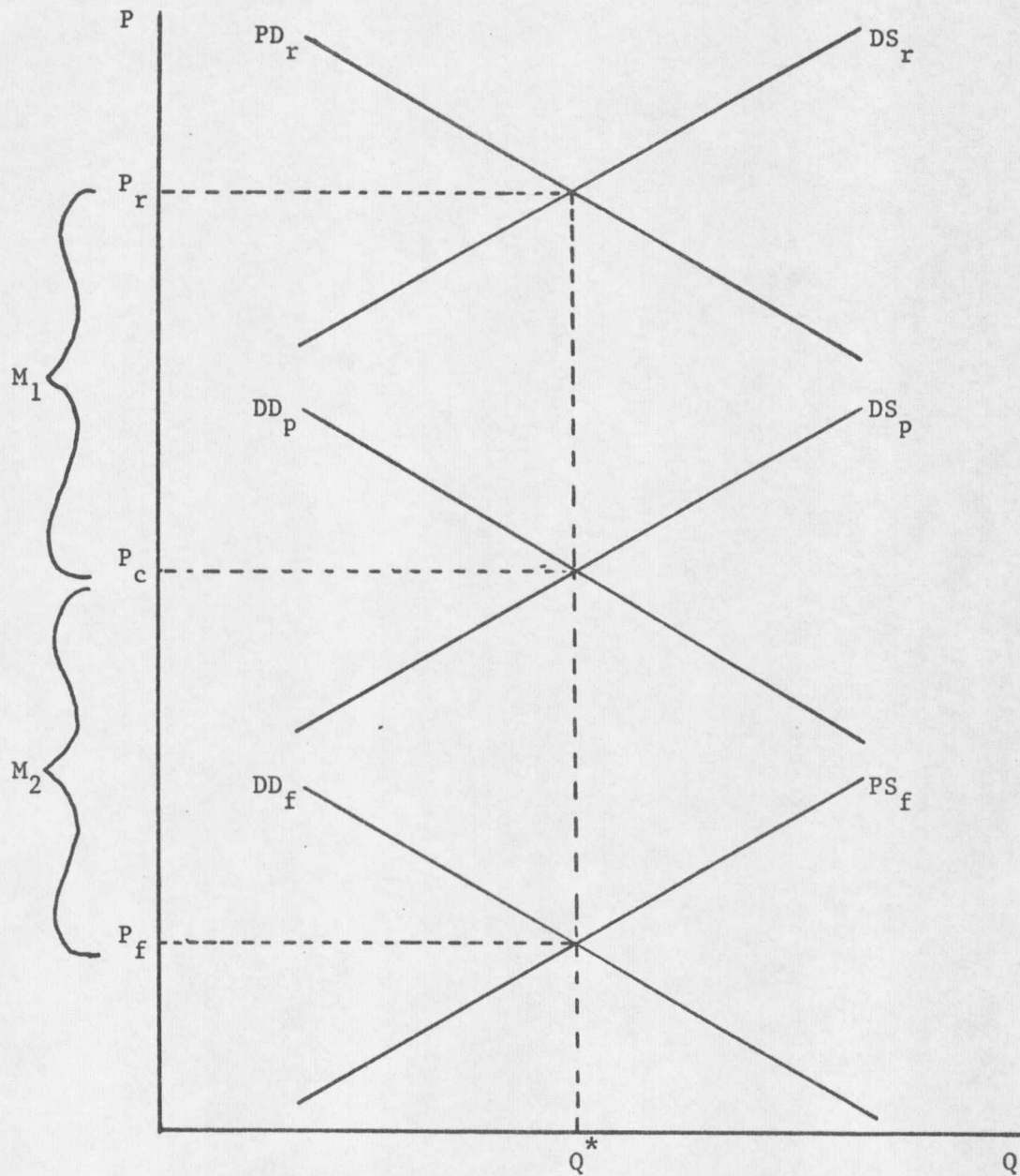


Figure 1. Illustration of Primary and Derived Functions and Marketing Margins.

P_c and P_f .

Marketing margins change over time as a result of changes in the determinants of the demand for and/or the supply of marketing services. Common demand shifters include tastes and preferences, consumer habits, and income. Common supply shifters include assembly, transportation, processing, distribution costs, and technologies. Changes in marketing margins either shift the primary or derived curves, depending upon the nature of the change. For example, changes in the costs of providing existing marketing services results in the shifting of the derived demand and derived supply curves. However, the adoption of new marketing services initially changes the primary demand curve. Changes in marketing margins do not directly effect the primary supply curve, yet it can be shifted through secondary market effects.

The incidence of changes in marketing margins is also determined by the nature of the change. For example, the introduction of a new service results in the formation of a new primary demand curve, and other things held constant, most likely a larger margin. Given that consumers accept this new service, the larger margin will be manifest in a higher retail price. Therefore, the incidence of the margin change through the introduction of a new service is born primarily by the retail level.

The incidence of a change in marketing margins resulting from a

change in the cost of existing marketing services falls, however, upon both the retail and producer levels. Since these margin changes affect the derived supply and demand curves, an increase in the margin has the effect of decreasing both derived demand (downward shift) and derived supply (upward shift). The result is an increase in retail price and a decrease in farm price, if all other factors in the market are held constant.

The magnitude of these price changes depends upon the relative slopes of the primary curves. Given linear relations, the magnitude of the price change will be greatest at the farm level if the supply curve is steeper, in absolute value, than the demand relation. Conversely, the magnitude of the price changes will be greater at the retail level if the demand relation is steeper than the supply relation. If the slopes of the two functions are equal, the magnitude of the price changes will fall equally upon the retail and farm levels.

Model Specification

An Overview

This chapter has briefly reviewed the economic theory necessary for the development of a structural model of the U.S. livestock-beef industry. At this point a general overview of the underlying model is presented prior to discussing the details of the model specification

and accompanying econometric theory. Figure 2 presents a flow diagram of the price and supply relationships inherent in the model. The arrows represent the directional flow of the endogenous variables in the market system. The remaining endogenous variables as designated by an asterisk and along with the exogenous variables are located to the left of the price equations and to the right of the supply equations.

Primary demand at the retail level is assumed to represent final market clearance and equilibrium conditions. Thus, regardless of the decisions and activities at the other marketing levels, it is the consumer who ultimately purchases beef. Given the perishable nature of processed beef, over the period of one year consumption will nearly equal production and price will be determined. Consequently, a retail price equation is specified as the primary demand relation. The remaining price relations are considered derived.

The price of retail beef then significantly influences carcass prices charged by packers, since in the final analysis it represents consumers' willingness to buy. The retail and carcass markets are linked together by the carcass-to-retail marketing margin, representing such factors as processing and distribution costs. The marketing margin is also an important variable in determining the level of carcass prices charged by packers.

The price of carcasses, an output price to packers, is

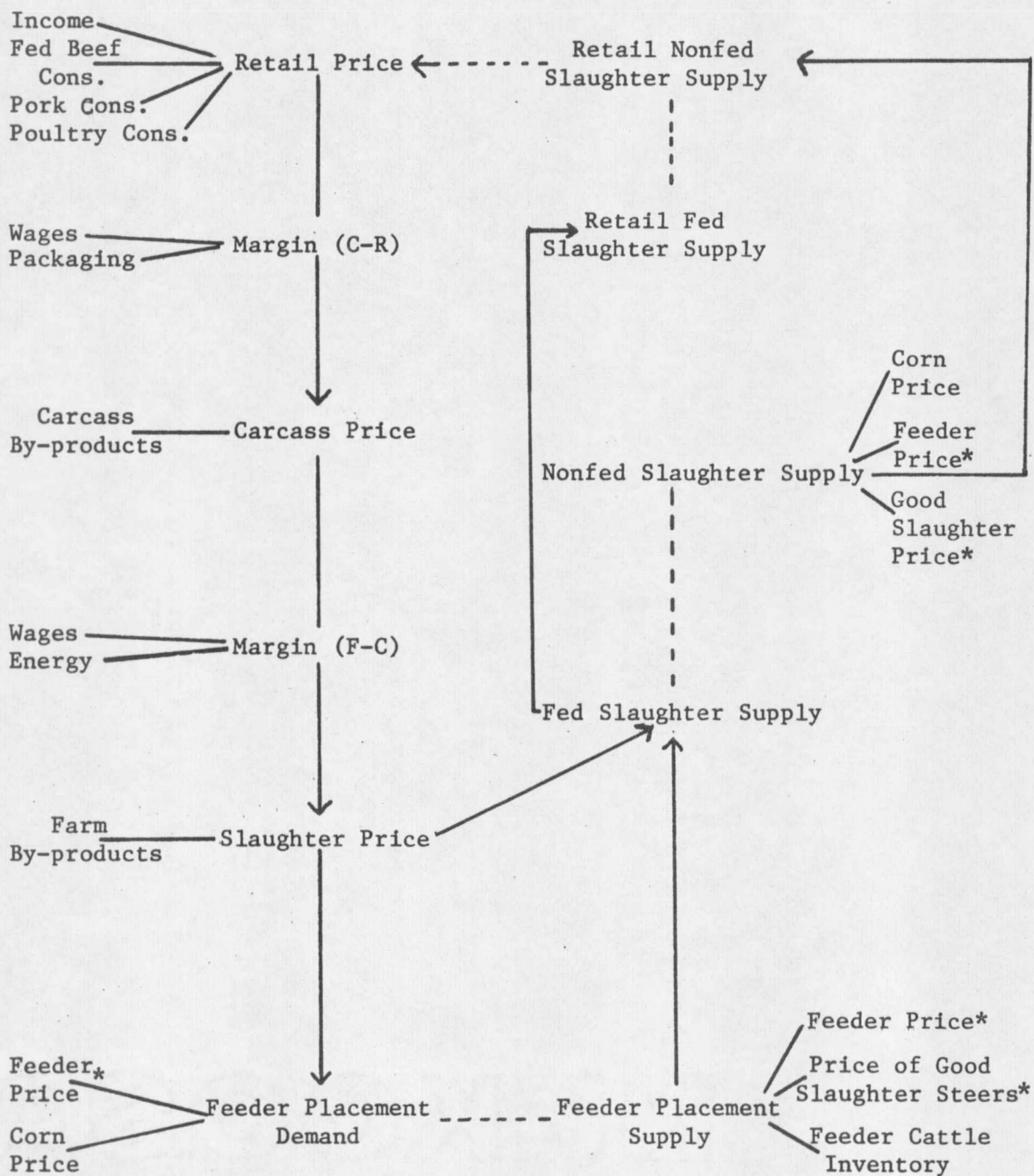


Figure 2. Flow Diagram of the Beef Price and Supply Model.

hypothesized to heavily influence packer price offers for slaughter cattle coming into slaughtering plants. The farm-to-carcass marketing margin connects the carcass market to the slaughter market and is considered significant in determining slaughter prices since it represents costs specific to that level.

The price of slaughter steers, representing an output price to cattle feeders, is expected to be a significant variable in establishing the demand for feeder cattle placements. This variable, along with corn prices, forms a slaughter steer-to-corn price ratio that serves as a proxy for feedlot profits.

On the supply side, the feeder placement supply equation represents the quantity of feeder cattle offered to feedlots by cow-calf and cow-yearling operators. This equation is considered as primary, with all other supply equations in the market considered as derived. The feeder supply and demand placement equations are linked together in that they interact to form a farm-level market clearing device for prices and quantities of feeder cattle.

The processing-level supply sector is separated into fed and nonfed components. The quantity supplied of feeders is hypothesized to be a significant variable in determining the level of fed slaughter. Also the price of slaughter steers (from the slaughter price equation) influences the quantity of fed cattle offered to the slaughter market by cattle feeders.

Nonfed slaughter supply is a function of variables representing the opportunity costs of producing nonfed beef. This equation and the fed beef supply equation directly determine, given dressed carcass weights, the levels of retail fed and nonfed beef supplies. The supply of nonfed beef enters the retail beef price equation as an endogenous variable since the decision to market nonfed cattle to slaughter is considered an internal part of the system.

