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AN ANALYSIS OF ECONOMIC RELATIONSHIPS IN THE U.S. BEEF INDUSTRY WITH EMPHASIS ON POLICY EVALUATION

by

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FORWARD

This report is based on the senior author's Master of Science thesis and reflects an in-depth investigation of the United States beef industry. The econometric model specified and estimated in this report stands alone as a comprehensive quantitative representation of the major behavioral components of that very important agricultural industry. In addition, the beef model is linked to the other commodity models maintained by the Food and Agricultural Policy Research Institute (FAPRI). The retail demand equations in the beef, pork, and broiler models include interacting variables. Similarly, crop production is linked to the beef model through crop prices (feed costs) and grain and protein consuming animal units (feed demand).

The model is used as a framework for anticipating and quantifying the effects of exogenous shocks (e.g., policy changes, macroeconomic changes) on the system and for explaining past behavior by the major players (producers, feedlots, packers, retailers, consumers) of the beef sector.

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SUMMARY

Since the middle 1970s, the U.S. beef industry has experienced a significant decline in beef cattle numbers. More changes are likely to occur. These changes and their impacts will directly influence all segments of the industry: cow-calf producers, cattle feeders, meat packers and processors, wholesale distributors, retailers, and institutional trade. Changes at one end of the marketing spectrum or the other will generate opportunities/consequences for all other segments.

The primary objectives of this study were twofold. The first objective was to develop a theoretical and empirical model that adequately captures the structure and behavior of the beef industry. The second objective was to analyze the impacts of changes in government policy and shifting consumer demand on the beef industry.

This study formulates a dynamic econometric model of the U.S. beef sector based on theoretical considerations of the firm and the consumer. The behavioral components of the model consist of grower production and demand facing growers for live animals, demand facing packers/retailers for beef products, and consumer demand for beef. Seventeen behavioral equations and nine technical relationships and identities constituted the model which was estimated via three-stage least squares regression over the period 1965 to 1987. Both in-sample and out-of-sample measures of performance were used to evaluate the structural integrity of the model and the overall goodness of fit. The performance of the econometric model developed in this research indicates that it is a useful instrument for evaluating the changes that would occur in the beef industry in response to changes in exogenous factors.

Impact multipliers were developed to quantify the short and long run effects of changes in exogenous variables (e.g., income, inflation, feed costs) on the endogenous variables (e.g., beef production, animal numbers, prices) in the system. Further, alternative scenarios were simulated using the parameter estimates of the econometric model in order to assess the impacts of changes in policy parameters (e.g., dairy termination program) or of shifting demand on the beef industry. The simulation results show that stabilizing beef demand should remain a high priority for the beef industry if it expects to stop the decline in the size of the United States beef industry during the decade of the 1990s. Government policy that allows crop prices (feed costs) to fall is beneficial to the beef industry while policy aimed at reducing the breeding herd in the dairy industry will be beneficial to the beef industry in the long run.

Estimation Results

Special attention was focused on the supply side of the beef model in order to capture behavioral relationships that occur during the cow-calf and backgrounding phases of production. Backgrounding, which reflects an important decision point in the production process, is often a missing component in econometric models of the beef industry.

The most significant of the estimation results of the model can be summarized as follows:

1. The coefficients associated with investment/disinvestment decision by the cow-calf producer, reflected in the heifers retained for breeding equation and the cow slaughter equation, are relatively inelastic with respect to feeder calf price and comparable to the results of previous studies. The response to feed costs at the cow-calf level was considerably less than that reported elsewhere.

2. Backgrounding of calves before placement in feedlots is explained by the available supply of animals and a feeder steer input price to the production process.

3. Because of the complexity and multiple stages of beef production, it is not surprising to find that naive or adaptive price expectations approaches performed about as well as a rational expectations approach in the supply response relationships.

4. Packer demand for fed cattle is inflexible in price dependent form but this result is modified somewhat by the retail beef price transmission coefficient.

5. Per capita demand for beef estimation was improved with the inclusion of a stochastic trend component which likely accounts for some of the structural changes in beef demand thought to be occurring over the analysis period. Retail beef demand is inelastic with respect to price (-0.66) and income (0.59). Pork and chicken were found to be important substitutes for beef.

The overall performance of each of the estimated equations was quite good. Each of the key equations in the model had an R-squared greater than .90 with the exception of the beef stocks equation. Performance statistics for the in-sample and out-of-sample dynamic and static simulations were reported. With the exception of non-fed steer and heifer slaughter, all of the endogenous variables had percent root mean square errors of 13 percent or less. The results showed that quantity variables contained smaller errors than the price variables. The dynamic and static in-sample simulations performance was nearly identical, lending credibility to the lagged structure defined in the model.

The response of the model to the shocks of exogenous variables showed that a 10 percent increase in per capita income caused prices at all levels of the marketing channel to increase more than 10 percent in the short run. In the long run, prices increase over 2 percent and supply increased by nearly 4 percent.

Model Applications with Alternative Policies

The beef model estimated and validated in this study provides a tool that can be used to evaluate the effects of alternative agricultural policies on the beef industry. With this approach, one can simulate how an industry would have reacted to different economic conditions or predict how it may react to potential future policy proposals or macroeconomic shocks. As such, the model can be used as a planning tool for future investment decisions.

Because several behavioral equations contain a considerable amount of unexplained error, it should be recognized that the model may not predict year to year variation in prices and quantities with great accuracy. However, the soundness of the structural model is believed to be good enough to allow several "what-if" type questions to be asked and the resulting simulations to be compared and evaluated.

Two policies implemented in recent years include the Food Security Act of 1985 (FSA85) and the Dairy Termination Program. Neither was directly related to the beef industry yet each has had significant short and long term effects on beef. FSA85 was designed to move U.S. crop production toward a more market-oriented environment, to reduce surplus crop stocks, and to make U.S. crop prices more competitive in international markets. A consequence of this policy was a sharp and sustained drop in crop prices which was largely beneficial to beef producers. The beef herd was shown to be larger than what would have occurred with a continuation of previous farm policy (the 1981 Farm Bill).

Evaluation of the Dairy Termination Program (DTP) shows that the beef industry was hurt by lower prices in the short run as the increased meat from the dairy sector entered the market. However, in the longer run, the beef industry enjoyed higher prices at all levels of the marketing channel as a smaller dairy cow herd generated fewer animals that flowed into the beef industry. Although the beef industry strongly opposes another DTP, the industry could benefit from this policy in the long run, particularly if there were no incentive for those dairy producers still in production to increase their dairy cow herds after the program was completed.

Based on investigating the impacts of several exogenous shocks, it appears that the beef industry is much more sensitive to macroeconomic changes such as income and inflation than to agriculturally-related shocks such as feed costs. Thus, growth in the economy without excessive inflation can lead to gains in the beef industry. Related to this is the need to stem the decline in beef demand. Stabilizing beef demand remains a high priority for the beef industry. The beef industry should continue to recognize declining demand for beef as a serious problem that needs to be addressed to halt the shrinking beef industry. If beef demand can be stabilized during the decade of the 1990s, the decline in the size of the United States beef industry will cease.

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1. INTRODUCTION

From 1960 to the mid 1970s, beef production increased 70 percent and per capita consumption increased from 63 pounds (retail weight) to more than 90 pounds. During the 1950s cash receipts from the sale of cattle and calves averaged about $6 billion annually or less than 20 percent of total cash farm receipts in the U.S. By 1972, cash receipts had grown to more than $18 billion or almost 30 percent of total cash farm receipts. Also in that year, consumers spent slightly more than $100 per capita on beef or about 2.7 percent of their disposable income.

Since the middle 1970s, the U.S. beef industry has shrunk. For the first time in many decades, the peak in the most recent beef cattle cycle (1979-89) was less than the previous peak (figure 1). By 1990, per capita consumption had fallen to 67 pounds, domestic beef production was less than 23 billion pounds. Per capita real expenditures and the percent of disposable income spent on beef have fallen over the past two decades.

Opinions vary regarding the reasons for the downsizing in the beef industry. Competitive price pressure from other meats, particularly chicken, over the past two and one-half decades has resulted in substantial substitution away from beef. Health and dietary concerns has also been suggested as an important factor causing consumers to reexamine their purchasing patterns of beef products (McNaughton, et al.). On the supply side, efficiency gains in production by both the broiler and the pork industries relative to beef have resulted in further losses in market share of the meat industry.

Regardless of the reasons, evidence exists to suggest that major structural changes have been occurring in the U.S. beef industry. That these changes are occurring and that they appear to be largely detrimental to the beef industry has caused beef producers to take a careful look at their industry. A recent study (Johnson, et al.) commissioned by the National Cattleman's Association concluded that lowering costs of beef production is among the most important steps the industry can take to regain market share. This view does not appear to be fully endorsed

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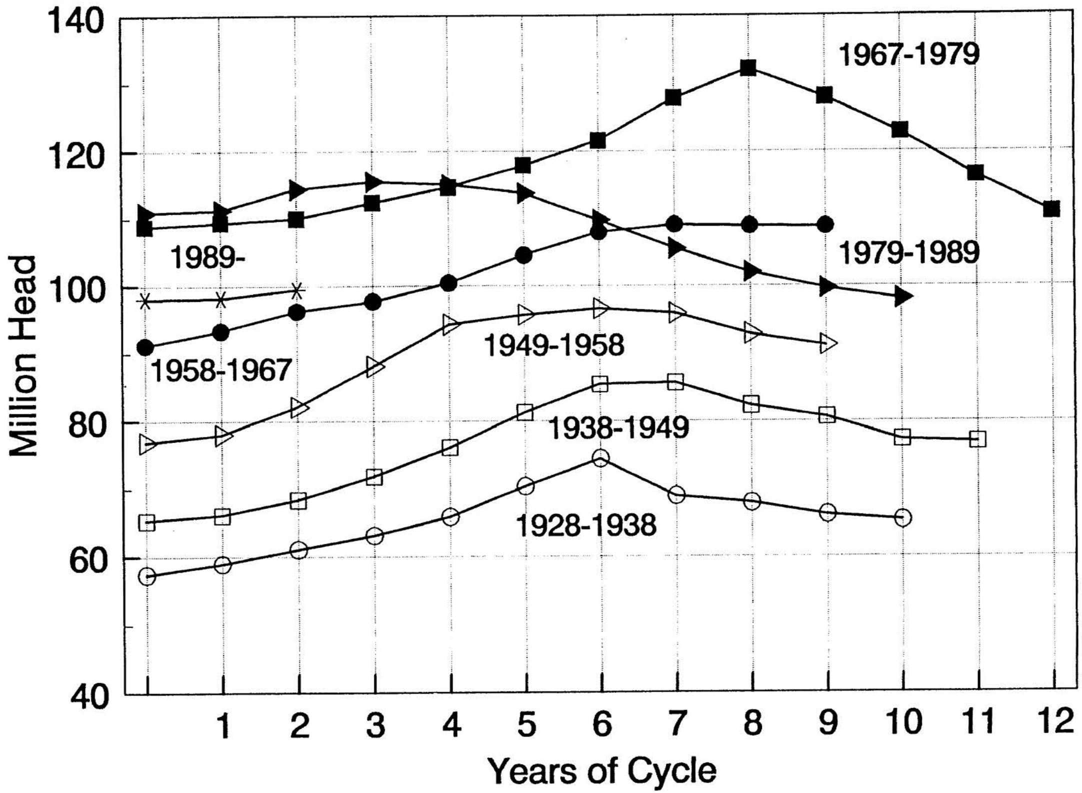


FIGURE 1. CATTLE AND CALVES, BY CYCLE, U.S., JANUARY 1

by other economists who have investigated the industry. Purcell believes economists have failed to recognize shifts in the structure of beef demand and were not as helpful as they might have been to generate information that could have been useful in guiding the industry through the painful adjustments that were occurring.

More changes will occur. These changes and their impacts will directly influence all segments of the industry: cow-calf producers, cattle feeders, meat packers and processors, wholesale distributors, retailers, and institutional trade. Changes at one end of the marketing spectrum or the other will generate opportunities/consequences for all other segments. In order to trace these activities and their economic implications through the production/marketing channel, a comprehensive economic model is developed which attempts to incorporate the major structural components and decision points of the U.S. beef industry. This development proceeds in three stages. First, a theoretical model which hypothesizes about the economic relationships required to model the industry is specified. In the development of the beef model, special attention is focused on the supply side of the model in order to provide more insight into the investment/disinvestment decisions and other behavioral relationships which occur. In particular, biological and alternative price expectation relationships in the production process are considered.

The second stage involves the empirical estimation of the parameters of the hypothesized relationships. The results are tested and evaluated for their reasonableness and are compared with alternative behavioral hypotheses. Expanded development of the model at this stage was somewhat constrained by data inadequacies and by the similar movement of several data series over time which prevented the sorting out of individual influences.

Stage three involved the application of the model through simulation analysis to investigate and evaluate the effects of several exogenous shocks to the system. These shocks were represented by policy changes and by shifting retail demand.

Section 2 of the report briefly describes the structure of the beef industry from producer to packer/retailer to consumer. In Section 3, the behavioral relationships which capture the decision making processes at all levels are specified. Literature germane to this development is reviewed and evaluated. Section 4 contains the empirical estimates of the model with discussion of individual structural equation performance as well as overall performance of the entire system. Section 5 focuses on the alternative scenarios simulated with the model and provides an interpretation of the exogenous variable impacts.

2. STRUCTURE OF THE INDUSTRY

The beef industry is very complex. Numerous decisions take place from before the time a calf is born until the final product reaches the consumer. As a result, a comprehensive econometric model of this industry becomes quite complex. A simplified flow diagram of the United States beef industry is shown in figure 2. This diagram attempts to replicate the flow of product through the market channel from the cow-calf producer to the ultimate consumer of the beef product. While this diagram cannot replicate all of the decisions occurring within the industry, the major behavioral relationships are represented.

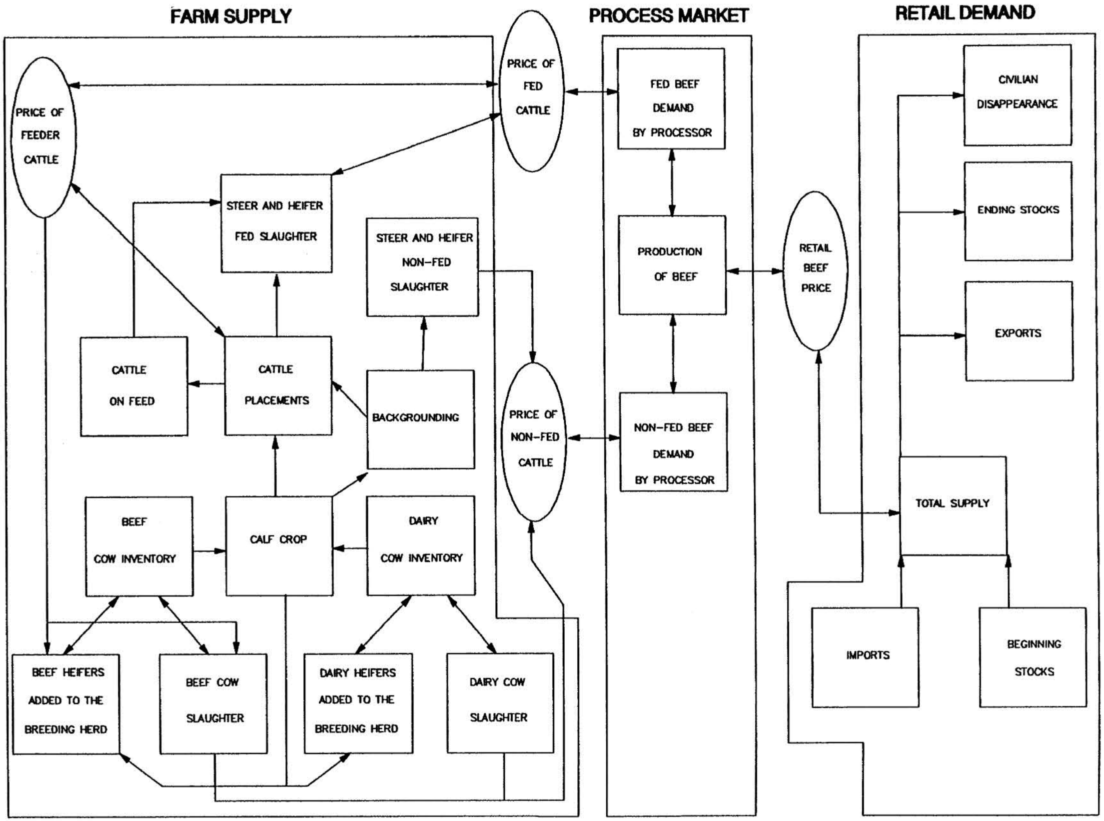


FIGURE 2. U.S. BEEF FLOW DIAGRAM

The beef industry is unique in the time it takes to alter production in response to changing market signals. Although the flow diagram in figure 2 shows the various paths that animals can take, it does not associate any time frame with the different routes. Two important factors differentiate the production of other meats (particularly pork and chicken). These are associated with the biological production lag (the amount of time needed to alter production) and the offspring per breeding animal per period. Figure 3 shows that it can take over two years for beef to reach the consumer's table from the time the cow-calf operator decides to produce. A decision by the cow-calf operator to expand the breeding herd can delay ultimate availability of meat to the consumer for more than four years.

This process is considerably longer than that of pork or chicken. Both of these industries, particularly chicken, can respond much more quickly to shocks on the system resulting from either supply or demand influences. As a result, both are more likely to shift production more rapidly than beef in response to favorable and unfavorable market situations.

The second factor reflects the reproduction rate of the breeding herd of an industry. For beef, less than one calf per cow per year is raised. A large inventory of breeding cows is necessary to produce enough calves which, after the growing phase, will ultimately reach the consumer in the form of beef. In contrast, 14 to 16 pigs per year can be expected from a female hog and substantially more broilers (young chicken) are born as a result of one breeder in a typical poultry flock. This causes the beef breeding herd to be a much higher percentage of the total inventory of animals than is either the pork breeding herd or poultry breeding flock.