The specification of each of the following model equations is performed within the guidelines of accepted economic theory and knowledge of the commodity sectors. Annual data is used for the variables and the sample period is from 1960-1980. A longer sample period was not used because of the difficulty in obtaining data on fed beef prior to 1960. Prior to this time period fed beef was not as important in determining total beef supplies. All prices, wages, and income are deflated by the Consumer Price Index (1967=100).

Retail Demand Sector

Primary demand is determined at the retail level. A dynamic price equation is specified with the price of retail beef, a function of consumer disposable income, per capita consumption of fed beef, and per capita consumption of substitute meats in a rational distributed lag structure. Specifically,

$$P^{rb} = f(Y, Q^{fed}, Q^{nfed}, Q^{pk}, Q^{plty})$$

where

p^{rb} = weighted average price of retail beef for choice table cuts, yield grade 3, cents/lb. (endogenous).

Y = per capita real disposable income, dollars, (exogenous).

Q^{fed} = per capita consumption of fed beef, pounds on a carcass weight basis, (exogenous).

Q^{nfed} = per capita consumption of nonfed beef, pounds on a carcass weight basis, (endogenous).

Q^{pk} = per capita consumption of pork, pounds on a carcass weight basis, (exogenous).

Q^{ply} = per capita consumption of poultry, pounds on a carcass weight basis, (exogenous).

Per capita disposable income measures the effect of consumer purchasing power, and is traditionally included in retail level demand equations. It is expected to be a significant demand shifter since historically 2.2 to 2.4 percent of consumer budgets have been allocated to beef purchases.

Economic theory suggests that demand equations describe the price-quantity relationship of a good. Since price is the dependent variable, quantity demanded in the form of per capita consumption of fed beef is included as a principal regressor. This regressor is treated as predetermined because of the nature of fed beef production. Usually, decisions are made and resources allocated in advance of contemporaneous slaughter and subsequent consumption. Since consumption ultimately equals production over the course of one year,

consumption of fed beef is treated as predetermined.

Most demand equations include variables for substitutes. Probably the closest substitute for fed beef is nonfed beef, and in the U.S. nonfed beef is usually in the form of ground beef. The quantity of nonfed beef consumed is assumed to be an endogenous variable because of the nature of nonfed beef production. Generally, it does not require as much advanced decision-making or resource allocation as compared to fed beef. For example, nonfed beef consisting of cull cows, bulls, and vealers are marketed by producers based on current economic criteria. Since nonfed beef production and consumption are nearly equal over a year, the latter is considered endogenous.

As the observed value of nonfed beef consumption is correlated with the error structure of the retail price equation, least squares predicted values for nonfed beef consumption from the nonfed beef retail supply equation will be used. The estimation method employed is essentially that of two-stage least squares.

Two other important substitutes for fed beef are pork and poultry. These commodities have historically been important in statistical demand studies for beef. Within the context of this model, the per capita consumption of each of these commodities is assumed to be predetermined.

The retail marketing level may be more complex than it appears

because of the rigidities in retailer margins and also rigidities in consumer habits. Consequently, to account for these rigidities the function was specified as dynamic by means of rational distributed lags on the right-hand side variables.

Carcass Demand Sector

The carcass price equation is a derived relation. It represents the demand price for carcasses by firms who further process them into retail cuts. The price equation is assumed to be static due to the nature of market decisions and interactions in the meat packing industry. That is, packer pricing decisions in the dressed meat trade account for contemporaneous information and probably rely very little on prices and other economic variables in the previous year.

The price of carcasses is hypothesized to be a function of retail beef prices, a marketing margin, and carcass by-product values. More specifically,

$$P_t^{car} = f(P_t^{rb}, M_t^{c-r}, P_t^{cby})$$

where

P_t^{car} = the price of choice grade carcass beef, yield grade 3, cents/lb. at Chicago, (endogenous).

P_t^{rb} = price of retail beef, (endogenous).

M_t^{c-r} = carcass-to-retail marketing margin, cents/lb. on a retail weight basis, (endogenous).

P_t^{cby} = price of carcass by-products, portion of gross carcass value attributed to fat and bone, cents/lb., (exogenous).

Firms that process carcass beef essentially produce two outputs: (1) carcass by-products, and (2) retail beef cuts. The former is the less obvious of the two commodities. However, it is common knowledge that meat processors depend upon by-products to cover their costs and profit margin. Hence, the price of carcass by-products is expected to be significant in determining carcass prices.

Likewise, the price of retail cuts should have a large impact on the price of carcasses since the consumer has the final decision in the marketplace. The retail price of beef, P^{rb} , enters the carcass price equation recursively under the assumption that the error structures between the carcass price and retail price equations are uncorrelated. This procedure is also employed in several other equations in the model. It seems logical that a processor would bid on carcasses based on the actual rather than predicted price of retail beef as daily information is available throughout the beef industry concerning price and supplies of beef.

Economic theory suggests that marketing margins are shifters of derived demand, and consequently the carcass-to-retail marketing margin should be specified as an independent variable in the carcass price equation. Since the marketing margin is jointly dependent with retail and carcass prices it is treated as an endogenous variable. Therefore predicted values of the margin from a reduced form equation are entered in the carcass price equation to purge the correlation

between the margin variable and the carcass price equation error structure.

A static behavioral equation is specified to generate the predicted values of the marketing margin:

$$M_t^{c-r} = f(W_t^{mp}, PK_t)$$

where

M_t^{c-r} = the carcass-to-retail price spread, cents/lb. on a retail equivalent basis, (endogenous).

W_t^{mp} = average real hourly earnings of production workers in the meat products industry, dollars, (exogenous).

PK_t = packaging costs for intermediate materials, supplies, and components - including materials for containers and supplies, and processed fuels, Wholesale Price Index (1967=100), (exogenous).

The carcass-retail marketing margin is determined by the costs of processing carcass beef into retail cuts. These processing costs are determined by such factors as wages, packaging, and fuel costs.

Slaughter Demand Sector

The slaughter price equation represents the demand for fed cattle by meat packers, i.e. it is the price schedule facing cattle feeders. The price of slaughter cattle is a derived price equation based on economic conditions in the dressed meat trade, and is also determined by factors specific to the slaughter level. It is given as,

$$p_t^{sl} = f(p_t^{car}, M_t^{f-c}, p_t^{fby})$$

where

p_t^{sl} = price of choice slaughter steers, 900-1100 lbs., Omaha, cents/lb., (endogenous).

p_t^{car} = price of carcass beef (endogenous).

M_t^{f-c} = farm-to-carcass marketing margin, cents/lb. on a retail weight basis, (endogenous).

p_t^{fby} = price of farm by-products, portion of gross farm value attributed to edible and inedible by-products, cents/lb., (exogenous).

The prices that meat packers are willing to bid for their input, fed cattle, is significantly determined by the price they receive for their output, carcasses. The observed values of carcass prices enter as predetermined for the same reason given above for the carcass price equation, i.e. a recursive structure in prices from the retail to carcass to slaughter levels. Meat packers also depend upon the value of by-products from slaughtered animals to pay slaughter costs and provide profit margins. In addition, by-products cover packer losses on slaughter cattle since it is not unusual for the value of the carcass to be less than the value of the slaughter animal.

Theoretically, the farm-carcass marketing margin is a shifter of the derived slaughter price relation. It is expected that a negative correlation exists since higher marketing costs force the packer to adjust his margin by offering a lower price for slaughter cattle. The predicted values of the margins are used in order to purge any correlation with the error structure. It is suspected that a jointly dependent relationship exists between the farm-carcass margin and

slaughter price.

The behavioral equation used to generate the predicted values includes a wage variable and energy variable:

$$M_t^{f-c} = f(W_t^{PP}, R_t)$$

where

M_t^{f-c} = farm-to-carcass marketing margin, cents/lb. on a retail weight basis, (endogenous).

W_t^{PP} = average real hourly wages of production workers in meat packing plants, dollars, (exogenous).

R_t = price of refined oil products, Wholesale Price Index (1967=100), (exogenous).

The farm-to-carcass marketing margin represents the costs of slaughtering live animals and processing them into carcasses. The two major items involved are labor costs and the costs of energy, together accounting for a large portion of total variable costs. The index for refined oil products serves as a proxy for total energy requirements.

Feeder Placement Demand Sector

The demand for cattle placements is a derived demand for feeders to be finished on a high concentrate ration. At this point the feedlot operator affects the livelihood of the cow-calf and cow-yearling operator since the size of feedlot profits translate into either strong or weak feeder demand. The rational distributed lag equation is of the form

$$Q^{dpl} = f(P^{fc}, \frac{P^{sl}}{P^c})$$

where

Q^{dpl} = placements of cattle on feed in the 23 major cattle feeding states, thousands of head, (endogenous).

P^{fc} = price of choice feeder steers, 600-700 lbs. Kansas City, dollars/cwt., (endogenous).

$\frac{P^{sl}}{P^c}$ = slaughter steer-to-corn price ratio; price of choice slaughter steers, Omaha, divided by the price of #2 yellow corn, Chicago, dollars/bushel, (exogenous).

The contemporaneous price of feeder cattle is considered important since the quantity of feeder cattle demanded by feedlot operators depends upon the price they must pay, other factors constant. The contemporaneous value of this variable is considered endogenous. Therefore, a reduced form equation will be used to generate the least squares predicted values for feeder prices. These values will be used as an instrumental variable in order to eliminate the problem created by joint dependence. It is also hypothesized that past prices of feeders may be significant in explaining feeder placement demand, particularly if there are lags in adjustment to changes in prices.

The price of the output of feedlots, slaughter steers, and the price of corn are stated as a ratio to proxy changes in feedlot

profitability, thus, impacting feeder placement demand. Corn is a key feedgrain and is used as the major feed input in the production of U.S. slaughter beef; it usually reflects economic changes in the total feedgrains market. The observed values of P^{sl} are used because slaughter price enters this equation recursively.

The placement demand equation is specified as dynamic which is an assumption about the behavior of feedlot operators. Decisions involving the feeding of cattle are made on the basis of expectations of future prices for both inputs and outputs. These expectations are formed in a variety of ways, e.g. average past prices, trend analysis, and intuition. Also, demand in one period tends to influence demand in a subsequent period due to customs, habit formations, and operators' desire for stability in their operations.

Since this equation is a derived demand relation, theory suggests that a marketing margin should be included in the specification. The proper marketing margin at this level would be one that represents production costs of feedlots and in some applications, transportation costs. The price of corn is a proxy for some of these production costs, and becomes manifest in feedlot profits as seen above. However, a desirable measure of this margin is not available and by necessity is excluded.

Feeder Placement Supply Sector

The quantity supplied of feeder cattle is considered the primary supply equation, and contains a rational distributed lag specification in the right-hand side variables of the following:

$$Q^{spl} = f(INV_t^{fc}, p^{fc}, p^{gsl})$$

where

Q^{spl} = placements of cattle on feed in the 23 major cattle feeding states, thousands of head, (endogenous).

INV_t^{fc} = January 1 inventory of feeder cattle in the 23 major cattle feeding states, thousands of head, (exogenous).

p^{fc} = price of feeder cattle (endogenous).

p^{gsl} = price of good grade slaughter steers, 900-1100 lbs., Omaha, cents/lb., (endogenous).

The equation describes the supply of feeders offered by cow-calf and cow-yearling producers to feedlot operators. The physical production of feeder calves directly follows the cattle cycle. Thus, it is assumed that a distributed lag specification may be appropriate in describing the supply of feeder cattle.

The first exogenous variable is a measure of the number of feeder calves available at the beginning of a given year for either fed or nonfed beef production. It is a measure of the physical limitation in any given year as to the total number of cattle, exclusive of cull cows and bulls, that would be available for meat production.