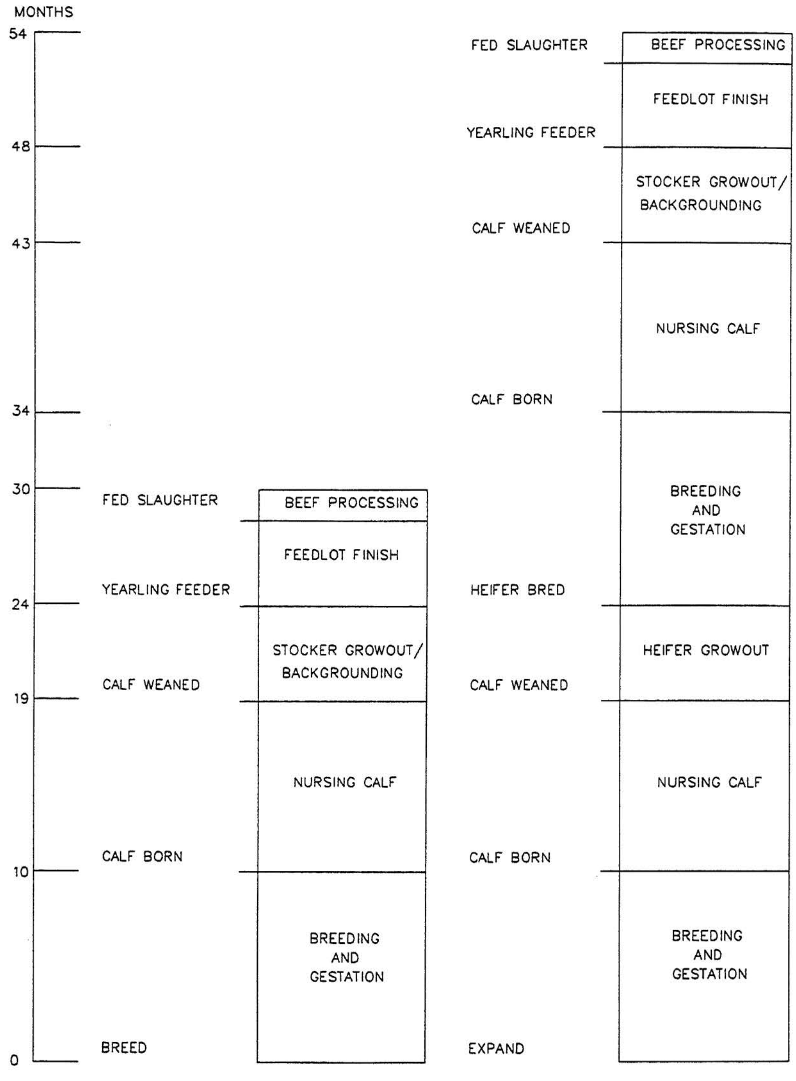
The many decisions that take place along the marketing channel from producer to consumer illustrate the complexity of the beef industry. The biological lags that are associated with some of the different decisions adds further intricacy to the model. The following sections will investigate each of the decisions that are made in the marketing channel. The decisions made by cow-calf producers on the level of the breeding herd will receive priority in this development.

Cow-Calf Level

Focusing on the farm supply portion of the flow diagram, it shows that the calf crop is determined by both beef and dairy cow herd sizes. The decision by the cow-calf producer to expand or contract the breeding herd determines the number of new animals produced during a given time frame. This decision involves determining the number of replacement heifers to add to the breeding herd along with the number of cull cows in the breeding herd to be slaughtered. Figure 2 illustrates that calves can move to the placement of cattle on feed, the backgrounding of cattle, or the retention of heifers in the breeding herd.

Beef cow numbers increased during the late 1960s and early 1970s reaching a peak in 1975 of 46 million head (Appendix A contains the data highlighted in this section). Since 1975, beef cow numbers have fallen almost every year until they reached 33 million head in 1989. The level in 1989 is nearly equal to the number of beef cows in 1965 yet beef production is 4.5 billion pounds greater in 1989 than in 1965. Productivity, measured in the terms of pounds of meat per beef cow, in the beef industry has increased significantly over this time period. Part

FIGURE 3. BEEF PRODUCTION SCHEDULE



Source: Adapted from Gilliam, p. 5.

of this productivity is associated with the increasing reproductive rate of beef cows over time. In 1965, .86 calves were born per cow while by 1989 that figure had increased to .92 calves per cow.

Feedlot Level

Cattle in the feedlot are fed on a full ration of grain to finish them to slaughter weight. Feedlot operators place animals on feed based in part on the price of feeder cattle, an input price, and the price of fed cattle, the output price, as well as other input costs. Steer and heifer fed slaughter follows from the cattle on feed at the beginning of the period plus those placed on feed during the period.

Some cattle are backgrounded in order to allow them to "grow"; that is, to allow their frame size to increase and/or allow them to add weight inexpensively. This growth process takes place by leaving cattle on pasture so that instead of increasing weight by developing muscle through a grain ration, these animals increase their weight largely by the growth of their structure. This growth process will allow for faster gain if and when they are put in the feedlot. Cattle that have been backgrounded can be placed on feed or slaughtered as non-fed animals. The reader is alerted to the fact that the backgrounding phase of beef production is included in this model (both theoretically and empirically) because of the link it provides between the cow-calf stage and the feedlot stage for a substantial number of cattle. This phase in the production process is important not only from an economic decision point of view but also from the perspective of accounting for animal numbers in the model.

The number, size, and location of feedlots has changed significantly over the last three decades. Cattle feeding has moved from the cornbelt states (Illinois, Iowa) to become more concentrated in the Plains states (Nebraska, Texas, Oklahoma, Kansas, Colorado). During this period the average size of feedlots has increased as well. In 1965, only five feedlots existed with a capacity of 32 thousand head or more in the 13 major cattle feeding states while by 1989 the number of feedlots with a capacity of 32 thousand head or more grew to 79 (U.S. Department of Agriculture, Cattle on Feed, 1966, 1991). While the number of large commercial feedlots increased, feedlots with a capacity of under one thousand head declined from 162.5 thousand in 1965 to 45.2 thousand in 1989. Associated with the increase in the number of larger feedlots, feedlots with a capacity of over 32 thousand head marketed 30 percent of all fed cattle in 1989 versus only 3 percent in 1965 while feedlots with a capacity under one thousand head marketing only 16 percent of all fed cattle in 1989 compared with over 50 percent in 1965.

Packer Level

The major components of the process market are fed beef demand and non-fed beef demand. The interaction between packers' demand for and feedlot producers' supply of fed steers and heifers determines the price of fed cattle. Similarly, the interaction between packers' demand for and beef producers' supply of non-fed steers and heifers and cows determines the price for non-fed cattle. In the process market, packers process the slaughtered animals into pounds of meat given the input prices discussed previously and the output price, the retail beef price.

It should be noted at this point that the "non-fed beef" and "fed beef" prices do not actually exist but that they are used here to differentiate between perceived differences in meat quality associated with both the age of the animal and the amount of grain used to finish the animal. By definition, beef that receives a USDA grade of Select or above is considered fed beef while that beef that grades below good is considered non-fed beef. Empirically, this will be clarified in a subsequent section.

The location of beef slaughter facilities has generally moved to the Plains states where a majority of the production takes place. Concentration within the beef packing industry has also occurred over the last 30 years. In 1972, the volume slaughtered by the top four meat packing firms was 29 percent while by 1990 it had increased to 69 percent (Crom, Missouri Farm News Service).

The packing industry became highly automated during the past three decades as technologies were developed and used that allowed the packing industry to become more efficient. Another major change that has occurred is the form in which beef is shipped to wholesalers and retailers. Boxed beef, the carcass cut into primal and sub-primal cuts, has become the preferred method of shipping meat to wholesalers and retailers instead of shipping the entire carcass.

Retail Level

In the retail portion of the flow diagram, total supply which includes imports and beginning stocks interacts with consumer demand, exports, and ending stocks to determine the retail price of beef. Supplies of and demands for competing products such as pork or chicken are also important factors affecting consumer demand for beef.

Beef consumption increased during the 1960s and early 1970s reaching a peak in 1976 of 94 pounds per person on a retail weight basis. Since then per capita beef consumption has generally declined. Over this same time period, pork per capita consumption has remained relatively stable while broiler per capita consumption has increased by over 40 pounds. The changes that have occurred in the meat bundle purchased by consumers can be attributed in part to changing tastes and preferences. Over the last three decades, consumers have become more health conscious and have reduced their intake of red meats.

Shifting demand for beef can be seen in figure 4 which shows that demand increased during the 1960s and early 1970s, remained fairly stable during the rest of the 1970s, and has shifted inward during the 1980s. This decline in demand for beef that has occurred during the 1980s has resulted in a much smaller beef industry and lower consumer prices (relative to the 1970s.)

3. THEORETICAL FRAMEWORK OF THE MODEL

This section develops a theoretical model of the structure of the beef industry from the time a calf is born until a product reaches the consumer. Included in this development are sections which specify the behavioral relationships that exist in the marketing channel of the beef industry (e.g., cow-calf, feedlot, and packer). Although all of the structural relationships are examined, emphasis is placed on the investment and disinvestment decisions that take place at the cow-calf level.

It should be recognized that this model or a comprehensive model of any industry cannot fully account for all of the decisions of the participants or the factors affecting those decisions. However, in this analysis, an attempt is made to identify through theory and quantify empirically the important variables that are thought to influence behavior. As such, the economic model is designed to emulate to the extent possible these key behavioral and technical relationships which cause changes to occur or decisions to be made during the production, marketing, processing, distribution, and consumption of beef. The degree of success accomplished in this process will influence the model's ability to explain changes that have occurred structurally or anticipate or predict the effects of changes that might occur in the future.

In order to analyze the effects of different exogenous factors (e.g., changes in government policy) on an industry, it is necessary to design a theoretical model that adequately captures the entire structure of the industry and then translates that theory into an estimable model that can measure these effects quantitatively. With few exceptions (e.g., Arzac and Wilkinson, Bedinger and Bobst, Folwell and Shapouri, Stillman), beef models focus only on a small portion or segment of the entire beef industry. This leaves them unable to fully analyze the industry-wide impacts of changes in exogenous factors or to trace through the effects of changes (endogenous or exogenous) in one stage of the production/market channel on other stages.

Cow-Calf Level

Because of the beef herd's low reproduction rate and long growing phases, economic incentives causing cow-calf operators to increase the breeding herd can reduce the near-term available supply of cattle for slaughter due to greater heifer retention and lower cow slaughter. The implication is that in the short-run an inverse supply response relationship could exist between output price and beef production. This seemingly contradictory empirical refutation of economic theory has caused much discussion in the literature regarding the "correct" sign of beef production with respect to output price.

Reutlinger was among the first to recognize that an inverse relationship could exist in the short-run because of the way different slaughter classes (cows, heifers, and steers) react to a change in the output price. Through theoretical derivation of supply equations for the individual classes, he was able to draw economically justifiable conclusions on the correct signs for the different classes. In fact, he showed that slaughter response for cows would be negative for an increase in output price. Others (Bessler and Brandt, Ospina and Shumway (1980, 1983), Nelson and Spreen) have reached similar conclusions regarding the short-run response of beef production to cattle price changes. The short-run was defined in an annual context by the above authors except for Bessler and Brandt who used quarterly data.

Given that the size of the beef breeding herd ultimately determines production, it becomes essential in an econometric model to capture changes in the level of the breeding herd. Reutlinger's development of the cow slaughter and heifer retention components recognized the

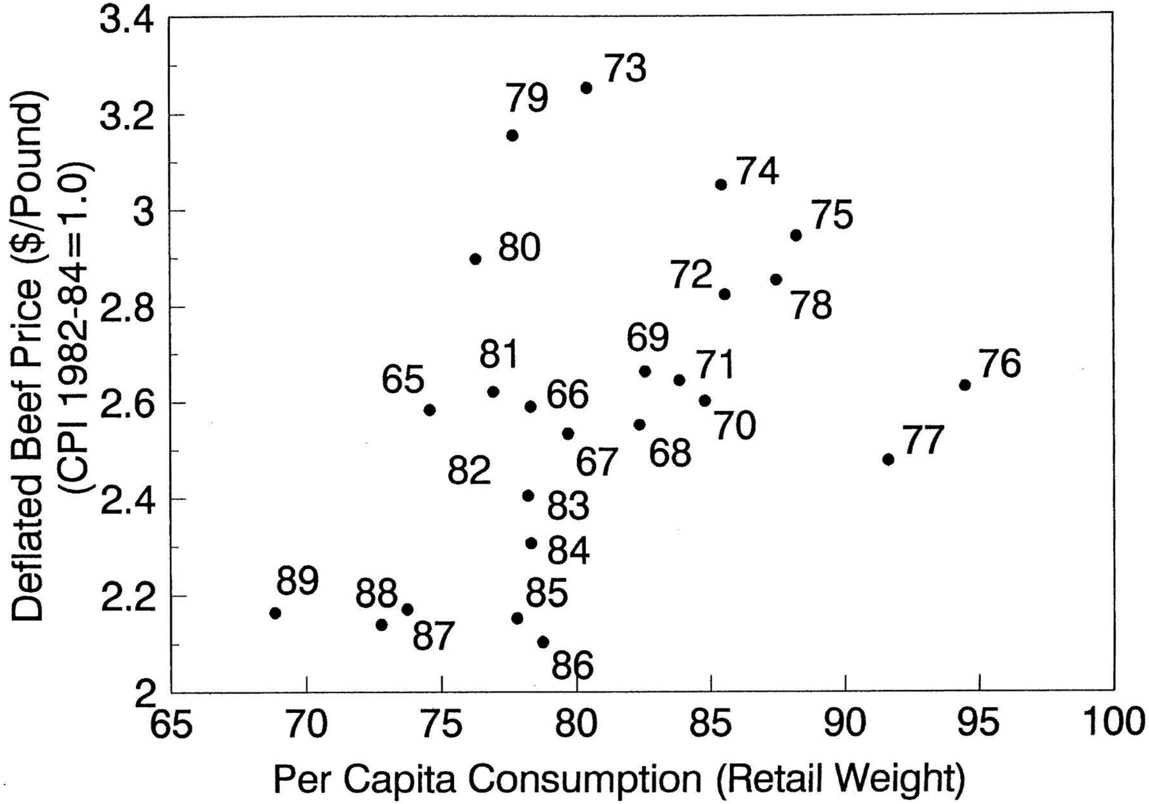


FIGURE 4. BEEF DEMAND

dual purpose of these animals. That is, they can be sold for slaughter or retained in the breeding herd by cow-calf producers for future production. Reutlinger's theoretical specification of those response equations contained output-to-input price expectation ratios to capture the economic incentive to change the breeding herd. Beginning cow inventory was included to reflect the "normal" culling rate as well as differences between desired inventory and actual inventory.

Capital formation theory has been developed to explain the investment or disinvestment in durable equipment. However, the application of capital formation theory to the beef cow herd has been slow to develop, leaving the changes that have occurred over time in the size of the beef cow herd partially unexplained.

Jarvis expanded upon the idea of the breeding herd being a capital good when he developed an econometric model of the Argentine cattle industry. He posited that there were two types of demand, producer and consumer, for the supply of animals. As long as producers were willing to outbid consumers (represented by packers and feedlot operators' derived demands), animals stayed in the herd but as soon as the consumers outbid producers, the animals would be slaughtered.

Jarvis developed a micro model of cow-calf production to determine the optimal slaughter age for cows as well as the optimal input stream to be used. The equation contained three terms: the present value of the expected calf revenue stream over the age of the cow, the present value of the cow at slaughter, and the present value of the input costs necessary to maintain the cow and her offspring over her life span. Jarvis showed that female animals have a bimodal slaughter age since more are born than can be used for breeding. Some become fattened and slaughtered at a younger age while others do enter the breeding herd and are not slaughtered until their breeding value declines. Jarvis showed that the short run response to an increase in output price would be negative for both cow slaughter and heifer slaughter. However, he pointed out that this is a partial equilibrium response and that expected output price plays the key role in determining slaughter response.

These studies formed the benchmark for much of the literature relating to livestock supply response. As asset theory was developed, economists applied it towards designing more appropriate inventory models of the livestock sectors. Perrin developed asset replacement criteria when production occurs with certainty. Since Perrin's discrete time criterion fits cow-calf production, much of the literature has used it as the starting point from which to build the theoretical model. The derivative of the present value of the stream of earnings with respect to age gives the marginal criterion for the optimal replacement age in a discrete time context. The marginal criterion states that replacement should occur when next period's net revenue plus the change in market value of the current asset is equal to the net present value of the stream of replacements.

Perrin's replacement policy was adapted by Bentley, Waters, and Shumway in order to account for the uncertainty of production of the asset due to stochastic elements. The stochastic elements incorporated were cow death loss, calving percentage, and the calf weaning weights. Following Burt's methodology, these stochastic elements were incorporated into the calculation of the net present value of the stream of replacement cows.

Although the criterion had been developed to determine the optimal culling age, most of the applications have used constant price expectations in determining the optimal age. In addition, the criterion did not allow for a non-constant herd size. That is, every deletion had a replacement. Bentley and Shumway developed a model that allowed for a non-constant herd size as well as looking at alternative price expectation schemes. The model attempted to maximize the present value of net revenue for a representative firm over a rolling time horizon given the different price schemes. They found under a cyclical price scheme that cyclical culling of cows and adding of heifers took place. One drawback with the study was that no specific culling or replacement criterion was established for each animal. Instead, it was inferred that the optimal replacement and culling strategies took place by the maximization of the firm's discounted net returns.

Plain and Williams expanded Bentley and Shumway's approach in the pork industry by setting up specific criteria on which to judge the merits of each animal. This approach assured that optimal culling and addition rules were followed instead of inferring that optimal decisions were made by the maximization of the producer's discounted net revenue. The culling criterion required that culling takes place whenever the current salvage value of the sow was greater than the net present value of her next litter plus her next period's salvage value. The addition criterion required that a gilt was added to the breeding herd if the net present value of her next four (arbitrarily chosen) litters and subsequent salvage value was greater than her current market value.

Over time, assumptions made in earlier models were relaxed in order to better capture the replacement decision. Trapp included non-constant herd size, non-constant prices and costs, a flexible planning horizon, and the incorporation of risk. If a producer looked only one period ahead or for that matter any arbitrary fixed time period (like Plain and Williams), he would not likely make the optimal choice of culling age. Trapp considered an infinite time period in order to determine the optimal culling age which maximized discounted expected returns.

Trapp's linkage between current investment and future investment was somewhat different than Perrin's. Each animal was considered on its own merit so that culling of one animal does not always mean investment in another. The linkage occurred through the cost structure of the individual firm. Since a portion of the firm's costs were fixed, changes in the herd size caused average total costs to change. Eventually, expansion of the firm drove up per unit cost of production. Current investment affected future costs which affected future investment. Trapp's development of optimal beef breeding herd management set forth the most refined theory as it related to the replacement or culling of an individual animal at the firm level.

More recently, Rosen presented a conceptual model to isolate the intertemporal substitution effect implied by optimal herd management. He determined that both rational expectations and appropriately formulated recursive (cobweb) models could explain the substitution effects. Rosen relates the backgrounding supply response to market conditions that vary with transitory versus permanent supply and demand shocks.