Economic theory suggests that the quantity supplied of a good is a function of its own price, in this case the price of feeders. The price of feeder cattle and the price of good grade slaughter steers together are measures of the relative opportunity costs of supplying feeders to the fed and nonfed sectors. For example, the price of feeder cattle represents the price offered to producers by feedlots, while the price of good grade slaughter steers is the price offered to producers by packing plants for cattle circumventing the feedlot. Like the price of feeder cattle variable, the least squares predicted values of the price of good grade slaughter steers will be obtained from a reduced form equation and used in this equation as an instrumental variable. Again, this procedure is essentially a two-stage least squares method.

The supply of feeder cattle in any given year depends heavily upon the amount of breeding stock available in the previous year. Given the biological and economic nature of the cattle cycle, the amount of breeding stock available in any given year is determined by complex market behavior that has occurred over several previous years. Consequently, it is hypothesized that a rational distributed lag model can measure this dynamic market behavior.

Processing Supply Sector

The processing supply sector is separated into fed and nonfed

components since the supply of each is influenced by distinctly different factors.

The specification for the quantity of fed beef slaughtered is

$$Q_t^{sfd} = f(Q_t^{spl}, Q_{t-1}^{spl}, P_t^{sl})$$

where

Q_t^{sfd} = number of commercially slaughtered fed cattle, thousands of head, (endogenous).

Q_t^{spl} = contemporaneous value of placements of cattle on feed, (endogenous).

Q_{t-1}^{spl} = lagged value of placements of cattle on feed, (exogenous).

P_t^{sl} = price of slaughter steers (endogenous).

The supply of fed beef is determined by fed slaughter price and the quantity of cattle placed in feedlots. It is hypothesized that feedlot operators make some adjustment in fed marketings to changes in slaughter price. The latter variable is expected to be significant in explaining fed beef slaughter since all animals that are placed in feedlots (less death loss) are slaughtered at some point in time. Those feeders that are placed in feedlots toward the end of a year would not be slaughtered until the following year. Consequently, contemporaneous and lagged values of feeder cattle placements are specified in the equation.

Both Q_t^{spl} and P_t^{sl} have previously been defined as endogenous variables. However, the contemporaneous values of Q_t^{spl} and P_t^{sl} enter

as predetermined since Q_t^{spl} enters the equation recursively from the feeder supply equation and P_t^{sl} enters the equation recursively from the slaughter price equation. The observed values for both variables are entered in the fed slaughter supply equation under the assumption that the error structures between the relevant equations are uncorrelated, or at least weakly correlated.

The nonfed slaughter supply relation is more complex and is specified in a rational distributed lag structure as

$$Q^{snfd} = f(P^{fc}, P^{gsl}, P^c)$$

where

Q^{snfd} = number of commercially slaughtered nonfed cattle, thousands of head, (endogenous).

P^{fc} = price of feeder cattle, (endogenous).

P^{gsl} = price of good grade slaughter steers, (endogenous).

P^c = price of corn, (exogenous).

The source of nonfed slaughter is based on culled breeding stock and grass fed steers and heifers. The price of feeder calves and the price of corn impacts the supply offered of each category, both in terms of packer-feeder competition for grass fed beef and the opportunity costs of holding breeding stock. For example, when feeder cattle prices decline, fewer feeder calves may be sold to feedlots and more go directly to slaughter (off grass) as packers effectively compete with feedlot operators. Similarly, if the price of corn

increases, the cost of feedlot gain increases, tending to give packers a competitive edge and results in fewer feeders being placed on feed, more going directly as nonfed slaughter. From the cow herd standpoint, a decline in feeder prices and an increase in corn prices increases the opportunity cost of holding cull cows. In addition, expectations of future profitability of feeder cattle production depends upon current and lagged prices of feeder cattle and corn taken jointly. Thus larger cow slaughter would be the expected as a result of a decline in feeder cattle prices and/or an increase in corn prices. The above arguments would be reversed with increases in feeder prices and decreases in corn prices.

Age also influences the opportunity costs of owning breeding stock. Generally, beyond some point, the value of breeding stock declines as age is increased. For this reason, nonfed slaughter supply is expected to capture some of these effects via a dynamic specification.

Retail Supply Sector

The retail supply sector is, like the processing sector, divided into fed and nonfed components. Since little processed beef is exported from the U.S., the retail supply equations are merely identities involving the processing supply equations. Specifically,

$$Q_t^{srfd} = (Q_t^{sfd})(ADW_t^{fed})(u)$$

where

Q_t^{srfd} = quantity supplied of retail fed beef, millions of pounds on a retail weight basis, (endogenous).

Q_t^{sfd} = number of commercially slaughtered fed cattle (endogenous).

ADW_t^{fed} = average dressed weight of fed beef, pounds per head, (exogenous).

μ = carcass weight to retail conversion factor (exogenous).
The value μ equals .68.

Domestic production of nonfed beef is equal to the product of nonfed beef slaughtered and the average dressed weight of nonfed beef. The total quantity supplied of nonfed beef on a carcass weight basis multiplied by the retail weight conversion factor equals the total quantity supplied of nonfed beef on a retail weight basis.

$$Q_t^{srnfd} = (Q_t^{snfd})(ADW_t^{nfd})(\mu)$$

where

Q_t^{srnfd} = quantity supplied of retail nonfed beef, millions of pounds on a retail weight basis, (endogenous).

Q_t^{snfd} = number of nonfed beef commercially slaughtered, (endogenous).

ADW_t^{nfd} = average dressed weight of nonfed beef, pounds per head, (exogenous).

Econometric Theory

The specification of a model and the relevant econometric theory are usually interrelated, many times dictating the estimation procedure to be employed. This section is separated into two

subsections. The first discusses the classical linear regression (CLR) model and its assumptions. The CLR model assumes the ordinary least squares (OLS) estimator yields the most desirable properties when specific assumptions are not violated. This is the case in several of the hypothesized equations. However, if any of the assumptions are violated, as is also the case in several of the hypothesized equations, the OLS estimator may not be the best estimator and alternatives to it should be investigated. The second subsection discusses the rationale and econometric theory associated with dynamics since several of the model equations are specified with lagged independent variables and difference equations.

General Linear Model

The classic linear regression model can be presented in matrix notation as,

$$(1) \quad Y = X\beta + U$$

where

$Y = n \times 1$ matrix of observations on the endogenous variable.

$X = n \times k$ matrix of observations on the exogenous variables.

$\beta = k \times 1$ matrix of coefficients specific to the exogenous variables.

$U = n \times 1$ matrix of observations on the disturbance terms.

The statistical assumptions of the classical linear regression model are:

- 1) the dependent variable can be calculated as a linear function of a set of independent variables plus a disturbance term.
- 2) the expected value of the disturbance term is zero.
- 3) the disturbance terms all have the same variance and are uncorrelated with one another.
- 4) the observations on the independent variable can be considered fixed in repeated samples.
- 5) the number of observations exceed the number of independent variables and there are no exact linear relationships between the independent variables.

The OLS estimator is considered the best estimator if all five of the above assumptions are met.

Violations of these assumptions usually occur in applied regression analysis. The first is that a relevant variable has been omitted or an irrelevant variable has been included. In the former case, the OLS estimator of the remaining variables will be biased but still efficient. The latter case results in an unbiased but inefficient OLS estimate. Clearly, a corrective measure to this problem is to properly specify the set of variables, assisted by relevant economic theory and familiarity with the commodity in question. Often times, however, measurements on theoretical variables are not available.

A second violation of the first assumption occurs when the functional form of the equation is nonlinear in parameters. An OLS regression of such a function is not feasible. An alternative is a

nonlinear least squares or a maximum likelihood procedure based on some type of iterative search routine. This type of procedure using large samples results in estimates of the parameters that have the desired asymptotic properties.

A third violation of the first assumption occurs when changing parameter values are incurred in time-series data. One example of this occurs when the parameters are random variables, e.g. a parameter which contains a random element. A procedure to overcome this problem is to substitute for the stochastic parameter a variable containing its mean value plus a disturbance term, thus removing the random element. This results in a more complicated error structure which requires a more sophisticated estimation procedure.

The second assumption of the CLR model is that the expected value of the disturbance term is zero. A violation of this assumption may occur if there were systematic positive or negative errors of measurement in the dependent variable. The only problem created in this situation is that an OLS regression results in a biased estimate of the intercept. This is not especially a problem and, in fact, it is desirable if the purpose of the equation is one of producing accurate predictions. However, a nonzero expected value of the disturbance term may be indicative of specification error.

The third assumption of the CLR model is that the error terms have equal variances and are statistically independent.

Heteroskedastic error terms implies each disturbance term is drawn from a different distribution for each observation. An OLS regression under these circumstances results in parameter estimates that are inefficient, violating the maximum likelihood criterion. A generalized least squares procedure is one method employed to counter the problems of heteroskedasticity.

A second violation of the third assumption occurs when the disturbance term associated with one observation is correlated with the disturbance term of another. The consequence of OLS regression with an autocorrelated error structure is that the variance of the estimate is greater than it would have been given randomly distributed errors. However, the estimates remain unbiased. Several different techniques are available to estimate the autocorrelated parameter and subsequently, the remaining parameter coefficients.

The fourth assumption of the CLR model is that the observations of the independent variables are considered fixed, i.e. obtaining the same values of the independent variables in repeated sampling. The OLS estimator maintains its desirable properties when this assumption is violated, assuming the independent variables are distributed independently of the disturbances.

The fourth assumption is violated when an errors-in-variables (incorrectly measured variables) problem occurs on an independent variable. The OLS estimator is biased in the case where the

independent variable is not distributed independently of the associated disturbance term. Weighted regression and instrumental variables are two methods of handling this problem.

Another violation of the fourth assumption occurs when a variable is influenced by its value in a previous period. This occurs when a lagged value of the dependent variable appears as a principle regressor, and is termed autoregression. Autoregression is a stochastic process when dealing with the lagged observed value of the dependent variable. However, in the thesis model several equations are hypothesized to contain the expectation of the lagged dependent variable. This is not a violation of the fourth assumption since the expectation of the lagged dependent variable represents a nonstochastic process, but it leads to nonlinearities in the parameters of the equation.

Autoregression may occur because economic theory suggests it to be a proper specification in an equation. It may occur indirectly when transforming equations with estimation problems to those that are empirically measurable. The OLS technique in this case may not be as appropriate as maximum likelihood or generalized least squares.

Another example of the violation of the fourth assumption occurs in a system of simultaneous equations where the endogenous variables are jointly determined. The OLS estimator is biased in this situation unless the system is recursive. A recursive system is one in which

each endogenous variable is determined by only exogenous variables and previously determined (time ordering of the process) endogenous variables. The OLS estimator is consistent for a recursive system, and if no lagged endogenous variables appear as regressors it is also unbiased.

Several techniques are available for estimating a nonrecursive simultaneous equation system. These can be separated into (a) single-equation methods, or (b) systems methods. Single-equation methods are referred to as "limited information" methods because they incorporate only the knowledge contained in the particular equation being estimated. The following is a list of single-equation methods:

- (1) Ordinary least squares
- (2) Indirect least squares
- (3) Instrumental variables
- (4) Two-stage least squares
- (5) Limited information-maximum likelihood.

Systems methods are referred to as "full information" methods since they utilize information contained in the entire system for estimating each parameter. Examples of systems methods include three-stage least squares and full information-maximum likelihood.

The fifth assumption of the CLR model is twofold. First, the number of observations must exceed the number of independent variables and second, no exact linear relationships exist between the

independent variables. If the former is violated, the estimating procedure used to obtain OLS estimates is impossible for mathematical reasons.

The second half of the fifth assumption does not usually occur. One would not expect exact linear relationships between variables to occur in economic data, other than data which is constructed by the researcher, thus being avoidable. However, approximate linear relationships are quite common among economic variables and are referred to as multicollinearity. Technically, only exact multicollinearity results in a violation of the fifth assumption. Statistically, multicollinearity usually results in large variances of the OLS parameter estimates of the collinear variables.