Cow-Calf Specification

Associated with the culling and replacement decisions for the firm are the aggregate beef cow slaughter and beef heifers bred decisions. Beef cow slaughter represents disinvestment from the beef cow herd. The theoretical specification for aggregate beef cow slaughter (similar to Trapp's firm development) is:

$$1) \quad TBCOWSL_t = \sum_{i=1}^{n} BCOWSL_t(i) = f\left(BCOW\#_t(i),\ DERET_t(i),\ \frac{COW\$_t(i)}{PPI_t}\right)$$

with $BCOWSL_t(i)$ representing beef cows slaughtered of calving age i in period t and n being the oldest age group of cows in the herd. (The reader is referred to table 1 for a list of definitions of other endogenous and exogenous variables.) Also note that any discussion relating to the age of the cow relates to her calving age (i.e., the number of calving periods) and not her physical age.

The variable which reflects beef cows in the herd at the beginning of each period of each age group is included to determine some "average" culling that takes place. The remaining two variables included in this specification attempt to modify the culling rate in response to current and expected economic signals. The utility cow price is included to reflect changes in the current market (salvage) value of the beef cow which is posited to have a positive relationship with beef cow slaughter. The last variable, $DERET_t(i)$, is the discounted expected returns from keeping a beef cow of age i in the herd. The assumption is made that the cost structure does not vary across firms so that aggregation across firms can occur. The importance of analyzing beef cow slaughter for each age group occurs in the calculation of discounted expected returns since calving rate, calf weaning weight, and cow loss depend on the age of the cow. The appropriate proxy for expected prices in calculating discounted expected returns will be developed in a following section.

Beef heifers bred reflects the opposite effect of beef cow slaughter since it represents a capital investment (rather than disinvestment) in the breeding herd. This specification is:

$$2) \quad BHEIFBRD_t = f\,(DERET_t(0),\ HEVAL_t,\ BCOW\#_t).$$

The specification for beef heifers bred is nearly identical to that for beef cow slaughter. BCOW# is included to account for the number of beef heifers needed to offset the "performance" culling of beef cows (Reutlinger). Due to the significant fixed cost of land in cow-calf production, the cow-calf operator must keep his herd size at some reasonable level to avoid average total costs per cow that are unacceptably high. The economic comparison in this equation is the tradeoff between selling the heifer today ($HEVAL_t$) and the discounted expected returns from breeding the heifer and keeping her in the herd until her optimal culling age ($DERET_t(0)$).

The following identities which link beef cow slaughter and beef heifers bred to the number of beef cows of each age group in the herd at the beginning of the period are:

TABLE 1. BEEF MODEL VARIABLE DEFINITION LIST

Endogenous Variables

$ANONGR_t$ = Animals on grass at the beginning of period t.

$BACK_t$ = Cattle backgrounded in period t.

$BCONS_t$ = Domestic beef consumption in period t.

$BCOW\#_t(i)$ = Beef cows in the herd of calving age i at the beginning of t.

$BHEIFBRD_t$ = Beef heifers bred in period t.

$BPERCAP_t$ = Per capita beef consumption in period t.

$BPROD_t$ = Beef production in period t.

$BRET\$_t$ = Beef retail price in period t.

$BSTOCK_t$ = Beef beginning stocks in period t.

$BSUPP_t$ = Beef supply in period t.

$CALDD_t$ = Calf death loss in period t.

$CALFCRP_t$ = Calves born in period t.

$CATDD_t$ = Cattle death loss excluding calves and cows in period t.

$CATNFSL_t$ = Total non-fed cattle slaughter in period t.

$CATOFD_t$ = Cattle on feed at the beginning of period t.

$CATOFRMS_t$ = All cattle on farms at the beginning of period t.

$CATPL_t$ = Cattle placements in period t.

$CCREPT_t$ = Cow-calf operation receipts per unit in year t.

$CCEXP_t$ = Cow-calf operation expenses per unit in year t.

$COW\$_t(i)$ = Price of a cow i years old in period t.

$FDEXP_t$ = Feed costs per 100 pounds of gain in the feedlot in year t.

$KCS\$_t$ = Kansas City 600-700# steer price in period t.

$S\&H\$_t$ = Omaha 9-1100# steer price in period t.

$SAHFDSL_t$ = Steer and heifer fed slaughter in period t.

$SAHNFSL_t$ = Steer and heifer non-fed slaughter in period t.

$TBCOWSL_t$ = Total beef cow slaughter in period t.

$TSCALF_t$ = Total supply of calves in period t.

TABLE 1. BEEF MODEL VARIABLE DEFINITION LIST (continued)

Exogenous Variables

$BEXPRT_t$ = Beef exports in period t.

$BIMPRT_t$ = Beef imports in period t.

$BULL\#_t$ = Bulls in beef herd at beginning of t.

$BULLSL_t$ = Bull beef slaughter in period t.

$CALFSL_t$ = Calf slaughter in period t.

$CATBAL_t$ = A USDA reported number of cattle required to balance cattle on farms.

$CATEX_t$ = Live cattle exports in period t.

$CATIM_t$ = Live cattle imports in period t.

$CATLOSS_t$ = Death loss of cattle on feed in period t.

CPI_t = Consumer price index in period t.

$CRET\$_t$ = Broiler retail price in period t.

$DCOW\#_t(i)$ = Dairy cows in the herd of age i at the beginning of t.

$DD\%_t(i)$ = Percentage death loss of beef cows of age i in period t.

$DHEIFBRD_t$ = Dairy heifers bred in period t.

$DERET_t(i)$ = Discounted expected deflated returns of a cow of calving age i in t.

$EFEDRET_t$ = Expected deflated feedlot returns in period t.

$ESGRET_t$ = Expected deflated stocker-grower returns in time t.

$F\&UI_t$ = Fuel and utilities index in period t.

HEVAL = Deflated market value of heifers in period t.

$INCOME_t$ = Consumer income in period t.

$INTRAT_t$ = Interest rate in period t.

POP_t = Civilian population in period t.

PPI_t = Producer price index in period t.

$PRET\$_t$ = Pork retail price in period t.

$TDCOWSL_t$ = Total dairy cow slaughter in period t.

W_t = Spring weather conditions in period t.

$WAG\$_t$ = Wage rate in the packing industry in period t.

$$
\begin{aligned}
&BCOW\#_t(1) = BHEIFBRD_{t-2} * (1-DD\%_t(0)) \\
&BCOW\#_t(2) = BCOW\#_{t-1}(1) * (1-DD\%_t(1)) - BCOWSL_{t-1}(1) \\
3)\quad &\vdots \\
&BCOW\#_t(n) = BCOW\#_{t-1}(n-1) * (1-DD\%_t(n-1)) - BCOWSL_{t-1}(n-1)
\end{aligned}
$$

where n is the oldest calving age group of beef cows. Beef cows in the herd at the beginning of period t that are one calving years old are the number of heifers that calved last period (or those bred two periods ago) adjusted by the percentage of beef heifers that died. While the beef cows that are greater than one year old ($BCOW\#_t(n)$) are calculated as the number of beef cows at the beginning of last period that were one year younger ($BCOW\#_{t-1}(n-1)$) modified by the death loss of that younger age category less the beef cows of that age group that were slaughtered last period ($BCOWSL_{t-1}(n-1)$.

The number of calves born (CALFCRP) follows from the breeding herd. The specification is:

$$
4)\quad CALFCRP_t = f\left(\sum_{i=0}^{n} BCOW\#_t(i),\ \sum_{i=0}^{n} DCOW\#_t(i),\ TBCOWSL_t,\ TDCOWSL_t\right)
$$

This equation determines the offspring produced from the dairy and beef breeding herds. The age distribution of the cow herds still remains important in this specification since the calving rate changes with the age of the cow. Dairy cows are also included in this specification since they also produce calves which ultimately are slaughtered. Following Yager, Greer, and Burt's argument that it is optimal for producers to hold open cows into the following year before slaughter, beef and dairy cow slaughter was included in the equation to capture this effect.

Following the flow of calves after they are born leads to calf death loss:

$$
5)\quad CALDD_t = f\ (CALFCRP_t,\ W_t)
$$

The coefficient associated with the calf crop variable in the equation captures the average calf death loss while W_t, a weather variable that measures temperature and precipitation over the December through May period when approximately 90 percent of calves are born (Boykin, Gilliam, and Gustafson), modifies average death loss for differing weather conditions over the calving period.

Similar to calf death loss, cattle death loss excluding calves and cows is specified as a function of the available pool of animals that could die. The specification is:

$$
6)\quad CATDD_t = f\ (CATOFRMS_t - BCOW\#_t - DCOW\#_t).
$$

This equation will estimate the average death loss percentage that occurs from this category.

The following identities close the cow-calf phase of the model and reflect the supply of cattle on farms at the beginning of the period (equation 7), the number of cattle on grass (equation 8), and the availability of calves for feeding or backgrounding (equation 9):

$$\begin{aligned} 7)\quad CATOFRMS_t = {} & CATOFRMS_{t-1} + CALFCRP_{t-1} + CATIM_{t-1} \\ & - SAHFDSL_{t-1} - SAHNFSL_{t-1} - TBCOWSL_{t-1} \\ & - TDCOWSL_{t-1} - CALFSL_{t-1} - CALDD_{t-1} - CATDD_{t-1} - CATEX_t. \end{aligned}$$

$$8)\quad ANONGR_t = CATOFRMS_t - BCOW\#_t - DCOW\#_t - CATOFD_t$$

$$9)\quad TSCALF_t = ANONGR_t + CALFCRP_t - CALFSL_t - CALDD_t$$

The "FARM" quadrant of figure 5 graphically summarizes the nine equation cow-calf phase of the model. The arrows associated with the variable shifters in each equation reflect the theoretically expected direction of influence on the dependent variable.

Feedlot, Non-Fed, and Packer Levels

Feedlot Specification

The supply of calves from the cow-calf producer interacts with the different demands for those animals. Feedlot, heifer replacement, and backgrounding demands constitute the total demand for the available supply of calves. Just as expected returns were important in the decisions affecting the breeding herd, they are also a primary factor influencing the derived demand for the animals in the feedlot, for backgrounding, or as replacements.

Feeder animals placed in feedlots consume grain until they are slaughtered. The costs of the animal and feed ration are known at the time the decision is made to place the animal on feed. However, the output price to be received at the time the animal is slaughtered is uncertain. Feedlot producers must therefore form some expectation of the output price. The formulation of price expectations will be discussed in detail in the empirical estimation of this report.

The specification of the derived demand for placement is:

$$10)\quad CATPL_t = f\,(CATOFD_t,\ EFEDRET_t).$$

Cattle on feed at the beginning of the period is included to capture the capacity constraint of feedlots within the year.

The backgrounding demand for calves specification will follow closely the derived demand for placements. The theoretical specification for this derived demand is:

$$11)\quad BACK_t = f\,(BACK_{t-1},\ ESGRET_t).$$

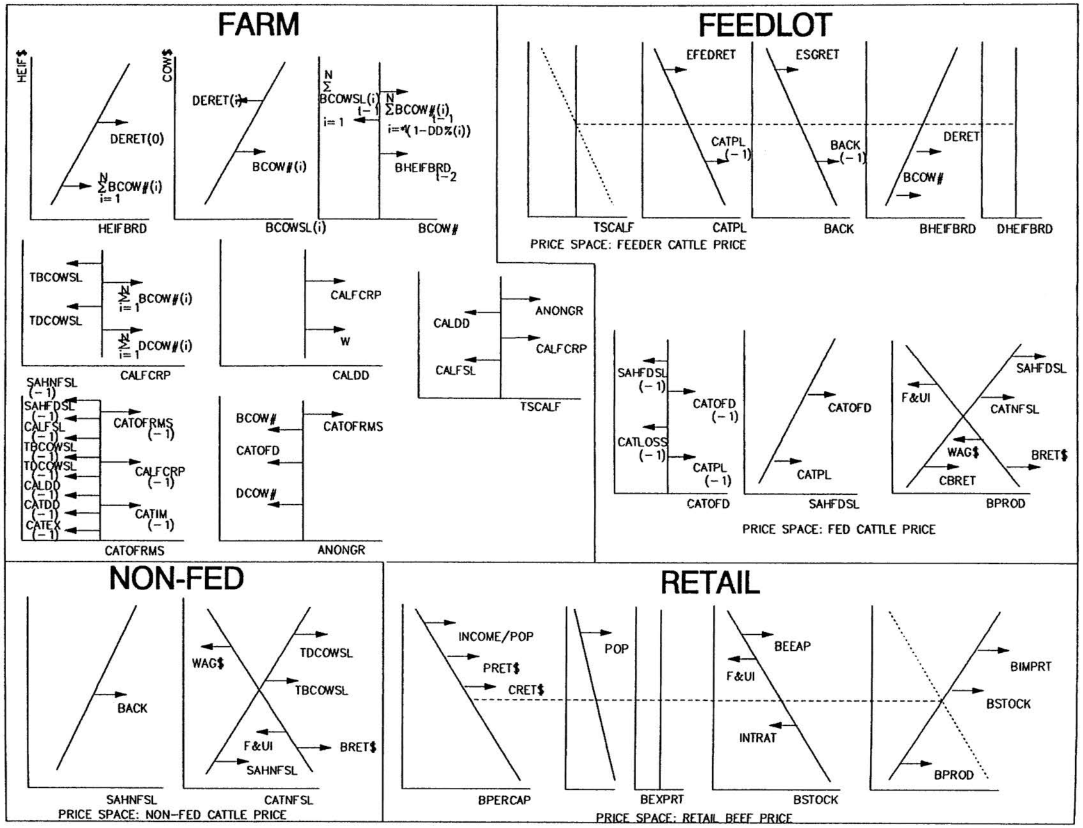


FIGURE 5. BEEF MODEL

Lagged backgrounding is included in this specification also to capture the partial adjustment process since there is the significant fixed cost of land to background these animals. Expected stocker-grower returns was included to capture increases (decreases) in the quantity backgrounded as returns increase (decrease).

Replacement breeding herd demand for calves was developed previously (equation 2). An identity ties the total supply of calves to the derived demands for those animals.

12) $$TSCALF_t = CATPL_t + BACK_t + BHEIFBRD_t + DHEIFBRD_t$$

The upper row of graphs in the "FEEDLOT" quadrant of figure 5 shows the relationships between the supply of and demand for calves.

Within the feedlot sector, the specification for steer and heifer fed slaughter follows from the placement of cattle on feed during the period and from those cattle on feed at the beginning of the period. The specification is:

13) $$SAHFDSL_t = f\,(CATOFD_t,\ CATPL_t).$$

The identify that tracks cattle on feed is:

14) $$CATOFD_t = CATOFD_{t-1} - SAHFDSL_{t-1} + CATPL_{t-1} - CATLOSS_{t-1}.$$

Cattle on feed at the beginning of the period equates to cattle on feed at the beginning of last period less steers and heifers that were slaughtered from those cattle that were on feed plus cattle that were placed on feed during last period less cattle that died while in the feedlot.

Non-Fed Specification

The non-fed sector contains those animals that have not been fed a full ration of grain and would not grade choice (or higher). These include non-fed steers and heifers as well as cull beef and dairy breeding herd animals. The identity that gives the total supply of non-fed animals is:

15) $$CATNFSL_t = TBCOWSL_t + TDCOWSL_t + SAHNFSL_t.$$

Beef cow slaughter (TBCOWSL) has been specified previously. Dairy cow slaughter (TDCOWSL) is exogenous to the model. The only part of non-fed supply that has not been considered yet is steer and heifer non-fed slaughter. The specification of this supply equation is:

16) $$SAHNFSL_t = f\left(BACK_t,\ \frac{COW\$_t}{PPI_t}\right).$$

The number of animals backgrounded is the available pool from which non-fed steer and heifer slaughter can occur while the non-fed (utility cow) price is included to capture the changes in the number slaughtered as non-fed animals in response to changes in the non-fed cattle price (Non-Fed quadrant of figure 5).

Packer Specification

The beef packer derived demand for these non-fed animals is given by:

$$17) \qquad CATNFSL_t = f\left(\frac{CATNF\$_t}{PPI_t}, \frac{BRET\$_t}{PPI_t}, \frac{F\&UI_t}{PPI_t}, \frac{WAG\$_t}{PPI_t}\right).$$

A wage rate and a fuel and utilities index are included to reflect changes in the packer's operating costs while the retail beef price is the output price and the non-fed cattle price is the major input price. The lower row of graphs in the "Feedlot" quadrant and the Non-Fed quadrant of figure 5 depict the fed and non-fed slaughter components of the beef model.

The next step in the vertical flow of the beef model is to convert the slaughtered animals into pounds of meat. This specification takes the form of:

$$18) \qquad BPROD_t = f\left(SAHFDSL_t, CATNFSL_t, \frac{S\&H\$_t}{PPI_t}\right).$$

The coefficients associated with the fed and non-fed animals slaughtered will give an average slaughter weight for each category. Current returns are included to capture the effect of feeding animals to various weights in response to changing short term economic conditions (Jarvis), although in an annual model, this latter effect may be difficult to capture.

The derived demand for animal slaughter comes from the packer. This specification is very similar to the non-fed derived demand and includes the packer's input price, output price, and those factors which affect the margin. The form of the equation is (see "BPROD" graph in Figure 5):

$$19) \qquad BPROD_t = f\left(\frac{S\&H\$_t}{PPI_t}, \frac{BRET\$_t}{PPI_t}, \frac{F\&UI_t}{PPI_t}, \frac{WAG\$_t}{PPI_t}\right).$$

An identity sums current beef production with stocks and imports to create available supply:

$$20) \qquad BSUPP_t = BPROD_t + BIMPRT_t + BSTOCK_{t-1}.$$

Retail Level

Consumer theory provides a means to determine the quantity of a good the consumer will purchase given the prices of all goods and a budget constraint. If preferences satisfy certain properties, there exists a utility function that represents the preference ordering. Maximization of the utility function subject to the budget constraint leads to ordinary demand functions. In addition to these traditional factors believed to influence the demand for beef, other causes include advertising, government intervention, new products, health and diet information and changing lifestyles. Many studies have been conducted over the past two decades regarding the demand for beef. Smallwood, Haidacher, and Blaylock provide an excellent review of more than 60 articles which have addressed these issues as well as a comparison of empirical results to date (and their shortcomings). They provide a list of reasons for the diversity of results. They summarize the literature as pointing to changing demand parameters for beef (and poultry but not pork). The authors are critical of previous research for failing to examine the reasons for structural change or for addressing the issue of just how much structural change has occurred. Wohlgenant (1982), who hypothesizes that quality changes in meat products as a major cause of parameter change, is an exception.