Several techniques may be employed to compensate for the problem of multicollinearity. They range from 'doing nothing' to selective elimination of certain collinear variables.¹¹

Distributed Lags

Static economic theory assumes that adjustments to changes in economic variables occur instantaneously. However, in reality this may not be the case since technological, institutional, and psychological barriers slow the adjustment process. Consequently,

¹¹For a further discussion of this or any of the topics mentioned in this section, see Kennedy (1979) or any beginning econometrics textbook.

certain adjustments to changes in economic variables may occur instantaneously while other adjustments are distributed over a longer period of time. This type of adjustment process by either consumers or producers is referred to as a "distributed lag." An infinite distributed lag model is given as

$$(2) \quad Y_t = \alpha_0 X_t + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \alpha_3 X_{t-3} + \dots + e_t$$

which shows that Y_t is not only dependent upon the contemporaneous values of X but also lagged values of X .

There are two major problems associated with estimating this distributed lag model. First, it is likely that the X 's will display a collinear relationship. This results in small values of the coefficient estimates relative to their standard errors. Secondly, the lagged values of the X 's must be arbitrarily truncated at some point in order to allow sufficient degrees of freedom to estimate the set of parameters. The truncation point may or may not occur where the distributed lag effect has become dissipated.

Koyck (Wonnacott, 1979) suggested a simplifying assumption in order to manage the above statistical problems. He assumed that the α_i 's decreased exponentially over time,

$$(3) \quad \alpha_i = \alpha_0 \lambda^i$$

where $0 \leq \lambda < 1$ and the index i represents the point from which the parametric estimation begins. By substituting restriction (3) into equation (2) the process reduces to a simple estimable form

$$(4) \quad Y_t = \lambda Y_{t-1} + \alpha_0 X_t + e_t - \lambda e_{t-1}.$$

The problem with (4) is that OLS regression results in biased and inconsistent parameter estimates because of the correlation between Y_{t-1} and the composite error structure. Koyck's assumption of a lag structure that exponentially decreases has been modified in a number of studies (see Almon, 1965) to allow for a variety of lag structures.

Cagan (1956) developed an adaptive expectations model which also described the lag structure as exponentially decreasing. His model assumed that the independent variable was some function of the expectation of price, where price expectations were revised in each period in proportion to the error associated with the previous period's expectations.

A declining distributed lag structure can also be found in Nerlove's (1958) partial adjustment model. This model assumes that the contemporaneous values of the independent variables determine some desired value of the dependent variable. Nerlove contends that only a small part of the desired adjustment will be accomplished in a given time period. Both the Nerlove and Cagan models can be simplified to the same reduced form with a Koyck transformation; however, the Nerlove model does not contain a serially correlated error structure if it was initially absent.

All the above studies use a finite lag structure to approximate an infinite lag structure. Jorgenson (1966) reported that these

procedures require a relatively large number of parameters to accurately approximate an infinite lag structure. Thus, he proposed the idea of rational distributed lags, which uses fewer parameters, to approximate an infinite distributed lag. He defines a function to be a rational distributed lag "if and only if it may be written with a finite number of lags in both the dependent and independent variables" (p. 138). Koyck's, Cagan's, and Nerlove's models can all be shown to be of this type.

Mathematically, Jorgenson's model can be expressed as;

$$(5) \quad Y_t = R(L)X_t = \frac{\alpha(L)}{\lambda(L)} X_t + e_t$$

where the rational lag function $R(L)X_t$ is characterized by the ratio of two polynomials $\alpha(L)$ and $\lambda(L)$, each of which has no characteristic roots in common. The lag operator L implies that $L^k X_t = X_{t-k}$.

Multiplying both sides of equation (5) by $\lambda(L)$ yields

$$(6) \quad \lambda(L)Y_t = \alpha(L)X_t + \lambda(L)e_t$$

so that

$$(7) \quad (1 + \lambda_1 L + \dots + \lambda_n L^n)Y_t = (\alpha_0 + \alpha_1 L + \dots + \alpha_m L^m)X_t + e_t^*$$

where $e_t^* = \lambda(L)e_t = \sum_{i=0}^n \lambda_i e_{t-i}$ and is autocorrelated. The rational distributed lag function may be written as

$$(8) \quad Y_t + \lambda_1 Y_{t-1} + \dots + \lambda_n Y_{t-n} = \alpha_0 X_t + \alpha_1 X_{t-1} + \dots + \alpha_m X_{t-m} + \lambda_1 e_{t-1} + \dots + \lambda_n e_{t-n} + e_t.$$

Thus, the rational lag structure of equation (6) is reduced to an n^{th}

order difference equation with an n^{th} order moving average error structure. Jorgenson concluded that an arbitrary distributed lag function can be approximated to any desired degree of accuracy by a rational lag function with sufficiently high values of m and n .

The maintained hypothesis of the livestock model discussed earlier specified several rational distributed lag equations. Burt (1978) reported that nonstochastic difference equations may be more appropriate in the measurement of agricultural supply response than stochastic difference equations. In 1980, he further noted this was the case in most rational distributed lag models for several reasons. First, the composition of the disturbance term in any regression equation is always unknown. However, parameter estimates of a nonstochastic difference equation are consistent even if the structure of the disturbance is misspecified. Second, the disturbance term of a nonstochastic difference equation is not transformed into a more complex structure in the conversion of a rational lag model to the difference equation formulation; which is the case with stochastic difference equations. Thus, the error structure of a nonstochastic difference equation is simpler than that of a stochastic difference equation. Third, a nonstochastic difference equation delineates between exogenous and endogenous components when an autocorrelated disturbance term exists. The parameter estimates of an autoregressive error term are asymptotically uncorrelated with those of the other

parameters in the model.

All statistical regression equations contain a stochastic disturbance term. However, the delineation of stochastic versus nonstochastic depends on the manner in which the lagged dependent variable enters the set of regressors. In equation (8), the observed values of the lagged dependent variable are used, thus they contain a stochastic component. A nonstochastic difference equation uses the "expected value" of the lagged dependent variable and incorporating this idea into a simple Koyck transformation yields

$$(9) \quad Y_t = \alpha + \beta X_t + \lambda E(Y_{t-1}) + \rho u_{t-1} + u_t$$

where $E(Y_{t-1})$ is the expected value of Y_{t-1} and u_t has the classic properties. Equation (9) is nonstochastic in that successive iterations yields $E(Y_t)$ only as a function of the historical values of X , and $E(Y_{t-1})$ is strictly an exogenous variable if the disturbance term is autocorrelated.

The lagged expectation of the dependent variable and/or the autocorrelated error structure produces some estimation problems for OLS because of the introduction of nonlinearities in the parameters. Therefore, the nonstochastic difference equations in this model are estimated by least squares (maximum likelihood under the assumption of normality) from a modified Marquardt nonlinear least squares algorithm.

Several studies have tested the idea of using nonstochastic

difference equations in estimating agricultural supply responses. LaFrance (1979) argues that, in terms of crop production, the correct behavioral response variable in an agricultural distributed lag model is expected output rather than actual output. His argument is that differences between planned and actual output levels are due to random events such as weather. Therefore, it would appear that the proper procedure in estimating such an equation would be to transfer the nonsystematic portion of the regressor to the error structure.

Rucker (1980) estimated beef cattle inventory and breeding herd functions for the state of Montana. He hypothesized that this supply function may best be estimated by a nonstochastic rather than stochastic difference equation. However, his reasons for this hypothesis were somewhat different from LaFrance's. Rucker theorized that the proper specification of his supply equation depended upon the assumed composition of the error structure. If the disturbance term were dominated by random disturbances caused by factors uncontrollable by producers, then the equation should be estimated as a nonstochastic difference equation. However, if the disturbance term were not dominated by such random disturbances, then a stochastic difference equation should be employed.

Chapter 3

EMPIRICAL RESULTS

The theoretical framework and specification of the dynamic beef model presented in Chapter 2 consisted of nine structural equations, two identities, and two reduced form equations. This chapter presents the statistical measurements and economic analysis of the empirical results specific to each sector. Tables 1, 3, and 4 present the statistical results of the behavioral price and supply equations while Table 2 presents the short- and long-term price flexibilities and supply elasticities.

Retail Demand Sector

The final retail price equation was estimated as a function of contemporaneous disposable income and meat consumption with a first-order nonstochastic difference equation. The statistical results are summarized in Table 1 and all of the signs of the estimated coefficients meet a priori expectations.

Disposable income is a shifter of primary demand, reflecting consumer purchasing power, and is positively correlated with retail beef prices. For example, a \$100 increase in per capita disposable income increases contemporaneous retail beef prices by 24 cents per pound. The short run price flexibility with respect to income is .758. This estimate compares favorably to Walters, Moore, and

Table 1. Regression Results of the Retail Price, Carcass Price, and Carcass-Retail Marketing Margin Equations.^a

Equations	Variables											Statistics ^b		
	Intercept	Y	Q ^{fed}	Q ^{nfed}	Q ^{pk+ply}	E(P ^{rb} _{t-1})	P ^{rb} _t	M ^{c-r} _t	P ^{cby} _t	W ^{mp} _t	P _{Kt}	R ²	S _y	D-W
P ^{rb}	64.211 (7.121)	.024 (7.833)	-.737 (-7.048)	-1.069 (-9.123)	-.240 (-2.218)	.723 (10.813)						.90045	2.13	2.423
P ^{car}	9.425 (2.917)						.422 (8.660)	-.689 (-9.268)	12.698 (4.509)			.94137	.950	1.592
M ^{c-r}	-76.141 (-5.106)									26.744 (5.782)	.261 (3.375)	.69891	2.21	1.519

^a All variables are significant at the 95 percent level; the appropriate t-ratios are in parentheses under each coefficient.

^b R² = adjusted multiple R-squared statistic.

S_y = standard error of the estimate.

D-W = Durbin-Watson statistic.

Table 2. Estimates of the Short and Long Run Price Flexibilities and Supply Elasticities of the Price and Supply Beef Model.^a

Equations	P^{rb}	Y	Q^{fed}	$\hat{Q}^{nfed}$	Q^{pk+ply}	P^{car}	$\hat{M}^{c-r}$	P^{cby}	P^{csl}	$\hat{M}^{f-c}$	P^{fby}	$\hat{P}^{fc}$	$\frac{P^{sl}}{P^c}$	INV^{fc}	$\hat{P}^{gsl}$	Q^{spl}	P^c	$\frac{\hat{P}^{fc}}{\hat{P}^{gsl}}$
P^{rb}		.758 (2.737)	-.572 (2.066)	-.357 (-1.288)	-.263 (-.949)													
P^{car}	.884 --						-.439 --	.338 --										
P^{sl}						.925 --				-.091 --	.102 --							
Q^{dpl}													-.622 (-29.614)	.342 (16.29)				
Q^{spl}													.411 (3.841)	1.128 --	1.02 (9.537)			
Q^{sfed}								-.192 --								.956 --		
Q^{snfed}																	.424 (.920)	-1.25 (-2.71)

^aThe top number in each row represents the short run effects evaluated at the means of the variables. The long run effects are in parentheses where applicable and are calculated by dividing the short run coefficients by one minus the appropriate difference equation coefficient.

Neghassi's (1975) estimate of .86 and also their reported estimates from other studies. The long run price flexibility is considerably larger. A 10 percent increase in disposable income will increase retail beef prices by approximately 27 percent, after a period of time sufficiently long for consumers to completely adjust to a change in income.

A negative relationship exists between retail prices and fed beef consumption, indicating that a change in Q_t^{fed} represents a movement along the inverse demand or price curve. A 10 pound increase in the per capita consumption of fed beef is associated with a contemporaneous price decrease of 7.3 cents per pound.