Declining demand for beef due to a decrease in the relative price of a substitute (say poultry) would have substantially different implications to the beef industry than shifts due to changing consumer lifestyles. Research dollars spent on productivity gains could help to address the former whereas advertising dollars spent to influence (educate) consumers could address the latter issue. Purcell has been critical of economists for failing to identify reasons for the shifts and to measure their effects. Chavas (1989) offers additional insights on the structure of meat demand but does not provide methods for measuring demand shifts. (For a comprehensive dialogue of meat demand, the reader is encouraged to review Buse.)

If tastes have not remained constant (for whatever reason), the traditional demand relation must be refashioned to account for the change in consumer tastes. This involves finding exogenous variable(s) that explain the change in consumers' tastes. Brown and Schrader developed a cholesterol index to explain changes in consumers' tastes for eggs. This data series is highly correlated with trend; however, it does attempt to account for new information which may influence consumer preferences. Similar exogenous variable(s) must be developed for beef to capture the changes in consumers tastes towards beef. The empirical section will investigate alternative exogenous variables that could account for changes in consumer demand for beef.

The retail sector in the U.S. beef industry requires two behavioral equations: retail demand and the demand to hold stocks. Following consumer theory, the retail demand for beef is specified as a function of own price, prices of substitutes (pork and chicken), and consumer income. The specification of this equation is:

$$21)\qquad BPERCAP_t = f\left(\frac{BRET\$_t}{CPI_t}, \frac{PRET\$_t}{CPI_t}, \frac{CRET\$_t}{CPI_t}, \frac{INCOME_t\,/POP_t}{CPI_t}\right).$$

The demand to hold stocks is specified as:

$$22)\qquad BSTOCK_t = f\left(BPROD_t, \frac{BRET\$_t}{CPI_t}, \frac{F\&UI_t}{CPI_t}, \frac{INTRAT_t}{CPI_t}\right).$$

It is hypothesized that a portion of production is held in stocks, modified by the changes in costs associated with holding those stocks, for example, the interest rate (cost of money) and utility costs (refrigeration cost).

Two identities that tie the retail sector together equate supplies with utilization:

23) $BCONS_t = BSUPP_t - BEXPRT_t - BSTOCK_t$

24) $BPERCAP = BCONS / POP.$

The lower right quadrant of figure 5 graphically depicts the retail price/quantity space.

This section has specified the theoretically important structural relationships and identities that constitute the United States beef industry. These have ranged from the beef breeding herd to the final consumer of the beef product. Figure 5 summarizes this information in graphical form.

4. DATA AND VARIABLE MEASUREMENT

The availability of data often limits the ability of the researcher to directly estimate the theoretical model in its original form. The structural beef model developed previously is no exception. This section briefly describes the sources of the data used in the analysis and any adjustments to the data or simplifying assumptions that were necessary. The data and variable definition list are in Appendix A. The majority of data were obtained from USDA Livestock and Meat Statistics and Agricultural Statistics. Some macroeconomic data were from the Economic Report of the President.

Numerous variables used in the estimation stage needed to be derived from existing data series. For example, in the theoretical model, it was recognized that different age groups of beef cows respond differently because of performance factors to changing economic information. The estimated model will not contain this information since data are not available on the age distribution of beef cows. Until recently (i.e., 1984), the data did not distinguish between beef cow and dairy cow slaughter. The number of beef heifers bred has never been reported. To resolve this problem, data series were derived for beef cow slaughter and beef heifers bred.

Following the approach used by Stillman, it was assumed that 70 percent of the dairy heifers kept for breeding at the beginning of the year actually calve during the year. Dairy cow slaughter can be derived from an identity that equates the dairy cow herd at the end of the year (ending stocks) to the dairy cow herd at the beginning of the year (beginning stocks) plus dairy heifers bred during the year (production) less dairy cows slaughtered during the year (use) less dairy cow death loss during the year. Given that total cow slaughter is reported, beef cow slaughter could be derived by subtracting dairy cow slaughter from total cow slaughter. Beef heifers bred could then be found by rearranging a similar identity for beef cows on farms. It is important to recognize that a portion of the variance associated with both beef cow slaughter and beef heifers bred could be associated with the dairy sector and could therefore cause the structural equations for these series to perform below expectations. It is also important to note that the initial assumption that 70 percent of the dairy heifers will actually be kept for breeding is very crucial and likely involves considerable error from year to year even though on average the assumption may be reasonable. As a result, the predictive ability of the beef heifers bred equation, while structurally a theoretically-correct specification, may be problematic from an empirical perspective.

Cow-calf returns are compiled from survey data from 1972 to present by the Economic Research Service (ERS), USDA (Economic Indicators of the Farm Sector). The use of survey data allows factors such as calf death loss to be incorporated into the returns variable, making it a better proxy for expected returns. The returns variable was backcasted prior to 1972 using the following two equations which were estimated using ordinary least squares over the period of 1972 to 1987 (t-statistics are inside parentheses):

$$CCREPT_t = \underset{(-6.18)}{-.5110\ E2} + \underset{(3.79)}{.4483\ E1}\ KCS\$_t + \underset{(0.24)}{.4827\ E0}\ COW\$_t$$

$$R^2 = .99 \qquad D.W. = 1.31$$

$$CCEXP_t = \underset{(-0.16)}{-.1221\ E1} + \underset{(2.36)}{.1083\ E1}\ CORN\$_{t-1} + \underset{(1.74)}{.5249\ E0}\ HAY\$_t$$

$$+ \underset{(3.37)}{.9482\ E\text{-}1}\ SMEAL\$_{t-1} + \underset{(15.60)}{.2092\ E1}\ PPI_t$$

$$R^2 = .99 \qquad D.W. = 1.20$$

Cow-calf returns are approximated by subtracting cow-calf expenses ($CCEXP_t$) from cow-calf receipts ($CCREPT_t$).

An important feature of this model is its ability to track an animal from the time it is born until slaughter occurs. Most models fail to keep track (in an accounting sense) of calves as they move from the cow-calf operator to the feedlot or grass. As a result, these models are missing an important link in the beef industry. That link is the decision-making process of the backgrounder. Previous models have usually estimated a reduced-form equation for the supply of calves entering the feedlot which attempts to account for decisions made by the backgrounder as well as the number of heifers entering the beef and dairy cow herds. As the backgrounder's demand for calves increases, the effect on the beef industry is two-fold. First, fewer calves enter the feedlot during the year so that current production may be lower than if these calves had not been backgrounded. Second, calves that have been backgrounded and then enter the feedlot usually have a larger frame size so that it is more likely to be economically feasible for feedlot operators to feed these animals to heavier weights causing future production to be greater than what would have occurred if these animals had not been backgrounded.

In order to complete this linkage, several data assumptions are necessary. Cattle-placed-on-feed data for thirteen major beef-producing states are available. However, since cattle placed on feed data are not reported for the United States, that series must be derived. This is accomplished by assuming that steer and heifer fed slaughter occurs only from cattle that were on feed. From that assumption, cattle placed on feed in the U.S. could be derived by taking the ending inventory of cattle on feed, subtracting the beginning inventory of cattle on feed, and adding steer and heifer fed slaughter and an assumed death loss of cattle in the feedlot. Figure 6 shows the derived United States series of cattle placed on feed along with the reported thirteen state cattle placed on feed series. The movements in these series seem to mirror each other very closely. Over time, the thirteen state number becomes a higher percentage of the United States number which is expected as the feeding of cattle has become more concentrated over this period.

The annual series for cattle backgrounded was obtained from subtracting cattle placed on feed, beef heifers bred, dairy heifers bred, calf slaughter, and calf death loss from the total supply of calves.

ERS reports the cost of 100 pounds of gain ($FDEXP_t$) in the feedlot for the years 1972 to 1987 (Economic Indicators of the Farm Sector). Prior to 1972, the following equation which was estimated from 1972 to 1987 is used to backcast this component.

$$FDEXP_t = \underset{(2.28)}{.6593\ E1} + \underset{(1.94)}{.1374\ E\text{-}1}\ SMEAL\$_t + \underset{(3.52)}{.3351\ E1}\ CORN\$_t + \underset{(3.79)}{.9391\ E\text{-}1}\ PPI$$

$$R^2 = .87 \qquad D.W. = 2.22$$

To summarize, several important variables had to be derived or generated based on other available data or assumptions believed to be reasonable for the analysis. These generated data series contain errors but nevertheless are used in the empirical analysis in order to complete the systems approach developed herein. As additional observations of only recently USDA published data become available and the linkages between these data and "generated" series become better understood, the errors associated with data measurement are likely to be reduced.

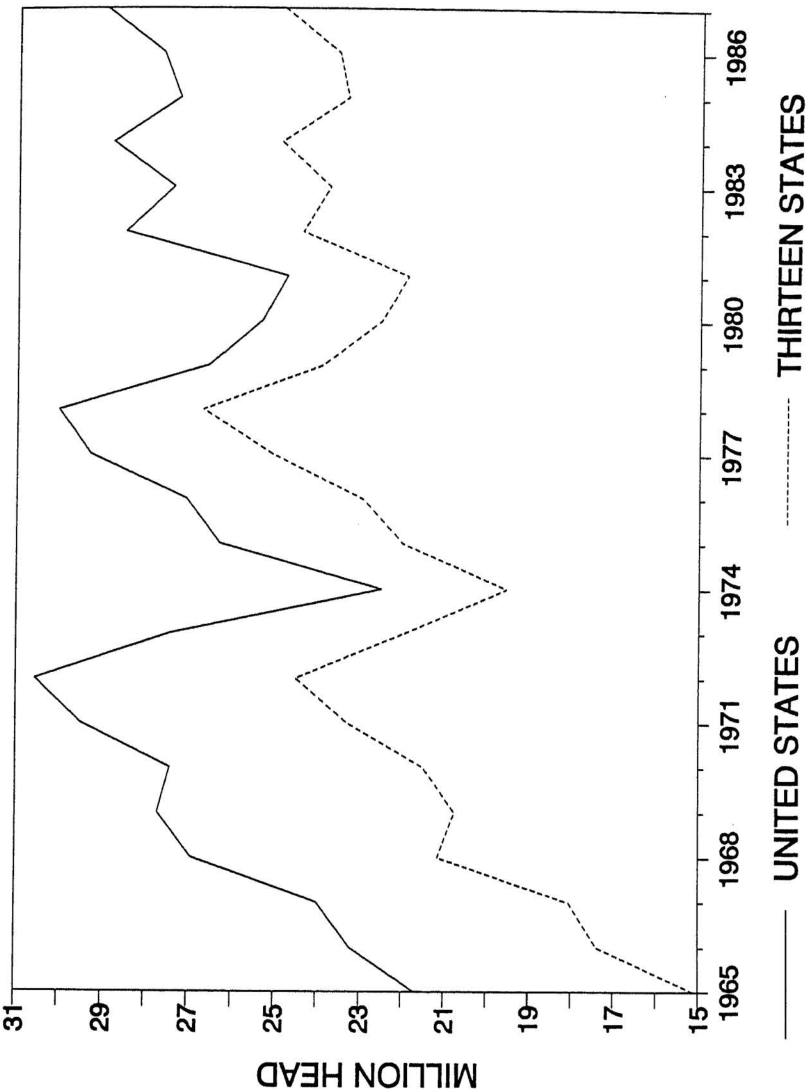
5. ESTIMATION RESULTS

The following sections present the empirical results from each of the structural equations developed in the previous chapter. The reader may wish to refer to figures 2 and 5 to follow the discussion of the empirical results that follow.

The empirical beef model is estimated using annual data from 1965 to 1987. Substantial data on the beef industry have been available for a very long time. However, the comprehensive nature of this model requires all data series to be consistent over the estimation period. Several inconsistencies prior to 1965 which could not be easily explained have resulted in elimination of that time period.

Given the simultaneous structure of the model, three-stage least squares estimation is employed to develop parameter estimates that are both unbiased and efficient. However, one problem that can occur with this system estimation technique is that the mis-specification of one equation can affect the parameter estimates of the other equations within the model. In preliminary investigation using both ordinary least squares and two-stage least squares, it was found that parameter estimates were not significantly different from those found using three-stage least squares lending some credibility to the overall structural specification of the model. In the

FIGURE 6. CATTLE PLACEMENTS



tables of results that follow, both the R^2 and Durbin-Watson statistics are reported for each equation. Given the system estimation procedure used, these statistics give only an approximation of the performance of each individual equation.

Cow-Calf Level

The empirical results of the cow-calf sector are summarized in table 2. (For additional detail regarding the performance of these equations, see Brown, Appendix B.) The beef heifers bred equation shows that about 11 percent of the beef cows on farms are replaced each year. After 1976, this percentage is decreased by approximately 4 percent. The shift in the percentage of beef cows replaced is included to reflect the increased reproductive life of the beef cow that has occurred through the development of better breeds of cattle and increased management by cow-calf operators. Examination of the data and empirical results suggested 1977 as the optimal point to begin this shift.

Current and lagged deflated cow-calf returns (CCREPT - CCEXP) were included in the equation as a proxy for expected returns. Both the current and lagged deflated cow-calf returns variables exhibit positive parameter estimates; however, current returns are insignificant in the specification. It will become clear why this insignificant variable is left in the equation when the disinvestment equation is discussed. The hypothesized reason for this insignificance is that in response to increased current returns, cow-calf operators may sell the heifer to the feedlot (negative influence on the parameter estimate) instead of adding her to the breeding herd (positive influence). It is expected that cow-calf operators would only add more heifers to the breeding herd if they expect future returns to increase, so in the short run (reflected by current year data), the responses to retain or sell are largely offsetting. Dummy variables were included to take care of outliers that possibly occurred through the derivation of the data series for beef heifers bred.

The estimated equation for beef cow slaughter is nearly identical to the equation for beef heifers bred since one represents investment (BHEIFBRD) and the other represents disinvestment (TBCOWSL) from the beef cow herd. It shows that the average culling rate of beef cows is approximately 16 percent. The difference in the average culling rates between the investment and disinvestment equations reflects in part the estimation period where a substantial downsizing of the beef cow herd (46 million in 1975 versus 34 million in 1987) has occurred. Current and lagged cow-calf returns were included as a proxy for expected returns. Both of the parameter estimates on these two variables were negative with current returns being a significant variable in the equation.

A shift variable for the years 1975 to 1978 was introduced after some preliminary investigation. It was found that rapid liquidation occurred over this time period in the beef cow herd (over 8 million head from 1975 to 1978). It is believed that the age distribution of beef cows was skewed to older age categories as prior to this period, profits to cow-calf operators were high and operators kept beef cows in the herd to an older age than normal. If the data existed on the age distribution of beef cows, estimation may have been possible to investigate this issue further.

TABLE 2. COW-CALF SECTOR, 1965 - 1987, THREE STAGE LEAST SQUARES RESULTS

(2.1)
$$BHEIFBRD_t = \underset{(1.50)}{.1644\ E4} + \underset{(3.60)}{.1061\ E0}\ BCOW\#_t - \underset{(-7.80)}{.3991\ E{-1}}\ (Shift77 * BCOW\#_t + \underset{(0.409)}{.1089\ E3} \left(\frac{CCREPT_t - CCEXP_t}{PPI_t}\right) + \underset{(2.36)}{.5522\ E3} \left(\frac{CCREPT_{t-1} - CCEXP_{t-1}}{PPI_{t-1}}\right) + \underset{(3.20)}{.1151\ E4}\ Dum73 + \underset{(2.07)}{.1199\ E4}\ Dum74 + \underset{(2.69)}{.1096\ E4}\ Dum79 - \underset{(-1.37)}{.6892\ E3}\ Dum81$$

$R^2 = .92$ $D.W. = 2.95$

(2.2)
$$TBCOWSL_t = \underset{(-1.11)}{-.1634\ E4} + \underset{(3.88)}{.1550\ E0}\ BCOW\#_t - \underset{(-3.64)}{.7417\ E3} \left(\frac{CCREPT_t - CCEXP_t}{PPI_t}\right) - \underset{(-1.08)}{.2620\ E3} \left(\frac{CCREPT_{t-1} - CCEXP_{t-1}}{PPI_{t-1}}\right) + \underset{(5.76)}{.2061\ E4}\ S75678$$

$R^2 = .96$ $D.W. = 1.13$

(2.3)
$$CALFCRP_t = \underset{(2.95)}{.4080\ E4} + \underset{(19.40)}{.8251\ E0}\ (BCOW\#_t + DCOW\#_t) + \underset{(7.37)}{.7640\ E0}\ (BHEIFBRD_{t-1} + DYHEBRD_{t-1}) - \underset{(-12.30)}{.7970\ E0}\ (TBCOWSL_t + TDCOWSL_t) - \underset{(-3.43)}{.1189\ E4}\ Dum79 - \underset{(-3.72)}{.9688\ E3}\ D812$$

$R^2 = .98$ $D.W. = 1.87$

(2.4)
$$CALDD_t = \underset{(-3.93)}{-.2647\ E4} + \underset{(6.89)}{.1017\ E0}\ CALFCRP_t + \underset{(2.67)}{.1261\ E5}\ W_t + \underset{(12.00)}{.1014\ E4}\ Shift73$$

$R^2 = .89$ $D.W. = 2.36$

(2.5)
$$CATDD_t = \underset{(-2.03)}{-.5290\ E3} = \underset{(5.46)}{.2254\ E{-1}}\ (CATOFRMS_t - BCOW\#_t - DCOW\#_t) + \underset{(5.12)}{.1837\ E3}\ Shift74 + \underset{(4.97)}{.3350\ E3}\ Dum73 - \underset{(-3.85)}{.2445\ E3}\ Dum76$$

$R^2 = .87$ $D.W. = 2.08$

From table 3, which contains the elasticities from the cow-calf sector, beef cow slaughter is shown to be more responsive in absolute terms to current returns than is beef heifers bred (-.016 and .002, respectively). One might interpret these elasticities to suggest that in the short run (represented by current year returns), beef cows which are already a part of the breeding herd are more likely to be retained in the herd with increasing returns than are heifers (to be added to the herd). Beef heifers bred are more responsive in absolute terms to lagged returns than is beef cow slaughter (.001 and -.005, respectively). Accordingly, with the longer run expectations (represented by lagged returns), heifers are more likely to be added to the herd than are beef cows (especially older cows) to be retained.