Substitutes for fed beef are shifters of demand and should also have an inverse effect on price. For example, an increase in the consumption of a substitute for fed beef reduces the demand for fed beef, i.e. shifts the primary demand curve to the left, and causes the price of fed beef to decline. Nonfed beef is a close substitute for fed beef, and the model indicates that a 10 percent increase in nonfed beef consumption has a long term effect of decreasing the price of fed beef by approximately 13 percent. The short run price flexibility is $-.357$ which appears to be consistent with Langemeir and Thompson's (1967) estimate of .380 for the 1947-1963 period.

A variable representing the per capita consumption of imported beef was also tested and found to be insignificant in explaining

retail choice beef prices. One explanation for this result is that imported beef (which primarily consists of nonfed beef) accounts for only 6 to 8 percent of total beef consumption, and therefore does not significantly affect fed beef prices.

Two other substitutes for fed beef are pork and poultry. However, the t-values from regressions containing these two variables as separate regressors indicated that the variables were not significantly different from zero. Both were hypothesized to be significant in explaining retail beef prices based upon previous studies and knowledge of the meat market. One explanation for their poor statistical performance may be that multicollinearity existed between the two variables. Therefore, the two variables were added together to form a new variable Q_t^{pk+ply} . This new variable represents an aggregate substitute meat commodity for beef and was found to be significant at the 95 percent level. Its short- and long-term price flexibility coefficients are approximately one-half of those for nonfed beef.

The retail price function is estimated as a first-order non-stochastic difference equation, showing that under normal conditions, a one cent per pound increase in retail prices in year t leads to a .7 cents per pound increase in year $t+1$. Thus, past consumption habits appear to influence the retail price structure. Several types of serial correlation error structures were also tested and found to be insignificant.

The distributed lag effects of retail price with respect to an initial change in income, fed beef consumption and nonfed beef consumption are all characterized by a geometrically declining lag structure, the rate of decline being influenced by the size of the first-order nonstochastic difference term. It appears that all three display similar effects in that each distributed lag dissipates around the tenth time period.

Carcass Demand Sector

The carcass demand sector consists of two equations, the carcass-retail marketing margin equation and the carcass price equation. The former is used to generate the predicted values of the margin to be used in the latter equation. The statistical results for both of these equations are also contained in Table 1.

Carcass-Retail Marketing Margin Equation

This equation is estimated as a function of wages and packaging costs. The signs of each variable are a priori correct, e.g., the margin increases whenever processing costs increase. Thus, a one dollar increase in hourly wages cause the margin to increase by nearly 27 cents per pound. It is difficult to determine the precise impact of an increase in packaging costs on the margin since packaging costs are defined, in this case, by a price index. It is sufficient to say that the positive sign of the estimated coefficient suggests a direct

relationship between packaging costs and the margin.

Several alternative specifications of this equation were attempted using such variables as an index of transportation costs and trend. Each of these variables were insignificant (based on the t-values) and did not improve the statistical results of the equation. Likewise, experimentation with dynamic structural forms also yielded less satisfactory results. This is probably not too surprising given the ability of the carcass-retail marketing sector to adjust price and output levels within a given year.

The adjusted multiple R-squared statistic of .69 is quite low. The reasons for this relatively poor fit may be two-fold. First, the proper data necessary to estimate this equation was not available and may not be measurable with a high degree of accuracy. Many of the variables tested and found to be insignificant may possibly have been so because of collinearity problems. Second, it may be that some of the variation in the carcass-retail marketing spread cannot be explained statistically because of the imperfectly competitive market structure associated with this sector, i.e. non-price competition may be involved in the determination of the marketing margin.

Carcass Price Equation

The statistical results of this equation also indicated satisfactory performance. Carcass price is estimated as a function of retail

beef prices, the predicted carcass-retail marketing margin, and carcass by-product values. All signs of the coefficients are as a priori expected.

The price of retail beef is very significant in determining carcass prices. This result is not surprising since the demand price facing processors for carcasses is greatly influenced by the final sale price of the commodity. A 10 cent per pound increase in the price of retail beef will raise carcass prices by 4.2 cents per pound, with a short run price flexibility of .884.

Theoretically, an increase in marketing margins decreases derived demand. Given the same level of quantity, price should also decrease in response to an increase in the margin, which is reflected by the negative sign of the carcass-retail marketing margin coefficient. A one cent per pound increase in the margin reduces carcass prices by nearly .7 cents per pound. The price flexibility coefficient from Table 2 suggests that a 10 percent increase in the margin reduces carcass prices by 4.4 percent. Marsh's (1977) estimate of the price flexibility coefficient suggested that a 10 percent increase in the margin would reduce carcass prices by 3.0 percent.

Meat processors usually depend upon by-product values to cover their production costs and profit margins. At this level, the by-products which accrue to processors are those extracted from the

carcasses. The carcass by-product variable included in the equation indicates a positive relationship, that is, carcass prices are bid up when by-product values increase and vice versa. The relationship is significant, for example, a 10 percent increase in carcass by-product values will increase carcass prices by 3.4 percent.

Experimentation with dynamic specifications yielded equations with poorer results. The nature of the structure and market interactions at the carcass-retail level suggests that prices in previous periods probably do not affect contemporaneous prices. The processing sector of the market relies heavily upon formula pricing based on yellow sheet price quotations. Decisions as to bid and offer prices between processors and retailers may occur on a weekly and in some cases on a daily basis. Thus, given annual time periods, it is not surprising that distributed lag effects do not exist.

A final observation is that, as seen earlier, the fit of the carcass-retail marketing margin equation was low. Consequently, use of the predicted values of the margin from the reduced form equation would seemingly cause poorer statistical results (in the carcass price equation) compared to using the observed values. An alternative specification of the carcass price equation using the observed values for the margin variable is relegated to Appendix C. Comparisons of the two specifications indicate that the equation reported in this section is superior to the equation reported in the appendix, apparently

because of the existence of joint dependance in the latter specification.

Slaughter Demand Sector

This sector consists of two equations, the specification and methodology being very similar to those reported in the carcass demand sector. The first is the farm-to-carcass marketing margin equation. It is estimated in order to generate the predicted values of the dependent variable which are entered into the second equation, the slaughter price equation. The statistical results for both equations are reported in Table 3.

Farm-Carcass Marketing Margin Equation

The farm-carcass marketing margin is estimated as a function of wages and energy costs, the latter defined as a price index for refined oil products. The positive signs for both these variables conform to a priori expectations.

Wages comprise a large component of variable costs in meat packing plants. As expected, the margin increases as wages increase. The statistical results show that a one dollar increase in hourly wages would increase the margin by almost 11 cents per pound.

Likewise, increases in energy costs widen the margin. It is difficult to determine the exact marginal impact of energy used by the plants since a price index proxies these costs.

Table 3. Regression Results of the Slaughter Price, Feeder Placement Demand, and Farm-Carcass Marketing Margin Equations.^a

Equations	Variables										Statistics ^b				
	Intercept	P_t^{car}	$\hat{M}_t^{f-c}$	P_t^{fby}	$\hat{P}_t^{fc}$	P_{t-1}^{fc}	P_{t-2}^{fc}	$\frac{P_t^{sl}}{P_t^c}$	$E(Q_{t-1}^{dpl})$	W_t^{dp}	R_t	t	$\bar{R}^2$	S_y	D-W
P^{sl}	1.750 (1.371)	.577 (14.003)	-.426 (-3.977)	.417 (3.716)									.95722	5.26	1.589
Q^{dpl}	7280.3 (5.68)				-364.65 (-3.954)	-236.75 (-3.385)	100.4 (1.828) ^c	364.45 (7.343)	.979 (31.338)				.95177	718.37	2.305
M^{f-c}	-27.032 (-2.330)									10.928 (2.960)	.034 (4.170)	-.730 (-4.698)	.86390	.55	2.036

^aAll variables but one are significant at the 95 percent probability level; the appropriate t-ratios are in parentheses under each coefficient.

$\bar{R}^2$ = adjusted multiple R-squared statistic.

S_y = standard error of the estimate.

D-W = Durbin-Watson statistic.

^cSignificant at the 90 percent level.

A trend variable was found to be significant, and its inclusion improved the statistical results of the equation compared to alternative specifications. The sign of the trend coefficient is negative indicating there may be decreasing cost structural changes occurring in the packing industry. For example, the introductions of boxed beef and single-level "assembly line" processing of fat cattle during the sample period could have decreased slaughtering costs and increased processing efficiency.

Attempts to estimate the equation in a dynamic structural form yielded undesirable results. This result is not surprising given the nature of market behavior in the slaughtering industry.

Slaughter Price Equation

The final estimate of the slaughter price equation specifies the dependent variable as a function of carcass price, the predicted values of the farm-carcass marketing margin, and the value of farm by-product allowances. The statistical results regarding the adjusted R^2 , standard error of the estimate, and t-values are satisfactory. The signs of the estimated coefficients also conform to a priori expectations.

The price of carcasses is highly significant in explaining the variation in slaughter prices. The price flexibility coefficient specific to this variable indicates that a 10 percent increase in

carcass prices results in a 9.3 percent increase in slaughter prices. The high correlation reflects the economic fact that the sale price of carcasses dictates the bid prices packers offer for fat cattle. In fact, under formula pricing, many packers adjust the Yellow Sheet carcass price for slaughter costs (including profit) to arrive at a live cattle price.

The observed values of the price of carcasses are used and considered predetermined since they enter the equation recursively. The absence of a serially correlated error structure seems to support the use of this procedure.

The sign of the coefficient specific to the predicted farm-carcass marketing margin variable is negative, indicating that its increase results in a reduction of slaughter price. Normally an increase, *ceterus paribus*, in the margin would reduce derived demand thereby lowering price. The statistical results show that a one cent per pound increase in the margin will decrease slaughter price by slightly less than one-half cent per pound.

As mentioned earlier, meat packing plants depend upon by-product values to cover slaughtering costs and profit margins. The sign of the farm by-products variable, which represents by-product allowances specific to this marketing level, is positive. Thus, packers are able to bid higher prices for slaughter cattle as by-product values

increase. A once cent per pound increase in farm by-product values results in an increase in slaughter cattle prices of about .42 cents per pound.

Attempts to estimate this equation in a rational distributed lag framework produced poor results. Again, the static structural form of the equation would be expected given that packer pricing decisions are very short term in nature.

Appendix D presents the results of estimating the equation using the observed rather than the predicted values of the farm-carcass marketing margin. While the alternative equation initially appears statistically superior to the one presented in this section, it was not accepted due to the correlation between the endogenous variable M_t^{C-R} and the error structure. The trade-off to accept the slightly poorer statistical results nevertheless eliminates the problem created by joint dependence.

Feeder Placement Demand Sector

The placement of cattle on feed is estimated as a first-order nonstochastic difference equation. The independent variables are the contemporaneous price of feeder cattle, first and second order lags on the price of feeder cattle, and the contemporaneous slaughter steer-to-corn price ratio. The statistical results of the equation are reported in Table 3.

The contemporaneous price of feeder cattle is assumed to be endogenous, thus there exists the problem created by joint dependence. To alleviate this problem an instrumental variable is substituted for the endogenous variable. The instrument employed is the least squares predicted values of feeder cattle prices from a reduced form equation. This is essentially a two-stage least squares procedure which purges the equation of joint dependence. The results of the reduced form equation are summarized in Appendix E.

The short- and long-term effects of feeder cattle prices upon the quantity demanded of feeder cattle are negative, which meets the expectations of a demand function. The short-term price flexibility coefficient indicates that a 10 percent increase in the price of feeder cattle results in a 6.2 percent decrease in the quantity demanded of feeders. The long-term price flexibility coefficient is relatively large (29.6) because of cattle feeders ability to completely adjust to price changes over an extended period of time.

The distributed lag effect of the price variable reflects the long term behavior of cattle prices due to the cattle cycle; also, expectations of future prices are probably based on past price behavior. A higher order lag on the price of feeders was tested and found to be insignificant.