Given the importance of the investment/disinvestment decisions in the overall structure of the beef model, table 4 compares elasticities of these equations with those from other studies. With respect to corn price, both dependent variables are much more inelastic than in other studies. This result is probably due to the other studies using only the corn price as the proxy for costs whereas this model uses a returns approach. Given that only a small amount of corn is needed by cow-calf operators, the inelastic nature of these equations with respect to corn price seems reasonable. For the output price, the other studies differ on which price to use as well as the lag structure on the output price. Yanagida and Conway and Grundmeier used the fed steer price while Brandt, Young, and Womack used the feeder steer price. The feeder steer price seems most appropriate since it is the price cow-calf operators receive. In the beef heifers bred equation, Brandt, Young, and Womack showed a negative elasticity with respect to the current feeder steer price while the equation estimated here shows a positive elasticity. The other two studies have implicitly assumed an elasticity of zero since the current fed cattle price is omitted from the specification. The offsetting effects of selling the heifer to the feedlot in response to higher prices or putting her in the breeding herd make the sign of the current price coefficient difficult to interpret. The elasticity on the lagged output price in the beef heifers bred equation is close to the estimates of the other studies.

In the beef cow slaughter equation, the other studies vary greatly on the choice of price variable and the lag structure that is used. Grundmeier used only the current fed steer price, Brandt, Young, and Womack used the current and one period lagged feeder steer price, and Yanagida and Conway used the current and one and two period lagged fed prices. The equation estimated for beef cow slaughter uses the current and one period lagged feeder prices. The elasticities fall within the range of elasticities that are reported from the other studies.

The equation for calves born (CALFCRP) is estimated as a function of beef and dairy cows on farms, beef and dairy heifers bred last year, and beef and dairy cows slaughtered (table 2). The equation shows that approximately 83 percent of all cows on farms produce a calf during the year. The parameter estimate on all heifers bred last period appears to be high at first glance at 67 percent. This estimate is high because, in the derivation of this series, heifers that are introduced to a bull but remain open (unbred) are not included in the series. The parameter estimate on cow slaughter shows that 80 percent of the cows slaughtered during the year did not produce a calf. This estimate is higher than expected but can be partially explained by the fact that some operators carry cows for a short period before they are slaughtered in order to increase their weight.

TABLE 3. ELASTICITIES FROM THE COW-CALF SECTOR[a]

Equation	BHEIFBRD	TBCOWSL	CALFCRP	CALDD	CATDD
Variable					
$BCOW\#_t$	.803	1.294	.693		-.806
$CCREPT_t$	.002	-.016			
$CCREPT_{t-1}$	.011	-.005			
$TBCOWSL_t$			-.083		
$TDCOWSL_t$			-.053		
$BHEIFBRD_{t-1}$			.086		
$DYHEBRD_{t-1}$			.051		
$DCOW\#_t$			.216		-.251
$CALFCRP_t$				1.356	
W_t				.226	
$CATOFRMS_t$					2.402

[a] Elasticities are calculated at the means of the data.

TABLE 4. COMPARISON OF ELASTICITIES FROM INVESTMENT/ DISINVESTMENT EQUATIONS WITH OTHER STUDIES[a]

Variable	S&H$ t	S&H$ t-1	S&H$ t-2	KCS$ t	KCS$ t-1	CORN$ t	CORN$ t-1	CORN$ t-2
BHEIFBRD								
Y. C.[b]		.13					-.13	
B. Y. W.[c]				-.27	.50	.27	-.50	
Grundmeier		.27					-.16	
Brown and Brandt				.072	.364	-.001	-.004	
TBCOWSL								
Y. C.	-.38	-.94	-.22			.38	.94	.22
B. Y. W.				-.35	-.77	.35	.77	
Grundmeier	-.97					.48		
Brown and Brandt				-.547	-.193	.005	.002	

[a]Elasticities are calculated at the means of the data.

[b]Yanagida and Conway.

[c]Brandt, Young, and Womack.

The last two equations in table 2 are calf death loss and cattle death loss excluding calves and cows. Each of these equations was fit as a function of the available pool of live animals. The calf death loss equation shows that about 10 percent of the calves born each year die. The cattle death loss equation shows that approximately 2 percent of the cattle die each year. The calf death loss equation includes a weather variable to modify the death loss to changing spring weather conditions. Shift variables were included for both of these equations after the data seemed to indicate changes in these series. Given the nature of these data series, both equations fit reasonably well and given the relatively small importance of these equations in the overall model, they should not adversely affect the performance of the model significantly.

Feedlot Level

Cattle backgrounded (BACK) is specified as a function of the current deflated Kansas City 600-700 pound feeder steer price and the available supply of calves which could be backgrounded (table 5). Most of the cattle backgrounding that is done is usually in the 400-500 pounds to 700-800 pounds range. Therefore, the Kansas City 600-700 pound feeder steer price proxies both the input and output prices. Because of this, difficulty arises in determining the sign of the Kansas City 600-700 pound feeder steer price. It was anticipated that the ratio of the Kansas City feeder steer price to the hay price would be an adequate proxy for expected returns. However, the current Kansas City feeder steer price seems to be a better proxy for the input price than the expected output price. Inclusion of the hay price by itself, added no greater explanatory power to the equation so it was not retained in the final specification. Dummy variables were included to take care of outliers that occurred because of the residual nature of this series.

The derived demand equation for cattle placed on feed has caused numerous problems in other studies. Freebairn and Rausser omitted the price of feeder cattle as an explanatory variable because it exhibited the wrong sign from a priori expectations. They suggested a possible problem of correlation between it and the fed steer price. Arzac and Wilkinson and Grundmeier, without explanation, also did not include the feeder cattle price in their placement equations. Brandt, Young, and Womack estimated a price-dependent cattle-placed-on-feed equation in which they restricted the placements coefficient. Theory suggests that both the feeder steer price and fed steer price should be included in this specification, along with other costs associated with feeding an animal to slaughter weight (Beattie and Taylor). However, when the animal is placed on feed, the fed steer price is unknown and some type of expectation of this price must be formed.

A brief discussion regarding price expectations is appropriate at this point. Researchers have explored a variety of ways to incorporate price expectations into their models. The most common price expectations formulations have included some form of past prices. These range from naive (Ezekiel) to adaptive (Nerlove). Alternatively, Muth developed a theoretically more appealing approach -- rational price expectations. Recently, Brown and Brandt empirically investigated the differences in supply response of fed cattle using a rational price expectations approach and a naive price expectations approach. Both in-sample estimation and out-of-sample forecasting suggested only marginal improvements in using rational expectations over naive expectations. The complexity of theoretically incorporating rational expectations in a comprehensive model such as this one and the large data demands associated with empirical

TABLE 5. DEMAND FOR CALVES, 1965-1987, THREE STAGE LEAST SQUARES

(5.1)

$$BACK_t = \underset{(-3.86)^a}{.1844\ E5} + \underset{(15.10)}{.7639\ E0}\ (ANONGR_t + CALFCRP_t)$$

$$- \underset{(-2.98)}{.4868\ E4} \left(\frac{KCS\$_t}{PPI_t}\right) + \underset{(-2.80)}{.5099\ E4}\ Dum74 - \underset{(-2.80)}{.3152\ E4}\ Dum77$$

$$+ \underset{(3.89)}{.3017\ E4}\ D801$$

$R^2 = .95$ $\quad$ $D.W. = 1.50$

(5.2)

$$\left(\frac{KCS\$_t}{PPI_t}\right) = \underset{(3.23)}{.2183\ E0} - \underset{(-2.61)}{.6831\ E5}\ CATPL_t + \underset{(3.88)}{.2373\ E4}\ CATOFD_t$$

$$+ \underset{(23.60)}{.9370\ E0} \left(\frac{10.5 * S\&H\$_t - 4 * FEDXP_t)/6.5}{PPI_t}\right) + \underset{(-7.27)}{.2041\ E0}$$

$$Dum74 - \underset{(-7.46)}{.1834\ E0}\ Dum75$$

$R^2 = .98$ $\quad$ $D.W. = 1.73$

[a] t-statistic within parentheses

estimation of a rational expectations approach overwhelms the small expected benefits from its approach in the estimation process. Furthermore, given the number of stages in the marketing channel, the geographic dispersion, and the large number of producers, it is quite likely that the conditions associated with the rational expectations approach do not apply well to the beef industry.

A variety of current and/or lagged price variable specifications have been explored at all levels of the beef production process reflecting alternative price expectation formulations. None seems to dominate in terms of goodness of fit at every level of production. Given the implied simultaneous nature of current supply/utilization with price determination for short run decision making combined with lagged prices which seem to reflect longer run considerations (Brandt, et al.), several price expectation specifications in this analysis employ both current and one period lagged price variables.

The equation for cattle placed on feed is fit in price-dependent form (table 5). The better performance of the price-dependent form (relative to the quantity-dependent form) is probably explained by the high correlation between the fed steer price and the feeder steer price (.97). The equation is a function of the quantity of cattle placed on feed during the year, the quantity of cattle on feed at the beginning of the year (proxy for the capacity of feedlots), the deflated fed steer price (output price), and the cost of putting 100 pounds of gain on the animal in the feedlot. The current fed steer price was used after trying the lagged prices as well as a combination of the current and lagged prices. Although a naive price expectations formulation suggests the use of a lagged price, since the average time on feed is only about 180 days and measurement of the data series for cattle on feed is annual, it could be more a simultaneous than recursive process and may preclude including the lagged steer price. All of the parameters have the correct signs and are statistically significant variables. Dummy variables for the early to mid 1970s were included to account for the unusually volatile crop production and price conditions.

The implied elasticity on the feeder steer price, which is the inverse of the flexibility shown in table 6, causes concern since it is more elastic than is the own-price coefficient in the retail demand equation. When the entire model is put together, the fed steer price transmission (1.43) offsets the high implied elasticity on the feeder steer price. Dynamic simulation of the entire model will determine if this specification will work.

Packer Level

The equation for steer and heifer fed slaughter is estimated as a function of cattle on feed at the beginning of the year and cattle placed on feed during the year (table 7, equation 7.1). The parameter estimate for cattle on feed shows that about 97 percent of the cattle on feed at the beginning of the year are slaughtered. This is a plausible estimate since it is expected that some death loss would be encountered in this category before slaughter (the parameter estimate implies a death loss of about 3 percent). This equation shows that about 53 percent of the cattle placed on feed during the year are slaughtered, while from 1981 forward that percentage increases to 58 percent. Dummy variables were included to account for years in which the length of time cattle were on feed varied from the average due perhaps to weather conditions or to differences in the weight of cattle being placed in or removed from the feedlot.

TABLE 6. ELASTICITIES AND FLEXIBILITIES FROM DERIVED DEMANDS FOR CATTLE[a]

Equation	BACK	KCS$
Variable		
$KCS\$_t$	-.080	
$ANONGR_t$	.723	
$CALFCRP_t$	.765	
$CATOFD_t$		.387
$CATPL_t$		-.247
$FDEXP_t$		-.249
$S\&H\$_t$		1.429

[a]Elasticities (BACK) and flexibilities (KCS$) are calculated at the means of the data.

The shift on cattle placements occurs because of the change in the calculation of steer and heifer fed slaughter. Prior to 1981, steer and heifer fed slaughter was derived by expanding the 23 state fed marketings number to a U.S. level by using the ratio of the U.S. cattle on feed to the 23 state cattle on feed. However, the 23 state number was discontinued in 1981 so the 13 state fed cattle marketing had to be expanded to derive steer and heifer fed slaughter. As Stillman reports, the problem that arises when switching from the 23 state data to the 13 state data is the loss of information available to derive the U.S. steer and heifer fed slaughter.

Steer and heifer non-fed slaughter (table 7, equation 7.2) is estimated as a function of steer and heifer fed slaughter, cattle backgrounded, and the deflated difference between the feeder steer price and the utility cow price. Steer and heifer fed slaughter was included since steer and heifer non-fed slaughter is the residual of total steer and heifer slaughter minus steer and heifer fed slaughter. Any error in steer and heifer fed slaughter would be contained in the non-fed slaughter category. The shift in 1981 is included to reflect the change in the calculation of steer and heifer fed slaughter.

The equation shows that about 8 percent of the cattle backgrounded (available pool from which to draw) are slaughtered as non-fed animals. The difference between the feeder steer price and cow utility price is included to reflect the decision process that producers holding these animals can make. As the feeder steer price increases, these animals would be sold to feedlots to be fed to a heavier weight, while an increase in the cow utility price (proxy for the non-fed price) would cause more animals to be slaughtered as non-fed animals.

The derived demand by packers for non-fed animals (table 7, equation 7.4) is estimated in a utility cow (COW$) price-dependent form as a function of non-fed cattle slaughter, deflated beef retail price, deflated wage rate, and deflated fuel and utility costs. All of the parameter estimates have the correct signs and all but deflated wages are significant at the 95 percent level. It should be noted that the implied elasticity (flexibilities and elasticities are shown in table 8) of cattle utility price with respect to non-fed cattle slaughter is high (-3.58), but it is expected that the elasticity on the retail beef price will offset the high elasticity on cattle utility price in the entire model.

In order to clarify these relationships a bit, the reader is referred to figure 6. Packer derived demand for slaughter cattle includes both a retail (output) price and a live cattle (input) price. Similarly, the feedlot operator's derived demand for feeder calves includes a live cattle (output) price and a feeder cattle (input) price. The linkages across these prices from retail to live cattle to feeder cattle is strong and the correlation is high. Thus, it is not unreasonable to expect a high coefficient and (thus implied large) price transmission between these variables.

The beef production equation turns animals slaughtered (thousand head) into meat (million pounds) (table 7, equation 7.3). The parameter estimate on fed steer and heifer slaughter shows that each of these animals convert into 594 pounds of meat when slaughtered. This is increased by the second component of this equation by about five pounds per year. The second component reflects the change to breeds of cattle that are more efficient converters of feed to meat allowing feedlot operators to feed them to a heavier weight. The equation shows that each non-fed animal slaughtered produces 492 pounds of meat. The returns variable is included to capture the effect

TABLE 7. CATTLE SLAUGHTER AND BEEF PRODUCTION ESTIMATION RESULTS, 1965 - 1987, THREE STAGE LEAST SQUARES

(7.1)

$$SAHFDSL_t = \underset{(-1.71)^a}{-.1418\ E4} + \underset{(15.90)}{.9697\ E0}\ CATOFD_t + \underset{(16.90)}{.5324\ E0}\ CATPL_t + \underset{(9.09)}{.4632\ E{-1}}\ Shift81*CATPL_t + \underset{(1.40)}{.4484\ E3}\ Dum74 - \underset{(-2.64)}{.6809\ E3}\ Dum75$$

$R^2 = .97$ $\qquad$ $D.W. = 1.36$

(7.2)

$$SAHNFSL_t = \underset{(9.60)}{.1186\ E5} - \underset{(-6.38)}{.2255\ E0}\ SAHFDSL_t - \underset{(-10.80)}{.0730\ E0}\ (Shift81*SAHFDSL_t) + \underset{(4.85)}{.7681\ E{-1}}\ BACK_t - \underset{(-14.20)}{.1944\ E5}\left(\frac{(KCS\$_t - COW\$_t)}{PPI_t}\right) - \underset{(-5.79)}{.1915\ E4}\ Dum74$$

$R^2 = .96$ $\qquad$ $D.W. = 2.17$

(7.3)

$$BPROD_t = \underset{(-6.92)}{-.7349\ E3} + \underset{(19.00)}{.5937\ E0}\ SAHFDSL_t + \underset{(12.00)}{.4518\ E2}\ (SAHFDSL_t*TREND) + \underset{(2.89)}{.2048\ E3}\left(\frac{(10.5*S\&H\$_t - 4*FDEXP_t)}{PPI_t}\right) \ \underset{(22.20)}{.4916\ E0}\ CATNFSL_t$$

$R^2 = .98$ $\qquad$ $D.W. = 2.66$

(7.4)

$$\left(\frac{COW\$_t}{PPI_t}\right) = \underset{(.81)}{-.1195\ E0} - \underset{(-3.90)}{.1014\ E{-4}}\ CATNFSL_t + \underset{(7.79)}{.3063\ E2}\left(\frac{BRET\$_t}{PPI_t}\right) - \underset{(-2.17)}{.8469\ E{-1}}\left(\frac{F\&UI_t}{PPI_t}\right) - \underset{(-2.23)}{.1106\ E{-1}}\left(\frac{WAG\$_t}{PPI_t}\right) - \underset{(2.61)}{.8062\ E{-1}}\ Dum74$$

$R^2 = .98$ $\qquad$ $D.W. = 1.99$

(7.5)

$$\left(\frac{S\&H\$_t}{CPI_t}\right) = \underset{(2.94)}{.1179\ E0} - \underset{(-8.20)}{.1076\ E{-4}}\ BPROD_t + \underset{(46.80)}{.3582\ E2}\left(\frac{BRET\$_t}{CPI_t}\right) - \underset{(-9.90)}{.1055\ E0}\left(\frac{F\&UI_t}{CPI_t}\right) + \underset{(5.50)}{.3523\ E{-1}}\ Dum84 - \underset{(-1.68)}{.1918\ E{-1}}\ Dum74$$

$R^2 = .98$ $\qquad$ $D.W. = 1.99$

TABLE 8. ELASTICITIES AND FLEXIBILITIES FROM PRODUCTION AND SLAUGHTER EQUATIONS[a]

Equation	SAHFDSL	SAHNFSL	COW$	BPROD	S&H$
Variable					
$CATOFD_t$	.470				
$CATPL_t$	.620				
$SAHFDSL_t$		-2.282		.724	
$BACK_t$		1.054			
$COW\$_t$		2.732			
$KCS\$_t$		-4.403			
$F\&UI_t$			-.133		-.107
$SAHNFSL_t$			-.071	.072	
$TBCOWSL_t$			-.098	.099	
$TDCOWSL_t$			-.065	.066	
$BULLSL_t$			-.002	.016	
$WAG\$_t$			-.023		
$S\&H\$_t$				.067	
$FDEXP_t$				-.012	
$BPROD_t$					-.340
$BRET\$_t$					1.286

[a]Elasticities (SAHFDSL, SAHNFSL, BPROD) and flexibilities (COW$, S&H$) are calculated at the means of the data.

of feeding to heavier (lighter) weights in response to an increase (decrease) in the current fed cattle price or a decrease (increase) in the current cost of additional gain.

The derived demand by the packer for pounds of production (table 7, equation 7.5) is also fit in price-dependent form. This equation probably fits better in this form because of the correlation between the retail beef price and the fed steer price (.99). Again the implied elasticity on the fed steer price is high, but it is suspected this will be offset by the retail beef price transmission coefficient (1.29). This equation is specified identical to the derived demand by packers for non-fed animals except that after some investigation, the wage variable was dropped from the specification since it contained a positive sign.

Retail Level

The demand for stocks (BSTOCK) is specified as a function of the beef retail price, interest rate, fuel and utilities index, and beef production (table 9). All of these variables are significant in the equation and have signs expected a priori. A shift variable is included to reflect the change in the method used by the USDA after 1977 to calculate the level of stocks on hand. Although the equation does not perform exceptionally well (R^2 = .78), it is not expected to adversely effect the performance of the entire model since it is such a small component of total demand.

The other demand equation in the retail sector is that of consumer demand for beef. Preliminary empirical investigation that used the real beef, pork, and broiler retail prices and deflated consumer income to explain per capita beef consumption did not perform as expected. Wrong signs were experienced on the substitute prices (pork and broiler) and the elasticity on the beef retail price was higher than that of previous research. While incorrect signs (indicating complementarity of these products) have been reported in previous research (see, for example, Nyankori and Miller, Moschini and Meilke, 1989), they are unacceptable when the goal is to perform simulation analysis.

Given the performance of the preliminary equation, it seems to indicate that an important variable or variables are missing from the specification. One possibility is that the price of a substitute or complement commodity is missing from the specification. Other meat prices (turkey and fish) were investigated in the estimation, but they did not significantly improve the performance of the equation.

Another possibility is that the structural demand for beef has changed over time. Although a great deal of discussion in the literature has addressed this issue, no consensus has been reached. Some have found that no structural demand shift has occurred (Leuthold and Nwagbo, Moschini and Meilke, 1984, Chalfant and Alston) while others found structural change (Chavas (1983), Braschler, Dahlgran, Nyankori and Miller, Wohlgenant (1982, 1986)).

In an attempt to capture changes in the structural demand for beef, a stochastic trend term was included in the specification (Harvey). The stochastic trend variable contains both a stochastic constant component and stochastic trend component. This gives the trend variable more flexibility than imposing the rigid restriction of a linear trend. The stochastic trend term

TABLE 9. RETAIL DEMAND ESTIMATION RESULTS, 1965-1987, THREE STAGE LEAST SQUARES

(9.1)
$$BSTOCK_t = \underset{(-.478)}{-.6541\ E1} - \underset{(-4.53)}{.5666\ E3}\left(\frac{BRET\$_t}{CPI_t}\right) INTRAT_t - \underset{(-3.01)}{.1311\ E3}\left(\frac{F\&UI_t}{CPI_t}\right) + \underset{(2.95)}{.1427\ E{-1}}\ BPROD_t + \underset{(4.98)}{.7668\ E2}\ Shift78 + \underset{(3.01)}{.1090\ E3}\ Dum76 - \underset{(-3.68)}{.1397\ E3}\ Dum81$$

$R^2 = .78$ $\quad D.W. = 1.68$

(9.2)
$$\ln(BPERCAP_t) = \underset{(-15.00)^a}{-.4416\ E2} - \underset{(-16.70)}{.6599\ E0}\ln\left(\frac{BRET\$_t}{CPI_t}\right) + \underset{(2.62)}{.881\ E{-1}}\ln\left(\frac{PRET\$_t}{CPI_t}\right) + \underset{(4.10)}{.1071\ E0}\ln\left(\frac{CRET\$_t}{CPI_t}\right) + \underset{(9.70)}{.5908\ E0}\ln\left(\frac{INCOME_t\ /POP_t}{CPI_t}\right) + \underset{(17.70)}{.3646\ E2}\ln(STREND_t) + \underset{(4.10)}{.4102\ E{-1}}\ Dum74$$

$R^2 = .97$ $\quad D.W. = 2.46$

[a]t-statistic within parentheses

explains additional variation in the dependent variable not captured by the remaining independent variables. The benefit of including the stochastic trend term is that a better estimate can be made of the other parameters in the specification since they will not be biased by the variation that the stochastic trend captures. One shortcoming of the stochastic trend term, or for that matter any trend term, is identifying or interpreting what the trend term is capturing. The statistical significance of the trend coefficient and the improvement in the signs and statistical significance of the other price and income coefficients suggests important variable(s) are missing and that demand has shifted (table 9, equation 9.2). However, it does not identify the cause of this shift.

The elasticity on the beef retail price (-.66) fell within the range reported by Smallwood, Haidacher, and Blaylock of -.6 to -1 in their review of literature on beef demand. In addition, the elasticity on income (.59) fell to within the range of .5 to .8 reported by the authors. Solving equation 9.2 for the stochastic trend term indicates it reached a peak in 1974 and declined thereafter. This corresponds to some of the literature reviewed by Smallwood, Haidacher, and Blaylock that found structural change occurred in the mid-1970s.

Seventeen structural relationships explain the decisions that take place along the marketing channel in the beef industry. Ten identities and technical relationships are used to close the model. Table 10 is a summary of these identities and technical relationships. The reader is referred again to figure 5 to examine a graphical representation of the beef model.

6. VALIDATION OF THE MODEL

The beef model was simulated using the Newton algorithm for non-linear systems. Two in-sample simulations (1965-1987) were conducted to assess the performance of the model. One was a static simulation where actual values were used for the lagged endogenous variables in the system. This simulation shows the period by period performance of the model. That is, errors in the dependent variable prediction that occur in one period are not allowed to affect future periods. The second in-sample simulation was a dynamic simulation where model-predicted values were used for lagged endogenous variables in the system. This simulation is a more rigorous test of the model than the static simulation since errors in endogenous variables are allowed to feed through to future periods. A third out-of-sample simulation (1988-1989) evaluates the performance of the model outside the period of fit.

Table 11 shows the percent root mean square errors for the three simulations. CCREPT, CCEXP, and FDEXP performance results are not shown since both expense categories are only functions of exogenous variables and do not perform differently from the ordinary least squares results and the receipt category is only a linear function of farm prices so its performance is nearly identical to the performance of the prices. Similarly, CATNFSL is simply the sum of TBCOWSL, TDCOWSL, SAHNFSL, and BULLSL. TSCALF is related to ANONGR, CALFCRP, AND CALDD.

With the exception of non-fed steer and heifer slaughter, all of the errors are below 15 percent. Since non-fed steer and heifer slaughter represents on average only about 10 percent of total slaughter, its performance does not significantly affect the performance of the remaining endogenous variables. However, the poor performance of SAHNFSL alerts the analyst to

TABLE 10. IDENTITIES AND TECHNICAL RELATIONSHIPS

(10.1) $CATOFRMS_t = CATOFRMS_{t-1} + CALFCRP_{t-1} + CATIM_{t-1} - SAHFDSL_{t-1} - SAHNFSL_{t-1} - TBCOWSL_{t-1} - TDCOWSL_{t-1} - CALSL_{t-1} - CATEX_{t-1} - CALDD_{t-1} - CATBAL_{t-1} - BULLSL_{t-1} - CATDD_{t-1}$

(10.2) $BCOW\#_t = .98 * BCOW\#_{t-1} + BHEIFBRD_{t-2} - TBCOWSL_{t-1}$

(10.3) $ANONGR_t = CATOFRMS_t - BCOW\#_t - DCOW\#_t - CATOFD_t - BULL\#_t$

(10.4) $TSCALF_t = ANONGR_t + CALFCRP_t - CALFSL_t - CALDD_t$

(10.5) $CATPL_t = TSCALF_t - BHEIFBRD_t - DHEIFBRD_t - BACK_t$

(10.6) $CATOFD_t = CATOFD_{t-1} - SAHFDSL_{t-1} + CATPL_{t-1} - CATLOSS_{t-1}$

(10.7) $CATNFSL_t = TBCOWSL_t + TDCOWSL_t + SAHNFSL_t + BULLSL_t$

(10.8) $BSUPP_t = BPROD_t + BIMPRT_t + BSTOCK_{t-1}$

(10.9) $BCONS_t = BSUPP_t - BSTOCK_t - BEXPRT_t$

(10.10) $BPERCAP_t = BCONS_t/POP_t$

potential problems in the model when the predicted value of the variable is negative and when that variable is a part of the predictive process of other equations. Further examination of the results finds that, in general, quantity variables fit better than price variables and that prices fit better at the retail level than the farm level. The small differences in performance between the static and dynamic in-sample simulations lend credibility to the lagged structure defined in the model. The out-of-sample results are good especially given that 1988 was a year of severe drought. The variables that do not perform exceptionally well are not the crucial variables in the model so their errors are not alarming.

Another useful simulation statistic used to evaluate the historical dynamic simulation is Theil's inequality coefficient (U). Ideally, U should be close to zero for the model results to be in an acceptable range. Table ll provides the results of the Theil U for the in-sample dynamic simulation. Excluding non-fed steer and heifer slaughter, the values of U are less than .052 for the remaining endogenous variables. Given these low values for U, the model seems to fit the data quite well.

An important criterion on which to base the performance of the model is its ability to predict the turning points of the endogenous variables. A casual review of the static simulation graphs shows that the model is able to capture a vast majority of the turning points (see Brown, Appendix B). Under dynamic simulation, the model still correctly predicts most of the turning points but the strong cyclical nature of the beef industry requires some time for the model to correct for prediction errors that occurred in previous years. Given the number of lagged endogenous variables that feed through to the quantity variables, this result is not unexpected.

7. MULTIPLIER ANALYSIS: SIMULATION OF EXOGENOUS SHOCKS ON THE BEEF MODEL

The model of the beef industry could be solved to predict year-to-year changes in each endogenous variable under a given set of exogenous conditions. In this section, changes in important exogenous variables will be permitted in order to explore the effects of these shocks on the system of endogenous variables.

Clearly, the accuracy of future projections depends on (1) the correctness of the model's parameter estimates in terms of magnitudes and signs of coefficients, (2) the soundness of the model's equations to capture the important structural components in the industry and the stability of the model over future time periods, and (3) the accuracy with which the exogenous variables can be predicted.

The authors are reasonably satisfied with the values of the estimated equation coefficients and with the soundness of the structural model. However, error terms associated with several equations are large as has been noted and will likely cause further distortions in simulation analysis. Similarly, some of the exogenous variables move with a fairly regular pattern and as such can be reasonably accurately predicted. Others such as weather and technology are more difficult to predict with accuracy.

TABLE 11. PERFORMANCE STATISTICS OF THE BEEF MODEL

Variable	Root Mean Square Errors In-Sample (1965-1987) Static	Root Mean Square Errors In-Sample (1965-1987) Dynamic	Root Mean Square Errors Out-of-Sample (1988-1989)	Theil's U Statistic
ANONGR	0	6	2	.027
BACK	3	7	6	.031
BCONS	3	4	3	.019
BCOW#	0	3	1	.014
BHEIFBRD	9	9	3	.036
BPERCAP	3	4	3	.019
BPROD	4	4	3	.020
BRET$	4	5	7	.024
BSTOCK	7	8	27	.038
BSUPP	3	4	3	.019
CALDD	6	6	9	.031
CALFCRP	1	2	2	.012
CATDD	7	8	19	.040
CATOFD	0	5	1	.025
CATOFRMS	0	3	1	.016
CATPL	4	4	4	.020
COW$	8	11	20	.049
KCS$	11	12	4	.049
S&H$	7	8	9	.039
SAHFDSL	3	4	4	.018
SAHNFSL	48	41	94	.144
TBCOWSL	13	12	13	.052

From this discussion, it becomes clear that the probability distributions of the projected values of the endogenous variables are complex functions of the error distribution associated with the estimates of equation parameters, changes in the structure of the industry, possible specification errors, and the probability distributions of projections of the future values of the exogenous variables. Because this compound distribution is unknown, it is not possible to construct meaningful confidence intervals for the endogenous projections. As such, the projections should be viewed as conditional solutions of the model rather than specific forecasts.

In the following sections, values of the exogenous variables are set at their 1985 to 1987 mean values and the model is dynamically simulated under a base scenario. Alternatively, rather than attempting to predict future time paths of selected exogenous variables, these variables are changed by 10 percent and the model is resimulated and dynamically solved. The results reflect the immediate, intermediate, and long run equilibrium effects of the exogenous variable changes in the U.S. beef system.

Trade Shocks

Tables 12 and 13 provide the results of shocking beef imports and exports. Increasing beef imports by 10 percent (about 216 million pounds) causes beef prices to fall in the short run but to moderate in the long run as domestic beef production declines to offset the higher level of imports. Increasing beef exports by 10 percent (about 54 million pounds) causes the opposite effect. Beef prices rise in the short run but are moderated over the long run as domestic beef production increases in response to greater demand. The results of this analysis show the same directional change in coefficients as those of Freebairn and Rausser and of Folwell and Shapouri but seem closer in magnitude to the former than the latter. Part of these differences is explained by the treatment of trade as an exogenous or an endogenous variable. Other differences are probably due to model specification and time period estimation. It is important to note that if the same absolute increase in beef imports and exports had occurred, the responses would have been identical except they would have had opposite signs. That is, a billion pound increase (decrease) in beef imports would have the same effect as a billion pound decrease (increase) in beef exports.

Substitute Retail Price Shocks

Tables 14 and 15 show the effects of increasing the prices of competing meats (broiler and pork). The results show that as demand for beef increases, the short run response is for higher prices as the supply side of the model has time to adjust, beef price increases are smaller. The models developed by Brandt et al., Grundmeier, and Heien and Matthews show the same movements in beef prices and production as this model does with increases in the price of competing meats.

Inflationary Shocks

Increasing the producer price index causes the costs in the marketing channel to increase (table 16). The equilibrium results which show beef production lower and beef prices higher indicates appropriate model behavior. The short run responses, however, are not totally

TABLE 12. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN BEEF IMPORTS (BIMPRT)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	-2.32%	-3.11%	-2.01%	0.19%	1.11%	0.00%	0.00%	-0.24%	-0.38%
2	-2.26%	-3.21%	-1.59%	0.17%	1.09%	-0.23%	-0.23%	-0.35%	-0.30%
3	-1.93%	-2.68%	-1.57%	0.02%	0.97%	-0.55%	-0.55%	-0.38%	-0.40%
4	-1.36%	-1.90%	-0.78%	-0.23%	0.72%	-0.95%	-0.88%	-0.50%	-0.51%
5	-0.78%	-1.12%	-0.39%	-0.49%	0.49%	-1.23%	-1.16%	-0.62%	-0.62%
10	0.14%	0.07%	0.00%	-0.86%	0.13%	-1.05%	-1.35%	-0.91%	-0.84%
20	-0.40%	-0.66%	-0.81%	-0.64%	0.34%	-0.89%	-1.13%	-0.78%	-0.73%
∞	-0.36%	-0.61%	-0.41%	-0.65%	0.32%	-0.87%	-1.14%	-0.79%	-0.74%

TABLE 13. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN BEEF EXPORTS (BEXPRT)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	0.68%	0.91%	0.40%	-0.06%	-0.32%	0.00%	0.00%	0.07%	0.11%
2	0.67%	0.95%	0.40%	-0.05%	-0.33%	0.07%	0.07%	0.11%	0.09%
3	0.57%	0.78%	0.39%	-0.01%	-0.27%	0.16%	0.16%	0.12%	0.12%
4	0.39%	0.55%	0.39%	0.07%	-0.22%	0.28%	0.26%	0.14%	0.15%
5	0.22%	0.31%	0.39%	0.14%	-0.14%	0.36%	0.34%	0.18%	0.18%
10	-0.05%	-0.01%	0.00%	0.25%	-0.03%	0.30%	0.39%	0.26%	0.24%
20	0.12%	0.19%	0.00%	0.18%	-0.08%	0.26%	0.33%	0.23%	0.21%
∞	0.11%	0.17%	0.41%	0.19%	-0.08%	0.25%	0.33%	0.23%	0.21%

TABLE 14. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE BROILER RETAIL PRICE (CRET$)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	2.61%	3.50%	1.61%	-0.22%	-0.21%	0.00%	0.00%	0.26%	0.43%
2	2.53%	3.59%	1.59%	-0.19%	-0.18%	0.26%	0.26%	0.40%	0.34%
3	2.11%	2.94%	1.57%	-0.02%	-0.01%	0.62%	0.62%	0.43%	0.44%
4	1.44%	2.03%	1.18%	0.27%	0.25%	1.06%	0.98%	0.55%	0.56%
5	0.80%	1.14%	0.79%	0.55%	0.50%	1.36%	1.28%	0.68%	0.68%
10	-0.09%	0.00%	0.00%	0.93%	0.87%	1.15%	1.47%	1.00%	0.92%
20	0.43%	0.72%	0.41%	0.71%	0.66%	0.98%	1.26%	0.87%	0.81%
∞	0.40%	0.68%	0.82%	0.73%	0.67%	0.97%	1.27%	0.88%	0.81%

TABLE 15. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE PORK RETAIL PRICE (PRET$)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	2.14%	2.86%	1.20%	-0.18%	-0.17%	0.00%	0.00%	0.22%	0.35%
2	2.09%	2.95%	1.19%	-0.16%	-0.16%	0.22%	0.22%	0.33%	0.28%
3	1.73%	2.41%	1.18%	-0.02%	-0.01%	0.51%	0.50%	0.35%	0.37%
4	1.18%	1.66%	1.18%	0.22%	0.20%	0.88%	0.81%	0.45%	0.46%
5	0.65%	0.94%	0.79%	0.45%	0.42%	1.12%	1.05%	0.56%	0.56%
10	-0.08%	0.00%	0.00%	0.77%	0.71%	0.94%	1.21%	0.82%	0.76%
20	0.35%	0.59%	0.41%	0.58%	0.55%	0.81%	1.04%	0.71%	0.66%
∞	0.32%	0.56%	0.41%	0.60%	0.56%	0.80%	1.04%	0.72%	0.67%

TABLE 16. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE PRODUCER PRICE INDEX (PPI)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	1.03%	-1.05%	-0.40%	0.04%	0.04%	0.00%	0.00%	-0.53%	-0.85%
2	1.61%	-0.50%	0.00%	-0.23%	-0.21%	-0.78%	-0.47%	-0.83%	-0.73%
3	2.37%	0.64%	0.78%	-0.57%	-0.52%	-1.83%	-1.09%	-0.89%	-0.90%
4	3.51%	2.20%	1.57%	-1.06%	-1.00%	-2.77%	-1.77%	-1.11%	-1.12%
5	4.74%	3.87%	2.36%	-1.59%	-1.48%	-3.42%	-2.39%	-1.35%	-1.36%
10	7.40%	7.38%	3.69%	-2.57%	-2.40%	-3.28%	-3.00%	-2.01%	-1.86%
20	5.89%	5.29%	2.85%	-1.98%	-1.84%	-2.79%	-2.39%	-1.66%	-1.55%
∞	6.05%	5.52%	3.27%	-2.04%	-1.90%	-2.77%	-2.43%	-1.71%	-1.59%

TABLE 17. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE CONSUMER PRICE INDEX (CPI)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	-9.30%	-12.44%	-4.02%	1.50%	1.39%	0.00%	0.00%	-0.95%	-1.52%
2	-8.42%	-11.87%	-3.57%	1.17%	1.09%	-0.92%	-1.27%	-1.54%	-1.40%
3	-6.35%	-8.81%	-2.35%	0.30%	0.29%	-2.09%	-2.70%	-1.82%	-1.90%
4	-3.67%	-5.19%	-0.39%	-0.85%	-0.79%	-3.51%	-4.03%	-2.34%	-2.38%
5	-1.37%	-2.07%	1.18%	-1.85%	-1.71%	-4.32%	-4.99%	-2.84%	-2.83%
10	0.34%	-0.01%	2.05%	-2.62%	-2.45%	-2.80%	-5.02%	-3.79%	-3.49%
20	-1.05%	-1.93%	0.81%	-2.05%	-1.91%	-2.55%	-4.57%	-3.41%	-3.18%
∞	-1.05%	-1.94%	1.22%	-2.05%	-1.91%	-2.48%	-4.55%	-3.43%	-3.19%

consistent. In the first year, the retail beef price falls as increased beef production is associated with some liquidation. Since the retail beef price falls, it is expected that the fed steer price would fall also since in addition to the retail beef price falling, packers' margins would also shrink from the increased cost of turning slaughtered animals to meat. The model, however, shows that the fed steer price would increase because fed slaughter is less than what occurred under the baseline.