The contemporaneous steer-corn price ratio is used as a proxy for feedlot profitability, reflecting economic conditions in the slaughter market and cost of gain. The sign of this variable is positive, indicating a larger number of cattle are placed on feed when profits increase. The short-term price flexibility coefficient shows that a 10 percent increase in the ratio results in a 3.4 percent increase in the quantity demanded of feeder cattle. The response is large in the long run, indicating cattle feeders can adjust to changes in feedlot profitability by changing plant size and adopting new technology.

The first-order nonstochastic difference equation is stable with the coefficient on the lagged expectation variable being quite large (.979). This implies large long run price flexibility coefficients and a lengthy geometric lag, i.e. an initial change in one of the exogenous variables will cause the adjustment of the dependent variable to be distributed over many periods.

Feeder Placement Supply Sector

The statistical results of the feeder placement supply equation are summarized in Table 4. Feeder placement supply is estimated as a function of a binary shifter, feeder cattle inventory, the price of feeder cattle, the price of good grade slaughter cattle, and a first-order nonstochastic difference equation.

Table 4. Regression Results of the Feeder Placement Supply, Fed Slaughter Supply, and Nonfed Slaughter Supply Equations.^a

Equations	Variables											Statistics ^b			
	Intercept	D ¹⁹⁷⁴	INV _t ^{fc}	$\hat{P}_t^{gs1}$	E(Q _{t-1} ^{spl})	$\frac{\hat{P}_t^{fc}}{\hat{P}_{t-1}^{gs1}}$	Q _t ^{spl}	Q _{t-1} ^{spl}	P _t ^{cs1}	$\hat{P}_t^{fc}$	P _t ^c	E(Q _{t-1} ^{snfd})	$\bar{R}^2$	S _y	D-W
Q _t ^{spl}	13541.0 (4.779)	-3893.2 (-2.817)	.483 (3.817)	-923.11 (-5.451)	.893 (10.223)					324.53 (3.010)			.90615	1104.4	1.62
Q _t ^{snfd}	5636.8 (4.156)						.347 (5.580)	.637 (11.378)	-159.96 (-3.695)				.98910	421.59	2.21
Q _t ^{snfd}	15276.0 (4.518)	-1725.7 (1.819) ^c				-13000.0 (-5.979)					3851.7 (4.630)	.539 (11.870)	.95206	710.83	1.73

^aAll variables are significant at the 95 percent probability level except one; the appropriate t-ratios are in parentheses under each coefficient.

$\bar{R}^2$ = adjusted multiple R-squared statistic.

S_y = standard error of the estimate.

D-W = Durbin-Watson statistic.

^cSignificant at the 90 percent level.

A binary or dummy variable was included for the year 1974. The equation fit was significantly improved with its inclusion since the prediction error for 1974 was very large, and the effect of an "outlier" is frequently magnified in a dynamic specification. The specification of the dummy variable is based on the market irregularities that occurred during the 1973 - 1974 period, that is, the consumer beef boycott in 1973 and a strike by the commercial trucking industry in early 1974 combined with the Nixon price freeze on beef and its subsequent delayed removal.

The exact effects of these actions are difficult to determine but it appears their impacts were significant in reducing beef consumption and feeder cattle placements and subsequently, fed cattle slaughter. As a result, the price of feeder cattle decreased from 1973 to 1974 by approximately 35 percent, thus increasing the quantity supplied of young feeders to nonfed production. Indeed, the number of nonfed cattle slaughtered in 1974 increased by 67 percent from 1973, the negative coefficient of the dummy variable indicating the downward shift in the number of cattle supplied to feedlots. Since the nonstochastic difference equation implies distributed lags for all the independent variables, the dummy variable was excluded from the difference equation so that it maintained only a contemporaneous impact.

The January 1 inventory of feeder cattle is a measure of the physical limitation of the number of feeders which can be supplied to feedlots in a given year. The sign of the estimated coefficient indicates that, a priori, greater quantities of feeder cattle are supplied to feedlots when inventories increase. It is assumed that the inventory variable in the equation exhibits only a contemporaneous effect. Therefore it is excluded from the distributed lag effects of the difference equation. The short run elasticity of the quantity supplied of feeder cattle with respect to inventories suggests that a 10 percent increase in the latter will result in an 11 percent increase in the dependent variable.

Generally, a supply equation that uses quantity as the dependent variable includes its own price as an independent variable and the two are expected to be positively correlated. This is indeed the case in this equation. The price of feeder cattle is defined as endogenous in the maintained hypotheses. The same instrumental variable used in the placement demand equation for the price of feeders is also used in this equation in order to alleviate the problem created by joint dependence. The estimated coefficient for this variable indicates that a one dollar per hundred weight increase in the price of feeder cattle increases the quantity supplied of feeder cattle by 324 thousand head. The short run supply elasticity coefficient is .411 while the long run coefficient is 3.841.

The price of good grade slaughter cattle is also defined as endogenous in the maintained hypothesis. The least squares predicted values from a reduced form equation are used as an instrumental variable for the endogenous price variable. The results of this reduced form equation are summarized in Appendix E.

The sign of the estimated coefficient for the good grade slaughter cattle price variable is negative, which is consistent with theoretical reasoning. This indicates that a greater amount of feeder cattle circumvent feedlots and enter the marketing system as nonfed beef when the price of nonfed beef increases. A one dollar per hundredweight increase in good grade slaughter beef, other factors constant, decreases the quantity supplied of feeder cattle to feedlots by approximately 923 thousand head. The short run supply elasticity indicates that a 10 percent increase in good slaughter prices will result in a 10 percent decrease in the dependent variable.

The difference equation coefficient indicates that a one thousand head increase in placements in period t results in an 893 head increase in placements in period $t+1$.

The distributed lag effects of the quantity supplied of placements with respect to an initial change in either price variable are characterized by a geometrically declining lag structure. The relatively large size of the difference equation coefficient causes the adjustment process to be distributed over many periods.

Processing Supply Sector

The processing supply sector consists of two equations. The first is the fed beef slaughter supply equation, and the second is the nonfed beef slaughter supply equation. The statistical results for both equations are summarized in Table 4.

Fed Beef Slaughter Supply Equation

Fed beef slaughter supply is specified as a function of both contemporaneous and a first-order lag on the quantity supplied of feeder cattle, and the price of choice grade slaughter cattle. The signs of the estimated coefficients for the contemporaneous and lagged values satisfy a priori expectations. The positive signs indicate that increases in the quantity of recent placements of feeder cattle, other factors constant, will increase the number of fed cattle slaughtered.

The contemporaneous placement supply variable is considered predetermined because it enters the equation recursively from the feeder placement supply equation. The statistical results of the equation shows that a 1,000 head increase in the number of feeder cattle placements in time period t increases the number of fed cattle slaughtered by 347 head in the same period. It is recognized that all animals placed on feed, less death loss, will eventually be slaughtered. Most likely those animals placed on feed in the early portion of a given year will be slaughtered in that same year. Animals placed on

feed in the latter part of the year may not be slaughtered until the following year due to the time required to finish cattle. Therefore, the first-order lagged value of the placement variable is included, and according to its t -value (11.378) is highly significant. The estimated coefficient indicates that a 1,000 head increase in the quantity supplied of placements in the period $t-1$ results in a 637 head increase in the number of fed beef slaughtered in period t . The supply elasticity coefficient suggests that a 10 percent increase in the former variable results in a 9.5 percent increase in the dependent variable. Close examination of the estimated coefficients of this variable reveals that the sum of the net effects in t and $t-1$ is almost equal to one. This is expected since, as mentioned earlier, all animals placed on feed net of death loss are eventually slaughtered.

The equation is also estimated as a function of choice slaughter price. The quantity variables represent the technical forces which determine fed cattle slaughter while price represents an economic component. Most supply equations include the own price of the commodity in question as a principal regressor and its sign is a priori expected to be positive. However, price may perform a slightly different role in this equation since only a certain quantity of fat cattle will be slaughtered in a given year, even if the price of fat cattle increases dramatically. Thus, given the nature of fed beef production, price has important implications specific to the level

of production between annual time periods.

The price variable in this equation functions as a timing mechanism since fed beef can be slaughtered within a range of weights, usually between 900 and 1,250 pounds. The specific weight at which fed cattle are slaughtered may depend upon prices. When slaughter prices are high, prices in the future are also expected to be high, which causes feedlot operators to feed cattle to higher weights in an attempt to capture expected revenue gains. Myers, Havlicek, and Henderson (1970) refer to this phenomenon as "reservation demand." Obviously, feedlot operators are not able to feed their cattle to heavier weights for an indefinite period of time. Assume that a feedlot operator expects prices to rise over the next several months and therefore decides to feed cattle to heavier weights. If each of the animals already weigh 1,000 pounds, the marketing of those animals may be delayed for 2 or possibly 3 months at the most. Those animals would be slaughtered in the current year if the situation occurs before the last quarter of the year, and if this type of situation dominates, then the sign of the price variable should be positive. However, examination of quarterly fed beef slaughterings shows that the bulk of these slaughterings occur in the first and fourth quarters of the year.

The sign of the estimated coefficient for the price of slaughter steers variable is negative. This is because expected increases in the price of fat cattle in the fourth quarter of a given year and the

first quarter of a subsequent year results in cattle being fed to heavier weights and ultimately delays their slaughter from period t to period $t+1$. Results of beef slaughter supply equations by Tryfos (1974) and Reutlinger (1966) both support this hypothesis. The statistical results show that a one dollar per hundredweight increase in the price of slaughter steers reduces fed cattle slaughter by approximately 160 thousand head. The short-run supply elasticity coefficient indicates that a 10 percent increase in contemporaneous choice slaughter price decreases the quantity supplied of fed cattle in period t by 1.9 percent.

Estimating the equation as a difference equation yielded less satisfactory results as did attempts to specify various structures on the disturbance term.

Nonfed Beef Slaughter Supply Equation

Nonfed beef slaughter is estimated as a function of a binary shift variable, a ratio between the contemporaneous prices of feeder cattle and good grade slaughter cattle, the contemporaneous price of corn, and a first-order nonstochastic difference equation.

The specification of the 1974 dummy variable is for the same economic reason as given in the placement supply equation. Its sign is negative indicating nonfed slaughter was reduced in relation to what the equation would normally predict for that year because of the market

impact of consumer boycotts and truckers' strikes.

The equation was originally specified with the prices of feeder and slaughter cattle being independent of one another. However, estimation of that specification suggested that the estimated coefficient of the price of good slaughter cattle was not significantly different from zero. This result is not consistent with economic reasoning in that the quantity supplied of a commodity should be a function of its own price. It was hypothesized that the insignificance of the slaughter price variable may have been the result of the existence of a high degree of collinearity between it and the feeder price variable. Therefore, a ratio between the two variables was constructed in an attempt to eliminate the collinearity problem while employing the information contained in both variables. Since both variables are defined as endogenous, the least squares predicted values from the previously estimated reduced form equations are again used as instrumental variables.

As expected, the sign of the price ratio is negative indicating that an increase in the ratio, i.e. the price of feeder cattle increases relative to the price of slaughter cattle, results in a decrease of nonfed slaughter. More specifically, the estimated coefficient suggests that a one cent increase in the ratio increases nonfed slaughter by 130 thousand head. The long run supply elasticity indicates that a 10 percent increase in the ratio, *ceterus paribus*,

will decrease nonfed slaughter by 27 percent given a sufficient period of time for a complete adjustment to occur.

The price of corn is significant based on its t-value (4.63) and is positively correlated with the dependent variable. The estimated coefficient suggests that a 10 cent per bushel increase in the price of corn results in an increase in nonfed slaughter numbers of 395 thousand head. This would be expected since increases in feed prices reduces feedlot profitabilities and allows grassfed beef producers and meat packers to competitively bid against feedlot operators for feeder cattle. The short run supply elasticity coefficient indicates that a 10 percent increase in the price of corn results in a 4 percent increase in nonfed slaughter numbers, while the long run supply elasticity shows a 9.3 percent increase.

The lagged expectation of the dependent variable is also significant (t-value of 11.870) yet the estimated coefficient is relatively small (.539), indicating the distributed lag effects dampen quickly over time. In fact, the distributed lag effects of an initial change in either price variable dissipate around the sixth time period. This is probably not surprising given that decisions made to divert cattle to nonfed production would not carry over into long periods of time. The estimated coefficient indicates that a 1,000 head increase in nonfed slaughter numbers in year t leads to a 539 head increase in

year $t+1$.

The predicted values of the dependent variable were multiplied by the average dressed weights of nonfed slaughter cattle, yielding carcass weight production. These values were then divided by population to obtain the predicted values of per capita nonfed beef consumption used in the retail equation.¹²

One final observation concerns the forecasting capability of the model. This facet of the model would be enhanced if the January 1 inventory of feeder cattle in the primary supply (placement supply) equation could be accurately predicted. Therefore, a feeder cattle inventory equation was estimated and the statistical results are summarized in Appendix F.

¹²Technically, the predicted 1974 observation for nonfed beef consumption used in the retail price equation is jointly dependent with that equation's error structure. The dummy variable used in the nonfed beef supply equation resulted in the predicted value of the dependent variable being equal to its observed value. A solution to this problem would have been to omit all of the 1974 observations in the retail price equation by using a dummy variable. However, from an inspection of the residuals of the retail equation as it was specified earlier in this chapter, it was concluded that the year 1974 was not an extreme observation. Therefore, the benefit of using a dummy variable for 1974 in the retail price equation would probably have been minimal when compared to the costs of losing another degree of freedom.

Chapter 4

SUMMARY AND CONCLUSIONS

This study addressed the problems reflected in the interrelationships of the marketing levels in the U.S. beef industry. A dynamic econometric model utilizing rational distributed lags interfaced the demand price and supply structure of the producing, processing, and consuming sectors. A recursive system of equations was estimated and the marketing levels were linked by appropriate marketing margins. The estimated coefficients of each equation were then employed to calculate the short and long run price flexibility and supply elasticity coefficients. The long run effects were particularly useful in analyzing distributed lag patterns of the endogenous variables.

The retail beef price equation was estimated as a primary inverse demand relation. The equation was estimated as a function of consumers' disposable income and per capita meat consumption. All of the independent variables were considered predetermined with the exception of nonfed beef consumption. An instrumental variable rather than the observed values for nonfed beef consumption was incorporated in the equation in order to avoid the problems created by joint dependence. The equation was estimated as a first-order nonstochastic difference equation reflecting consumer habits and market rigidities.

The price of retail beef then entered the carcass price equation recursively and was treated as predetermined, along with carcass by-products. A carcass-retail marketing margin variable was also specified as an independent variable; its least squares predicted values from a carcass-retail marketing margin equation were used as an instrumental variable in order to alleviate problems created by joint dependence. The margin equation was estimated as a function of wages and packaging costs. Not surprisingly, dynamic structures appeared to be nonexistent in both equations.

Carcass price then recursively entered the slaughter price equation. Farm by-product allowances were also specified along with a farm-carcass marketing margin variable. The predicted values of a farm-carcass marketing margin equation were used as an instrumental variable in the slaughter price equation, after the former was estimated as a function of wages and energy costs. The fits of both equations were satisfactory and both appeared to be static in nature.

The demand for feeder placements was estimated as a first-order nonstochastic difference equation. The estimated coefficient of the difference equation was .979, which indicated that a lengthy time period was required to complete placement adjustments from changes in exogenous variables. The predicted values from a reduced form equation for contemporaneous feeder cattle price were used in this equation in what was essentially a two-stage least squares procedure.

That variable along with the first and second order lags on the price of feeder cattle were significant in explaining feeder demand, as was the contemporaneous steer-corn price ratio.

The supply of feeder placements was assumed to be the primary supply relation and was estimated as a function of feeder cattle inventory, the price of feeder cattle, the price of good grade slaughter steers, and a first-order nonstochastic difference equation. A dummy variable for the year 1974 was also included and found to be statistically significant because of market irregularities that occurred in 1973-74; specifically, a consumer beef boycott and a strike by the commercial trucking industry as well as the Nixon price freeze. The dummy and inventory variables were both excluded from distributed lag effects since it was assumed that they exhibited only contemporaneous impacts. Since both price variables were considered endogenous, reduced form equations were estimated for both and the least squares predicted values from those equations were used as instrumental variables in this supply equation.

The supply of feeder cattle placements then entered recursively into a fed slaughter supply equation along with the price of choice slaughter cattle. The latter also entered recursively from the slaughter price equation. The first order lagged value of the quantity of feeder cattle placements was also included in the specification. The sign of the estimated coefficient for the

slaughter price variable was negative, indicating that feedlot operators delay slaughter marketings when prices are rising in an attempt to capture expected revenue gains. This equation determines the quantity of fed beef supplied at the retail level via an identity.

A nonfed slaughter supply equation was estimated as a function of the contemporaneous ratio between feeder cattle prices and good grade slaughter cattle prices, the contemporaneous price of corn, and a first-order nonstochastic difference equation. Specification of a dummy variable for the year 1974 was included for the same reason as given in the placement supply equation. The bulk of nonfed slaughter is essentially comprised of breeding stock. The price ratio measures the relative values of the two products of breeding stock, i.e. feeder cattle if the breeding stock is not sold and nonfed slaughter cattle if the breeding stock is marketed. The price of corn impacts the supply of nonfed slaughter cattle both in terms of the competition between meat packers and cattle feeders for grass fed cattle and the opportunity costs of owning breeding stock. The nonfed slaughter supply equation along with average dressed weight determine the supply of nonfed beef at the retail level via an identity.

The estimated demand and supply elasticity and price flexibility coefficients of the model were calculated so that comparisons could be made between this model and other related works. It was felt that favorable comparisons would help to validate the results of the model.

Several of these comparisons were mentioned in Chapter 3. It was not possible to make comparisons for all the variables due to different methodologies and data used by other researchers. However, it was found that, where applicable, most of the estimates of these elasticities and flexibilities compared favorably with estimates in other studies.

Several inferences are readily apparent from this study. It is evident that certain behavioral equations are of a dynamic structure, where complete adjustments to changes in exogenous variables do not occur instantaneously but in fact are distributed over several time periods. Additionally, the recursive nature of the system suggests that attempts to statistically model the beef industry without interfacing all of the major marketing levels can result in serious shortcomings. Examples include interactions of processor formula pricing and retailer margins and the impact upon the slaughter and feeder markets.

The model indicates that consumer behavior is very important in determining demand prices for beef, since this sector has the final dollar vote, and subsequently market supplies of beef. Consequently, factors which affect consumer behavior and purchasing power (i.e. inflation and unemployment) will have significant impacts on the derived markets in the beef industry. In addition, changes in marketing margins or price spreads are crucial, since they have a

significant inverse effect on carcass, slaughter, and feeder prices.

The model presented in this thesis contains several limitations. First, certain variables such as pork and poultry consumption and corn prices were treated as predetermined. A more comprehensive model may be needed to treat the possibilities of joint dependency. Second, the estimation of a price equation for nonfed beef may have resulted in better economic and statistical information.

Carcass prices were estimated as the demand price relation at the meat processing level. However, currently much of the beef trade in the dressed meat market is in the form of boxed beef. Thus, information incorporating the economics of the boxed beef trade may more effectively describe behavior in the processing sector.

Also, the results of this study should be interpreted in view of the fact that perfect competition is probably not the actual market structure that characterizes the beef industry, particularly in the higher order markets. Regional market concentration exists in the beef processing and retail sectors, and formula pricing based on thin markets significantly describe institutional constraints to perfect competition. The encouraging point is, however, that regardless of the existence of short term anomalies in behavior, over the long term the consumer determines the levels of sales and prices.

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APPENDICES

Appendix Table A. Original Data Used for the Price, Demand, and Supply Equations.^a

OBS	Carcass Price	Feeder Price	Consumer Price Index	Per Capita Disposable Income	Corn Price	Feeder Cattle Inventory
1	.44200E+02	.26390E+02	.88700E+00	.19470E+04	.11000E+01	.38033E+05
2	.41340E+02	.25870E+02	.89600E+00	.19910E+04	.11100E+01	.39384E+05
3	.44830E+02	.27000E+02	.90600E+00	.20730E+04	.11900E+01	.41390E+05
4	.41130E+02	.25780E+02	.91700E+00	.21440E+04	.12000E+01	.44206E+05
5	.39480E+02	.21920E+02	.92900E+00	.22960E+04	.12600E+01	.46216E+05
6	.42510E+02	.26130E+02	.94500E+00	.23910E+04	.12700E+01	.48688E+05
7	.43040E+02	.27440E+02	.97200E+00	.25840E+04	.13600E+01	.49612E+05
8	.41200E+02	.26680E+02	.10000E+01	.27410E+04	.11200E+01	.49770E+05
9	.43820E+02	.27920E+02	.10420E+01	.29290E+04	.11700E+01	.50340E+05
10	.47740E+02	.31780E+02	.10980E+01	.31040E+04	.12500E+01	.50657E+05
11	.47350E+02	.33700E+02	.11630E+01	.33430E+04	.14400E+01	.52173E+05
12	.52670E+02	.34870E+02	.12130E+01	.35740E+04	.11800E+01	.52948E+05
13	.55670E+02	.41400E+02	.12530E+01	.37990E+04	.18200E+01	.55272E+05
14	.67830E+02	.53170E+02	.13310E+01	.42910E+04	.28600E+01	.56253E+05
15	.67770E+02	.37880E+02	.14770E+01	.46410E+04	.32300E+01	.59102E+05
16	.73180E+02	.33910E+02	.16120E+01	.50530E+04	.26900E+01	.59531E+05
17	.61000E+02	.39400E+02	.17050E+01	.55040E+04	.24500E+01	.59999E+05
18	.62190E+02	.40180E+02	.18150E+01	.60080E+04	.22600E+01	.58415E+05
19	.80430E+02	.58780E+02	.19540E+01	.66430E+04	.25400E+01	.55713E+05
20	.10162E+03	.83110E+02	.21740E+01	.73620E+04	.28100E+01	.51882E+05
21	.10444E+03	.75230E+02	.24860E+01	.81760E+04	.34900E+01	.51420E+05

^aObservations 1-21 represent years 1960-1980.