Increases in the consumer price index cause the prices of other goods for consumers to increase (table 17). The short run response of the model shows that the retail price of beef falls as consumers have less money to spend on meat. As beef prices fall, liquidation occurs (increase in breeding herd slaughter) and beef production actually increases. The equilibrium response is that production is about 2 percent lower whereas retail prices raise about one percent (and less than the inflationary shock). Although declining farm prices and an increased retail price cause concern about the consistency of the model, increased packer margins are responsible for a portion of this result. Real prices are lower at all levels of the market channel.

It is important to note that the inconsistencies that arose in the above inflationary shocks could be the direct result that shocking each of the price indexes separately is not appropriate since any increase in inflation would be reflected in both the consumer and producer levels simultaneously. A more appropriate inflationary shock would involve shocking both levels at the same time. Taking this approach would probably reduce the inconsistencies presented above.

Feed Cost Shocks

Tables 18 and 19 show that the changes in prices and quantities that occur in response to higher feed costs (corn and soybean meal prices) are consistent with expectations. The magnitude of these changes requires further discussion. Ospina and Shumway (1980, 1981) report the long run elasticity of beef supply with respect to corn price is -.11. This model shows the long run elasticity to be -.02. The difference between these results seems to lie in the specification of the models. Ospina and Shumway do not incorporate animal numbers in their model. They only estimate the supply of each meat category (i.e., choice, good, utility). Without incorporating animal numbers, their model appears to lack the biological restrictions that are inherent in the beef industry. Folwell and Shapouri show results similar to these, particularly for the long run. Heien and Matthews report results that are closer to those found in this model. The long run elasticity of beef supply with respect to corn price is reported by Heien and Matthews at -.04. Westcott, et al., using a quarterly model generated similar results to these in this analysis both in sign and magnitude of the coefficients. Their analysis included only a five year simulation period and examined the effects of a 25 percent change in feed grain prices, however.

The short run response from increasing feed costs is for liquidation to occur initially, causing beef production to increase. This, in turn, lowers the prices both at farm and retail. The intermediate and equilibrium responses show lower beef production and higher farm and retail prices. The long run elasticities of beef variables with respect to soybean meal price and corn price increases are very similar, as expected.

TABLE 18. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE SOYBEAN MEAL PRICE (SMEAL$)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	-0.23%	-0.48%	-0.49%	0.10%	0.10%	0.00%	0.00%	-0.02%	-0.03%
2	-0.24%	-0.57%	-0.40%	0.11%	0.10%	-0.08%	-0.08%	-0.04%	-0.04%
3	-0.12%	-0.38%	-0.39%	0.05%	0.04%	-0.21%	-0.19%	-0.06%	-0.07%
4	0.09%	-0.11%	0.39%	-0.04%	-0.04%	-0.34%	-0.31%	-0.10%	-0.10%
5	0.29%	0.17%	0.39%	-0.13%	-0.13%	-0.44%	-0.41%	-0.14%	-0.15%
10	0.62%	0.60%	0.41%	-0.26%	-0.24%	-0.38%	-0.48%	-0.25%	-0.24%
20	0.46%	0.37%	0.28%	-0.20%	-0.18%	-0.33%	-0.42%	-0.22%	-0.20%
∞	0.46%	0.39%	0.41%	-0.20%	-0.18%	-0.33%	-0.42%	-0.22%	-0.20%

TABLE 19. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN THE CORN PRICE (CORN$)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	-0.26%	-0.73%	-0.40%	0.11%	0.10%	0.00%	0.00%	-0.06%	-0.08%
2	-0.27%	-0.88%	-0.40%	0.12%	0.10%	-0.06%	-0.09%	-0.10%	-0.11%
3	-0.12%	-0.66%	-0.39%	0.05%	0.04%	-0.15%	-0.20%	-0.14%	-0.14%
4	0.09%	-0.38%	0.39%	-0.04%	-0.04%	-0.25%	-0.31%	-0.18%	-0.18%
5	0.28%	-0.13%	0.39%	-0.12%	-0.12%	-0.33%	-0.40%	-0.23%	-0.22%
10	0.48%	0.10%	0.29%	-0.20%	-0.18%	-0.21%	-0.42%	-0.31%	-0.28%
20	0.34%	-0.10%	0.20%	-0.15%	-0.13%	-0.18%	-0.37%	-0.27%	-0.26%
∞	0.34%	-0.09%	0.21%	-0.15%	-0.14%	-0.17%	-0.37%	-0.27%	-0.26%

Income Shock

Table 20 shows the results from shocking per capita consumer income by 10 percent. In the short run, beef prices rise considerably since production is almost fixed. However, beef production does decrease slightly as the beef breeding herd is built. In the intermediate run (four to five years), beef production begins to increase and moderates the initial price increases. The equilibrium response is that beef prices moderate as beef production increases in response to the higher beef prices. The equilibrium results show an income flexibility with respect to the retail price of beef of .29 and an income elasticity with respect to beef supply of .41 whereas Heien and Matthews find an income flexibility of .88 and an income elasticity of .34.

Exogenous Shocks Summary

Overall, the model responds correctly to shocks of exogenous variables. The short run response of the model is for prices to adjust since beef supply is nearly fixed, but over time the supply side adjusts to moderate the changes in beef prices. Interestingly, the model shows that changes in macroeconomic variables cause more change to the beef industry than variables that are more agriculturally specific. Analysis of the structural equations estimated in this chapter shows that each describes the variation of the dependent variable very well. The model simulations also show that it does an adequate job of replicating the endogenous variables in both in-sample and out-of-sample evaluations. Shocks of exogenous variables in the model provide consistent results with a priori expectations.

8. IMPACT OF ALTERNATIVE SCENARIOS ON THE BEEF INDUSTRY

In the previous section, the impacts of constant and persistent changes in (one at a time) selected exogenous variables on the beef model were investigated. In this section, a larger set of changes in exogenous variables will be considered. In particular, this section will investigate the effects of alternative agricultural policies. Changes to the size of the beef industry can often be attributed to impacts which are not under direct control of the industry. Government policy changes directed at specific agricultural commodities (e.g., feedgrains and dairy) have spillover effects in the beef industry. Likewise changes in the general economy can lead to significant changes in the beef industry.

The empirical model constructed in the previous section is used to explore the effects of three alternative scenarios on the beef industry. The first two scenarios deal with changes in government policy. One is the feedgrains policy enacted in the Food Security Act of 1985 (FSA85) and the other in the Dairy Termination Program contained in FSA85. The remaining scenario involves analyzing the impacts of declining demand for beef. Although these three scenarios reflect only a subset of the possible scenarios that could be evaluated, they have often been associated with the changes that have occurred in the beef industry during the 1980s.

TABLE 20. SELECTED VARIABLE RESPONSES FROM A 10% INCREASE IN CONSUMER INCOME (INCOME/POP)

Period	S&H$	KCS$	BRET$	BPROD	BPERCAPR	BCOW#	CATOFRMS	SAHFDSL	CATPL
1	15.23%	20.36%	10.84%	-1.27%	-1.21%	0.00%	0.00%	1.55%	2.49%
2	14.72%	20.85%	10.71%	-1.14%	-1.06%	1.54%	1.53%	2.31%	1.95%
3	12.06%	16.77%	9.02%	-0.10%	-0.10%	3.59%	3.58%	2.48%	2.54%
4	7.95%	11.13%	6.67%	1.61%	1.49%	6.18%	5.70%	3.12%	3.17%
5	4.17%	5.98%	4.33%	3.24%	3.01%	7.86%	7.39%	3.85%	3.89%
10	-0.55%	-0.03%	1.23%	5.24%	4.90%	6.40%	8.26%	5.62%	5.19%
20	2.42%	4.01%	2.85%	3.97%	3.72%	5.51%	7.07%	4.85%	4.52%
∞	2.22%	3.79%	2.86%	4.05%	3.80%	5.43%	7.10%	4.93%	4.58%

Each of the scenarios will be evaluated independently. The first section develops the baseline that will be used for comparison purposes for each scenario. The following sections analyze in detail each of the alternative scenarios.

Baseline

For convenience, the baseline was constructed by adjusting each of the structural equations by the residuals found in the three stage least squares estimation for the in-sample period and by the forecast errors each of the structural equations generated in the out-of-sample period (1988 and 1989). This process allows the baseline values for the endogenous variables in the system to align to the actual observed values for the endogenous variables. Although the scenarios start at different years, the years that they have in common contain the same values for the baseline (the historically observed values). This construction allows for easier interpretation of the scenarios that are to follow since the scenario results may be directly compared to the observed historical values.

Dairy Termination Program (DTP)

The Food Security Act of 1985 contained a provision that allowed dairy producers to submit bids to terminate milk production for a five year period. Commonly known as the Dairy Termination Program (DTP), this provision involved the liquidation of dairy cows, replacement heifers, and calves greater than 18 months of age for those dairy producers whose bids were accepted. This liquidation occurred over a 17 month period from April 1986 to August 1987. In order to offset the increased supply of beef, provisions were included for the U.S. Department of Agriculture to purchase up to 400 million pounds of beef or allow some dairy animals to be exported instead of slaughtered.

The beef industry was concerned about the negative impact the additional supplies of beef would have on live cattle prices and successfully lobbied to keep another DTP from occurring under the 1990 Farm Bill. The following will analyze the equilibrium prices and quantities that would have resulted from 1986 through 1989 in the beef industry in the absence of the DTP.

Data Assumptions

The DTP took place in three time periods: April 1, 1986 - August 31, 1986; September 1, 1986 - February 28, 1987; March 1, 1987 - August 31, 1987. In order to integrate these three periods into the annual model, it was assumed that two-thirds of the middle period's slaughter took place in 1986 and one-third in 1987 while period 1 occurred in 1986 and period 3 in 1987. USDA reported dairy cow slaughter and dairy heifer slaughter that occurred under each period of the DTP. In order to remove the impact of the DTP, dairy cow slaughter was reduced by 625 thousand head in 1986 and 224 thousand head in 1987 (U.S. Department of Agriculture, NEWS). Dairy heifer slaughter was reduced by 212 thousand head in 1986 and 80 thousand head in 1987. Dairy cows on farms were allowed to adjust to the decline in dairy cow slaughter and dairy heifer slaughter. Since the milk price was near the support price, it was assumed the additional dairy cows would not cause the milk price to change since government removals would increase to offset the increased supply of milk.

Results

Results from removing the effects of DTP are summarized in table 21. Each year of the analysis is shown along with the average of the four year period. Interpretation of the results and their impact on the beef industry will be discussed in the following paragraphs.

The decline in beef production in 1986 (due in large part to the reduced dairy slaughter) of .38 billion pounds causes the Omaha fed steer price to increase by $2.30 per hundredweight. This result is consistent with Marsh who found an increase of $1.67 per hundredweight in period 1 of the DTP. Similar results are seen in the Kansas City feeder steer price (increase of $3.33 per hundredweight) and beef retail price (increase of $0.05 per pound).

Beef production declines in 1987, relative to the baseline, but the decline is moderated by slightly higher beef slaughter as well as an increase in slaughter weights. The results found in 1987 are not dramatically different than the baseline results because the increase in beef production nearly offsets the decrease in dairy slaughter. The major difference occurs in cattle and calves (1.3 percent higher) since the dairy cow herd has increased relative to the baseline.

The third and fourth years of the analysis show some interesting results for the beef industry. Since the dairy cow herd remains larger (over one million head larger) in the absence of the DTP, the offspring of these additional dairy cows cause the supply of beef to increase relative to the level of supply associated with the DTP. The increased supply of beef lowers the Omaha fed steer price by $1.80 per hundredweight in 1988 and $2.68 per hundredweight in 1989. Declines in the other beef prices also occur the last two years of the analysis. A two million head increase in cattle and calves observed during the latter two years of the analysis is due mainly to the increased dairy cow herd and its associated offspring.

The average of the four year period shows beef production slightly higher (.3 percent) and beef prices slightly lower (-.5 percent to -.8 percent) in the absence of the DTP. The beef industry received lower prices during the first two years of the baseline (which includes the DTP). However, since the program reduced the supply of dairy cattle for the following years, the beef industry actually enjoyed higher prices than they would have received without a DTP. On average over the four years, steer and heifer prices were $0.52 per hundredweight higher under the baseline. Successful efforts by the beef industry to stop future dairy termination programs is a gain for the industry in the short run but may be detrimental to the industry in the long run.

Continuation of the 1981 Farm Bill

With the signing of the Food Security Act of 1985 (FSA85), the signals (in the form of crop prices) received by beef producers were quite different than those experienced under the 1981 Farm Bill. Loan rates declined under FSA85 which allowed feed prices to fall for the beef industry. This scenario will analyze the impact of the changes in crop policy enacted under FSA85 on the beef industry relative to a continuation of the 1981 Farm Bill.

TABLE 21. DAIRY TERMINATION PROGRAM SCENARIO RESULTS

Year	1986	1987	1988	1989	Average 1986-89
Beef Production (billion lbs.)					
Baseline	24.37	23.57	23.59	23.14	23.67
Without DTP	23.99	23.55	23.86	23.51	23.73
Difference	-0.38	-0.02	0.27	0.37	0.06
% Difference	-1.6%	-0.1%	1.1%	1.6%	0.3%
Beef Cows (million head)					
Baseline	33.75	33.95	33.18	33.52	33.60
Without DTP	33.75	34.06	33.35	33.67	33.71
Difference	0.00	0.11	0.17	0.15	0.11
% Difference	0.0%	0.3%	0.5%	0.4%	0.3%
Cattle on Farms (million head)					
Baseline	105.38	102.12	99.62	99.18	101.58
Without DTP	105.38	103.46	101.75	101.46	103.01
Difference	0.00	1.34	2.13	2.28	1.44
% Difference	0.0%	1.3%	2.1%	2.3%	1.4%
Omaha, 900-1100 lb. Steer Price (dollars/cwt)					
Baseline	57.75	65.12	69.54	72.52	66.23
Without DTP	60.05	65.24	67.74	69.84	65.72
Difference	2.30	0.12	-1.80	-2.68	-0.52
% Difference	4.0%	0.2%	-2.6%	-3.7%	-0.8%
Kansas City, 600-700 lb. Steer Price (dollars/cwt)					
Baseline	62.79	71.00	83.67	86.20	75.92
Without DTP	66.12	71.32	80.96	82.16	75.14
Difference	3.33	0.32	-2.71	-4.04	-0.78
% Difference	5.3%	0.5%	-3.2%	-4.7%	-1.0%
Beef Consumption Per Capita (lbs.)					
Baseline	78.36	73.37	72.68	68.77	73.30
Without DTP	77.23	73.32	73.45	69.81	73.45
Difference	-1.13	-0.05	0.77	1.04	0.16
% Difference	-1.4%	-0.1%	1.1%	1.5%	0.2%
Retail Beef Price (dollars/lb.)					
Baseline	2.31	2.43	2.55	2.70	2.50
Without DTP	2.36	2.43	2.51	2.64	2.49
Difference	0.05	0.00	-0.04	-0.06	-0.01
% Difference	2.2%	0.0%	-1.6%	-2.2%	-0.5%

Data Assumptions

With a continuation of the 1981 Farm Bill, it is assumed that the corn loan rate is fixed at $2.55, its 1985/86 level. It is anticipated that the large level of corn stocks will depress the corn market price down to the loan rate. A linear linkage was estimated between the corn and soybean meal price over the 1965 to 1985 period (the R-square was .74). The equation showed that each $0.01 per bushel increase in the corn price caused a $0.47 per ton increase in the soybean meal price. The soybean meal price under the FSA85 was adjusted by this linkage to determine the price that would have occurred with a continuation of the 1981 Farm Bill. The soybean meal prices obtained are: $212.23 for crop year 1986/87, $250.67 for 1987/88, and $232.53 for 1988/89. Although a more accurate soybean meal price could be found by developing an oilseed model and a feedgrain model, such development is beyond the scope of this research.

Results

The analysis begins in 1987 since the 1986/87 crop prices are the first to show changes from the baseline and they do not enter the beef model until calendar year 1987. Table 22 presents the results of continuing the 1981 Farm Bill relative to the baseline. In the first year of the scenario, beef production increases as liquidation of the beef cow herd begins in response to higher input (feed) prices and a lower feeder steer price. Both the beef retail price (-$0.04) and Omaha fed steer price (-$1.41) fall as the increased supply of meat enters the marketplace. The feeder steer price falls over 6 percent while the Omaha fed steer price falls 2.2 percent. This is due in part to feedlots bidding less aggressively for feeder animals since the cost of fattening the animal increases with the increased crop prices.

In the second year of the analysis, liquidation continues to occur, causing beef production to increase although the increase in production is much less than in the first year. Prices at all levels of the marketing channel continue to fall relative to the baseline but the decline in prices is much less than observed during 1987.

By 1989, over one million head of cattle and calves are liquidated. There are 360 thousand head fewer beef cows on farms by the beginning of 1989. As a result of the liquidation, beef production under the 1981 Farm Bill scenario falls below the baseline by the third year of the analysis. The decline in production allows prices to increase from 0.7 percent at the retail level to 1.6 percent at the feeder calf level.

The last column in table 22 shows the average over the three years of analysis. Overall, most of the variables do not exhibit major changes from their baseline levels. The one exception is the feeder steer price which falls $1.82 per hundredweight relative to the baseline. Adoption of the crop policy provisions contained in the Food Security Act of 1985 was clearly beneficial to cow-calf producers.