Appendix Table A. (cont'd)

OBS	Numbers of Nonfed Beef Slaughtering	Predicted Per Capita Consumption Nonfed Beef	Predicted Feeder Cattle Price	Predicted Good Slaughter Steer Price	Per Capita Consumption of Imported Nonfed Beef	Predicted Nonfed Slaughter Numbers
1	.11767E+05	.00000E+00	.00000E+00	.00000E+00	.42600E+01	-----
2	.11172E+05	.31810E+02	.00000E+00	.00000E+00	.57200E+01	.112142E+05
3	.10795E+05	.29240E+02	.30280E+02	.27270E+02	.78600E+01	.115770E+05
4	.10518E+05	.31420E+02	.26360E+02	.23450E+02	.90500E+01	.118964E+05
5	.12586E+05	.34390E+02	.24570E+02	.22800E+02	.63100E+01	.126501E+05
6	.13525E+05	.33690E+02	.25810E+02	.24460E+02	.50200E+01	.135089E+05
7	.13218E+05	.31560E+02	.28280E+02	.24460E+02	.62300E+01	.125554E+05
8	.11880E+05	.31640E+02	.27260E+02	.23280E+02	.68000E+01	.120545E+05
9	.11231E+05	.26900E+02	.25800E+02	.23620E+02	.77100E+01	.117093E+05
10	.10184E+05	.23930E+02	.29310E+02	.24850E+02	.82400E+01	.103532E+05
11	.93950E+04	.23180E+02	.29840E+02	.23760E+02	.91100E+01	.866312E+04
12	.95460E+04	.24700E+02	.27930E+02	.23820E+02	.86000E+01	.926837E+04
13	.81310E+04	.19060E+02	.33890E+02	.26920E+02	.96000E+01	.752605E+04
14	.76300E+04	.19240E+02	.38840E+02	.31290E+02	.97100E+01	.845492E+04
15	.12768E+05	.31970E+02	.25950E+02	.26370E+02	.78500E+01	.127680E+05
16	.19795E+05	.46710E+02	.21520E+02	.24610E+02	.84300E+01	.194370E+05
17	.17759E+05	.45080E+02	.21620E+02	.20200E+02	.94100E+01	.179148E+05
18	.16257E+05	.38460E+02	.23670E+02	.21450E+02	.91400E+01	.157842E+05
19	.12087E+05	.29590E+02	.29270E+02	.23840E+02	.10620E+02	.122738E+05
20	.83150E+04	.21920E+02	.38740E+02	.29140E+02	.11020E+02	.910262E+04
21	.99400E+04	.22340E+02	.29990E+02	.24900E+02	.93500E+01	.887200E+04

Appendix Table A. (cont'd)

OBS	Predicted Farm-Carcass Margin	Price of Farm By-product	Predicted Carcass-Retail Margin	Price of Carcass By-product	Good Slaughter Steer price	Numbers of Fed Beef Slaughtering
1	.92020E+01	.62000E+01	.24380E+02	.11000E+01	.23860E+02	.13457E+05
2	.84090E+01	.63000E+01	.24680E+02	.11000E+01	.22810E+02	.14463E+05
3	.78330E+01	.64000E+01	.23840E+02	.12000E+01	.24800E+02	.15288E+05
4	.72170E+01	.55000E+01	.23310E+02	.10000E+01	.22300E+02	.16714E+05
5	.69030E+01	.53000E+01	.24410E+02	.10000E+01	.20290E+02	.18233E+05
6	.65750E+01	.61000E+01	.24490E+02	.11000E+01	.22600E+02	.18822E+05
7	.61530E+01	.67000E+01	.24560E+02	.11000E+01	.24000E+02	.20509E+05
8	.59700E+01	.52000E+01	.24870E+02	.11000E+01	.23740E+02	.21989E+05
9	.58140E+01	.52000E+01	.26250E+02	.12000E+01	.24790E+02	.23795E+05
10	.52110E+01	.62000E+01	.25300E+02	.13000E+01	.27140E+02	.25053E+05
11	.53220E+01	.63000E+01	.25790E+02	.13000E+01	.27040E+02	.25630E+05
12	.48010E+01	.62000E+01	.26240E+02	.14000E+01	.29380E+02	.26039E+05
13	.56230E+01	.94000E+01	.29080E+02	.15000E+01	.33430E+02	.27648E+05
14	.47410E+01	.12600E+02	.29260E+02	.18000E+01	.42010E+02	.26057E+05
15	.53180E+01	.10100E+02	.31080E+02	.18000E+01	.38710E+02	.24044E+05
16	.48070E+01	.96000E+01	.31670E+02	.20000E+01	.39450E+02	.21116E+05
17	.49720E+01	.10400E+02	.32710E+02	.17000E+01	.35870E+02	.24895E+05
18	.44350E+01	.11800E+02	.32610E+02	.19000E+01	.36700E+02	.25599E+05
19	.41700E+01	.15000E+02	.33430E+02	.23000E+01	.47980E+02	.27465E+05
20	.42540E+01	.22600E+02	.31650E+02	.28000E+01	.62850E+02	.25363E+05
21	.46630E+01	.16900E+02	.29150E+02	.23000E+01	.62160E+02	.23867E+05

Appendix Table A. (cont'd)

OBS	Per Capita Poultry Consumption	Per Capita Pork Consumption	Per Capita Fed Beef Consumption	Choice Slaughter Steer Price	Retail Beef Price	Placements of Cattle on feed
1	.23400E+02	.64900E+02	.48510E+02	.26320E+02	.82440E+02	.13281E+05
2	.25900E+02	.62000E+02	.51480E+02	.24760E+02	.80640E+02	.14165E+05
3	.25800E+02	.63500E+02	.52430E+02	.27450E+02	.83940E+02	.15749E+05
4	.27100E+02	.65300E+02	.57890E+02	.24000E+02	.80740E+02	.16066E+05
5	.27700E+02	.65300E+02	.61490E+02	.23120E+02	.78740E+02	.17491E+05
6	.29600E+02	.56000E+02	.60580E+02	.26150E+02	.82030E+02	.18512E+05
7	.32000E+02	.57200E+02	.66530E+02	.26370E+02	.84400E+02	.20265E+05
8	.32400E+02	.63200E+02	.70230E+02	.26000E+02	.84630E+02	.21079E+05
9	.32800E+02	.65300E+02	.73100E+02	.27740E+02	.88650E+02	.23792E+05
10	.34800E+02	.64100E+02	.77550E+02	.29680E+02	.98600E+02	.24539E+05
11	.36900E+02	.72700E+02	.81290E+02	.29340E+02	.10165E+03	.24449E+05
12	.36700E+02	.79000E+02	.80450E+02	.32400E+02	.10810E+03	.26402E+05
13	.38400E+02	.71300E+02	.84470E+02	.35780E+02	.11865E+03	.27374E+05
14	.37400E+02	.63900E+02	.79790E+02	.44540E+02	.14208E+03	.24507E+05
15	.37500E+02	.69100E+02	.74520E+02	.41890E+02	.14630E+03	.19896E+05
16	.36900E+02	.56100E+02	.63200E+02	.44610E+02	.15485E+03	.23206E+05
17	.40400E+02	.59500E+02	.74480E+02	.39110E+02	.14820E+03	.23790E+05
18	.41700E+02	.61500E+02	.75870E+02	.40380E+02	.14785E+03	.25716E+05
19	.44700E+02	.61400E+02	.79690E+02	.52340E+02	.18188E+03	.26535E+05
20	.48500E+02	.70200E+02	.75920E+02	.67670E+02	.22629E+03	.23657E+05
21	.48100E+02	.75100E+02	.70690E+02	.67040E+02	.23763E+03	.22575E+05

Appendix Table B. Original Data Used For The Marketing Margin Equations.^a

OBS	Wages Meat Products	Wages Meat Packing Plants	Packaging Costs Index	Refined Oil Products Index	Actual Carcass-Retail Margin	Actual Farm-Carcass Margin
1	.24000E+01	.27000E+01	.95600E+02	.95500E+02	.18900E+02	.83000E+01
2	.24500E+01	.27200E+01	.95000E+02	.97200E+02	.21600E+02	.79000E+01
3	.24600E+01	.27700E+01	.94900E+02	.96100E+02	.19200E+02	.66000E+01
4	.24800E+01	.28200E+01	.95200E+02	.95100E+02	.24000E+02	.69000E+01
5	.25600E+01	.29100E+01	.95500E+02	.90700E+02	.24000E+02	.71000E+01
6	.26100E+01	.29900E+01	.96000E+02	.93800E+02	.22900E+02	.62000E+01
7	.26900E+01	.31000E+01	.99300E+02	.97400E+02	.24800E+02	.53000E+01
8	.28000E+01	.32600E+01	.10000E+03	.10000E+03	.24000E+02	.54000E+01
9	.29900E+01	.34500E+01	.10230E+03	.98100E+02	.24400E+02	.55000E+01
10	.31300E+01	.36600E+01	.10590E+03	.99600E+02	.28600E+02	.55000E+01
11	.33600E+01	.39800E+01	.10980E+03	.10110E+03	.31900E+02	.59000E+01
12	.35300E+01	.41700E+01	.11400E+03	.10680E+03	.30700E+02	.69000E+01
13	.37700E+01	.44900E+01	.11870E+03	.10890E+03	.36700E+02	.64000E+01
14	.39600E+01	.47100E+01	.13160E+03	.12870E+03	.41400E+02	.65000E+01
15	.43300E+01	.51500E+01	.16290E+03	.22340E+03	.46300E+02	.86000E+01
16	.47400E+01	.56100E+01	.18000E+03	.25750E+03	.46600E+02	.92000E+01
17	.50900E+01	.60600E+01	.18930E+03	.27660E+03	.56700E+02	.74000E+01
18	.54100E+01	.64400E+01	.20170E+03	.30810E+03	.54600E+02	.83000E+01
19	.59000E+01	.70500E+01	.21550E+03	.32100E+03	.62600E+02	.82000E+01
20	.63900E+01	.77300E+01	.24200E+03	.46480E+03	.75800E+02	.97000E+01
21	.69800E+01	.85000E+01	.28010E+03	.67440E+03	.82200E+02	.10400E+02

^aObservations 1-21 represent years 1960-1980.

Appendix Table C. Carcass Price Equation Using the Observed Values of the Carcass-Retail Marketing Margin.

	Intercept	P_t^{rb}	M_t^{c-r}	P_t^{cby}
Coefficients	6.871	.709	-.896	-.260
"t"-value	2.004	9.213	-8.411	-.631

Adjusted Multiple R-squared: .93114

Standard Error of the Estimate: 1.029

Durbin-Watson Statistic: 1.175

Appendix Table D. Slaughter Price Equation Using the Observed Value of the Farm-Carcass Marketing Margin.

	Intercept	p_{t}^{car}	M_{t}^{f-c}	p^{fby}
Coefficients	.969	.604	-.500	.359
"t"-value	1.007	18.211	-6.365	4.291

Adjusted Multiple R-squared: .97623

Standard Error of the Estimate: .392

Durbin-Watson Statistic: 1.811

Appendix Table E. Regression Results of the Feeder Price and Good Slaughter Price
Reduced Form Equations.^a

Variables ^b														Statistics ^c	
Equations	Intercept	Q_t^{pk+ply}	PK_t	W_t^{pp}	R_t	P_t^{fby}	P_t^c	P_{t-1}^{fc}	P_{t-2}^{fc}	INV_t^{fc}	Y_t	P_t^{cby}	$\bar{R}^2$	S_y	D-W
P^{fc}	60.84 (2.02)	-.23 (-1.75)	-.91 (-4.29)	34.0 (2.38)	.08 (2.55)	2.14 (4.90)	6.95 (1.98)	.34 (1.86)	-.35 (-1.99)	-.001 (-2.77)			.92951	1.29	3.34
P^{gs1}	32.84 (3.24)	-.09 (-1.95)	-.32 (-3.66)		.04 (2.97)	.93 (3.72)		.21 (3.08)	.05 (5.93)		.0007 (.66)	12.47 (3.82)	.91813	.75	2.95

^aIn a true two-stage least squares model, the least squares predicted values from the first stage are used as an instrumental variable in the second stage. The first stage regression uses all of the exogenous variables in the entire system. However, this was not possible for these two equations because of insufficient degrees of freedom. Therefore, the exogenous variables were chosen based on their respective t-values and prior knowledge of the industry.

^bThe appropriate t-values are in parentheses under each coefficient.

$\bar{R}^2$ = adjusted multiple R-squared statistics.

S_y = standard error of the estimate

D-W = Durbin Watson statistic.

Appendix Table F. Regression Results of the January 1 Inventory of Feeder Cattle Equation.

	Intercept	P_{t-1}^{fc}	P_{t-2}^{fc}	P_{t-3}^{fc}	$\frac{P_{t-1}^{csl}}{P_{t-1}^c}$	$E(INV_{t-1}^{fc})$	$E(INV_{t-2}^{fc})$	e_{t-1}^a
coefficients	-4274.2	-81.40	91.80	80.00	201.54	1.626	-.673	-.88
"t-value"	-12.382	-3.260	2.741	3.202	13.81	30.68	-14.37	-7.83

Adjusted Multiple R-squared: .99371

Standard Error of the Estimate: 332.90

Durbin-Watson Statistic: 2.947

^aFirst-order autoregressive error term.

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