Stable Retail Demand (SRD)

The demand for beef has been studied extensively during the 1980s regarding whether a structural shift has occurred. Yet, no consensus has been reached by the professional

TABLE 22. 1981 FARM BILL SCENARIO RESULTS

Year	1987	1988	1989	Average 1987-89
Beef Production (billion lbs.)				
Baseline	23.57	23.59	23.14	23.43
1981 Farm Bill	23.79	23.68	23.01	23.49
Difference	0.22	0.09	-0.13	0.06
% Difference	0.9%	0.4%	-0.6%	0.3%
Beef Cows (million head)				
Baseline	33.95	33.18	33.52	33.55
1981 Farm Bill	33.95	32.99	33.16	33.37
Difference	0.00	-0.19	-0.36	-0.18
% Difference	0.0%	-0.6%	-1.1%	-0.5%
Cattle on Farms (million head)				
Baseline	102.12	99.62	99.18	100.31
1981 Farm Bill	102.12	98.88	97.88	99.63
Difference	0.00	-0.74	-1.30	-0.68
% Difference	0.0%	-0.7%	-1.3%	-0.7%
Omaha, 900-1100 lb. Steer Price (dollars/cwt)				
Baseline	65.12	69.54	72.52	69.06
1981 Farm Bill	63.71	68.92	73.50	68.71
Difference	-1.41	-0.62	0.98	-0.35
% Difference	-2.2%	-0.9%	1.4%	-0.5%
Kansas City, 600-700 lb. Steer Price (dollars/cwt)				
Baseline	71.00	83.67	86.20	80.29
1981 Farm Bill	66.60	81.19	87.62	78.47
Difference	-4.40	-2.48	1.42	-1.82
% Difference	-6.2%	-3.0%	1.6%	-2.3%
Beef Consumption Per Capita (lbs.)				
Baseline	73.37	72.68	68.77	71.61
1981 Farm Bill	74.01	72.94	68.39	71.78
Difference	0.64	0.26	-0.38	0.17
% Difference	0.9%	0.4%	-0.6%	0.2%
Retail Beef Price (dollars/lb.)				
Baseline	2.43	2.55	2.70	2.56
1981 Farm Bill	2.39	2.53	2.72	2.55
Difference	-0.04	-0.02	0.02	-0.01
% Difference	-1.6%	-0.8%	0.7%	-0.5%

community. The retail demand equation estimated in the previous section was the culmination of looking at a number of alternative specifications. No other specification evaluated in the empirical chapter performed as well as the one that included the stochastic trend. Although this specification does not shed any light on the specific cause of the decrease in beef demand, it does allow an assessment of the size of the beef industry under conditions where the demand decline in the early 1980s could have been halted.

Data Assumptions

Retail beef demand is stabilized in 1980 by holding the stochastic trend component constant at its 1980 value. That is, while the baseline allows demand to decline, the SRD scenario levels off the stochastic trend coefficient which shows a strong negative characteristic. It should be noted that this analysis involves only the beef industry and that a more rigorous analysis could be done by incorporating pork and poultry models into the analysis. The results are broken into three time periods: 1980 through 1983 (short run), 1984 through 1986 (intermediate run), and 1987 through 1989 (longer run).

Results

In the short run, SRD scenario production is somewhat lower than the baseline as heifers are retained to increase the breeding herd in response to stabilized demand (table 23). The result of lower production and stabilized demand cause prices at all levels of the marketing channel to increase by more than 8 percent. By the intermediate run, beef cows have increased over two million head while cattle and calves have increased over seven million head compared to the baseline. Prices continue to increase dramatically as demand remains stable and production begins to respond to the increased demand.

In the longer run, production responds more rapidly (three billion pounds higher). Prices continue to be higher than the baseline in the longer run period but the percentage increases are somewhat less than the intermediate period. The aggregation of the results may lead the reader to question the stability of the model, but in 1989 prices are very near the baseline levels showing the model is converging towards an equilibrium. The longer run shows seven million head more beef cows and over 20 million head more cattle and calves. The last column in table 23 shows that stabilizing demand results in a significantly larger beef industry. The beef cow herd averages over 39 million head for the entire period compared with 36 million head under the baseline. The retail beef price averages $0.40 higher than the baseline average. The reader is again cautioned that the results are obtained by holding the other meat prices constant and would likely be moderated as additional livestock industries are encouraged to expand production.

Undoubtedly, the beef industry has been affected by a number of factors beyond the direct control of the industry during the decade of the 1980s. The scenarios evaluated in this section lead to results that the beef industry can use to remain a viable industry through the decade of the 1990s. The beef subsector is not insulted from the rest of the economy and must evaluate new information to respond in a manner that leads to a healthier industry.

TABLE 23. RETAIL DEMAND SCENARIO RESULTS

Year	1981-83	1984-86	1987-89	Average 1981-89
Beef Production (billion lbs.)				
Baseline	22.72	23.90	23.43	23.35
SRD	22.54	24.01	26.66	24.40
Difference	-0.18	0.11	3.23	1.05
% Difference	-0.8%	0.5%	13.8%	4.5%
Beef Cows (million head)				
Baseline	38.65	35.55	33.55	35.91
SRD	38.91	38.19	40.73	39.28
Difference	0.26	2.65	7.18	3.36
% Difference	0.7%	7.4%	21.4%	9.4%
Cattle on Farms (million head)				
Baseline	114.93	109.44	100.31	108.23
SRD	115.73	116.87	120.46	117.69
Difference	0.80	7.43	20.16	9.46
% Difference	0.7%	6.8%	20.1%	8.7%
Omaha, 900-1100 lb. Steer Price (dollars/cwt)				
Baseline	63.53	60.32	69.06	64.30
SRD	70.65	77.80	83.18	77.21
Difference	7.13	17.48	14.12	12.91
% Difference	11.2%	29.0%	20.5%	20.1%
Kansas City, 600-700 lb. Steer Price (dollars/cwt)				
Baseline	64.92	64.21	80.29	69.81
SRD	75.62	90.71	101.58	89.30
Difference	10.70	26.49	21.29	19.49
% Difference	16.5%	41.3%	26.5%	27.9%
Beef Consumption Per Capita (lbs.)				
Baseline	77.36	78.40	71.61	75.79
SRD	76.77	78.72	80.78	78.76
Difference	-0.59	0.32	9.17	2.97
% Difference	-0.8%	0.4%	12.8%	3.9%
Retail Beef Price (dollars/lb.)				
Baseline	2.40	2.35	2.56	2.44
SRD	2.59	2.83	3.07	2.83
Difference	0.19	0.49	0.51	0.40
% Difference	8.1%	20.7%	19.8%	16.2%

9. MODEL EVALUATION

The model specified and estimated in this study appears to reasonably replicate the behavior of the beef industry over the past 25 years. Structural components include cow-calf producer, feed lot operator, meat packer, and consumer. Additional attention could have been devoted to endogenizing exports and imports of beef in a larger trade model. Other marketing agents including distributors and retailers might also have been included in the analysis.

Any empirical analysis of industry behavior or commodity supply and utilization is likely to be constrained by data limitations. This study was no exception. Beef cow slaughter data were unavailable for most of the period of analysis. Data reflecting the number of heifers bred and retained for the breeding herd is calculated as a residual series and, as such, is subject to substantial error.

Analyzing the declining demand for beef occurred without regard to the simultaneous adjustments likely to occur in the pork, poultry, and other meat industries. Stabilization or further weakening of beef demand has important consequences for these other industries as well.

In this analysis, the coefficients of all parameters were of the expected sign. However, in several cases the choice of the normalized (dependent) variable in the simultaneous estimation was critical to insure correct signs of explanatory variables and/or stability of the model. Conclusions reached as a result of these arbitrarily selected specifications must be viewed with at least some caution.

LITERATURE CITED

Arzac, Enrique R. and Maurice Wilkinson. "A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of Its Policy Implications." Amer. J. Agr. Econ. 61(1979): 297-308.

Beattie. B.R. and C.R. Taylor. The Economics of Production. New York: John Wiley and Sons, 1985.

Bedinger, Touba and Barry W. Bobst. "A Dynamic Analysis of Demand and Supply Relationships for the U.S. Beef Cattle Industry and their Policy Implications." University of Kentucky, Agricultural Economics Research Report 49, March 1988.

Bentley, Ernest and Richard Shumway. "Adaptive Planning Over the Cattle Price Cycle." So. J. Agr. Econ. 13(1981): 139-48.

Bentley, Ernest, James R. Waters, and C. Richard Shumway. "Determining Optimal Replacement Age of Beef Cows in the Presence of Stochastic Elements." So. J. Agr. Econ. 8(1976): 13-18.

Bessler, David A. and Jon A. Brandt. "Causality Tests in Livestock Markets." Amer. J. Agr. Econ. 64(1982): 140-44.

Boykin, C.C., H.C. Gilliam Jr., and R.A. Gustafson. Structural Characteristics of the Beef Cattle Raising in the United States. AER-450. U.S. Dept. of Agr., Econ. Stat. Coop. Serv., March 1980.

Brandt, Jon A., Robert E. Young II, and Abner W. Womack. "Modelling the Impacts of Two Agricultural Policies on the U.S. Livestock Sector: A Systems Approach." Agricultural Systems 35(1991): 129-55.

Braschler, C. "The Changing Demand Structure for Pork and Beef in the 1970s: Implications for the 1980s." So. J. Agr. Econ. 15(1983): 105-10.

Brown, Douglas Scott. "An Econometric Model of the U.S. Beef Sector with Emphasis on Policy Evaluation." Unpublished Master of Science Thesis, University of Missouri-Columbia, 1991.

Brown, D. Scott and Jon A. Brandt. "Supply Response and Price Expectations: An Analysis of the Fed-Beef Industry." In Applied Commodity Price Analysis, Forecasting, and Market Risk Management, NCR-134, Chicago, Illinois, April 20-21, 1989, pp. 354-66.

Brown, Deborah J. and Lee F. Schrader. "Cholesterol Information and Shell Egg Consumption." Amer. J. Agr. Econ. 72(1990): 548-55.

Burt, Oscar R. "Optimal Replacement Under Risk." J. Farm Econ. 47(1965): 324-45.

Buse, Rueben C. (editor). The Economics of Meat Demand. Department of Agricultural Economics, University of Wisconsin, 1989, 375 pp.

Chalfant, James A. and Julian M. Alston. "Accounting for Changes in Tastes." J. Pol. Econ. 96(1986): 391-410.

Chavas, J.P. "Structural Change in the Demand for Meats." Amer. J. Agr. Econ. 65(1983): 148-53.

Chavas, Jean-Paul. "On the Structure of Demand for Meat." In The Economics of Meat Demand. (Rueben C. Buse, ed.), Department of Agricultural Economics, University of Wisconsin, 1989, pp. 125-35.

Crom, Richard J. Economics of the U.S. Meat Industry. AIBN-545, U.S. Dept. of Agr., Econ. Res. Serv., November 1988.

Dahlgran, R.A. "Determinants of Structural Change in Demand Systems: An Application to U.S. Meat Demands." Paper presented at So. Agr. Econ. Assoc. Annual Meeting, Orlando, Florida, February 2-5, 1986,

Economic Report of the President, 1989. Council of Economic Advisors, U.S. G.P.O., Washington, D.C., 1989.

Ezekiel, Mordecai. "The Cobweb Theorem." Qtr. J. Econ. 52(1938): 255-80.

Folwell, Raymond J. and Hossein Shapouri. An Econometric Model of the U.S. Livestock and Broiler Sectors. Washington State University, Technical Bulletin 0094, 1980.

Freebairn, J.W. and Gordon C. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." Amer. J. Agr. Econ. 51(1975): 676-88.

Gilliam, Henry C. Jr. The U.S. Beef Cow-Calf Industry. AER-515, U.S. Dept. of Agr., Econ. Res. Serv., September 1984.

Grundmeier, Eric, Karl Skold, H.H. Jenson, and S.R. Johnson. "CARD Livestock Model Documentation: Beef." Technical Report 88-TR2, Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa, March 1989.

Harvey, Andrew C. "The Kalman Filter and its Application to Econometrics and Time Series." Methods of Operations Research 44(1982): 3-18.

Heien, Dale and Jimmy L. Matthews. "An Econometric Model of the U.S. Beef Cattle Industry." USDA/ERS Working Paper, 1973.

Jarvis, Lovell S. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector." J. Pol. Econ. 82(1974): 489-520.

Johnson, D. Gale, John M. Connor, Timothy Josling, Andrew Schmitz, and G. Edward Schuh. "Competitive Issues in the Beef Sector: Can Beef Compete in the 1990s?" University of Minnesota, Hubert H. Humphrey Institute of Public Affairs, Humphrey Institute Report No. 1, October 1989.

Leuthold, R.M. and E. Nwagbo. "Changes in the Retail Elasticities of Demand for Beef, Pork, and Broilers." Illinois Agr. Econ., July 1977, pp. 22-27.

Marsh, John M. "The Effects of the Dairy Termination Program on Live Cattle and Wholesale Beef Prices." Amer. J. Agr. Econ. 70(1988): 919-28.

McNaughton, Janet P., Carolyn R. Boyle, and Ellen S. Bryant. Beef and Pork Consumers: Socioeconomic, Personal, and Lifestyle Characteristics. Mississippi Agricultural Experiment Station Technical Bulletin 172, June 1990.

Missouri Farm News Service. "It's a Small World...and Just a Few Companies Own It." Extension and Ag Information, University of Missouri-Columbia, March 1991.

Moschini, Giancarlo and Karl D. Meilke. "Modeling the Pattern of Structural Change in U.S. Meat Demand." Amer. J. Agr. Econ. 71(1989): 253-61.

Moschini, G. and K.D. Meilke. "Parameter Stability and the U.S. Demand for Beef." West. J. Agr. Econ. 9(1984): 271-82.

Muth, John F. "Rational Expectations and the Theory of Price Movements." Econometrica 29(1961): 315-35.

Nelson, Glenn and Thomas Spreen. "Monthly Steer and Heifer Supply." Amer. J. Agr. Econ. 60(1978): 117-25.

Nerlove, Marc. The Dynamics of Supply: Estimation of Farmers' Response to Price. Johns Hopkins Press, 1958.

Nyankori, J.C.O. and G.H. Miller. "Some Evidence and Implications of Structural Change in Retail Demand for Meats." So. J. Agr. Econ. 14(1982): 65-70.

Ospina, E. and C.R. Shumway. Disaggregated Econometric Analysis of U.S. Slaughter Beef Supply. Texas Agr. Exp. Sta. Tech. Mono. 9, February 1980.

Ospina, Enrique and C. Richard Shumway. "Impact of Corn Prices on Slaughter Beef Composition and Prices." Amer. J. Agr. Econ. 63(1981): 700-03.

Perrin, R.K. "Asset Replacement Principles." Amer. J. Agr. Econ. 54(1972): 60-67.

Plain, Ronald L. and Joseph E. Williams. "Adaptive Planning Under Price Uncertainty in Pork Production." So. J. Agr. Econ. 13(1981): 39-46.

Purcell, Wayne D. "The Case of Beef Demand -- A Failure by the Discipline." In Choices, 2nd Quarter, 1989, pp. 16-19.

Reutlinger, Shlomo. "Short Run Beef Supply Response." Amer. J. Agr. Econ. 48(1966): 909-19.

Rosen, Sherwin. "Dynamic Animal Economics." Amer. J. Agr. Econ. 69(1987): 547-57.

Smallwood, David M., Richard C. Haidacher, and James R. Blaylock. "A Review of the Literature on Meat Demand." In The Economics of Meat Demand (Rueben C. Buse, ed.), Department of Agricultural Economics, University of Wisconsin, 1989, pp. 93-124.

Stillman, Richard P. "A Quarterly Model of the Livestock Industry." USDA-ERS, Tech. Bul. #1711, Washington, D.C., 1985.

Theil, Henri. Principles of Econometrics. New York: John Wiley and Sons, 1971.

Trapp, James A. "Investment and Disinvestment Principles with Nonconstant Prices and Varying Firm Size applied to the Beef Breeding Herds." Amer. J. Agr. Econ. 67(1986): 691-703.

United States Department of Agriculture. Agricultural Statistics, 1988. USDA, U.S. G.P.O., Washington, D.C., 1988.

Cattle on Feed. Crop Reporting Board, Washington, D.C., various issues.

Economic Indicators of the Farm Sector. Costs of Production -- Livestock and Dairy, 1989. ECIFS 9-1, Econ. Res. Serv., Washington, D.C., August 1990.

Livestock and Meat Statistics, 1984-88. SBN-784, Econ. Res. Serv., Washington, D.C., September 1989.

Livestock and Poultry Situation and Outlook Report. Econ. Res. Serv., Washington, D.C., various issues.

NEWS. News Div., Office of Information, Washington, D.C., August 1986.

Westcott, Paul C., Richard P. Stillman, and Keith J. Collins. "Quarterly Livestock Sector Adjustments to Changes in Feed Grain Prices." Agr. Econ. Res. 39(1987): 13-24.

Wohlgenant, Michael K. "Structural Shifts in Demand for Meats: Taste or Quality Changes?" Selected paper for AAEA Annual Meeting, Logan, Utah, August 1982.

Wohlgenant, Michael K. "Discussion: Assessing Structural Change in Demand for Food Commodities." So. J. Agr. Econ. 15(1986): 39-41.

Yager, William A., R. Clyde Greer, and Oscar R. Burt. "Optimal Policies for Marketing Cull Beef Cows." Amer. J. Agr. Econ. 62(1980): 455-67.

Yanagida, John F. and Roger K. Conway. "The Annual Livestock Model: Beef, Pork, Poultry and Eggs, and Dairy Sectors." USDA, ERS Documentation Manual, November 1979.

APPENDIX

A.1. VARIABLE DEFINITION AND DATA SOURCES

Variable	Definition	Units	Source
ENDOGENOUS			
ANONGR	Animals on Grass, Jan. 1	Thousand Head	1
BACK	Cattle Backgrounded	Thousand Head	1
BCONS	Total Beef Consumption	Million Pounds	2
BCOW#	Beef Cows on Farms, Jan. 1	Thousand Head	2
BHEIFBRD	Beef Heifers Bred	Thousand Head	1
BPERCAP	Per Capita Beef Consumption (Carcass Weight Basis)	Pounds per Person	2
BPERCAPR	Per Capita Beef Consumption (Retail Weight Basis)	Pounds per Person	2
BPROD	Beef Production, Including Farm Production	Million Pounds	2
BRET$	Beef Retail Price	Dollars per Pound	2
BSTOCK	Beef Ending Stocks	Million Pounds	2
BSUPP	Beef Supply	Million Pounds	2
CALDD	Calf Death Loss	Thousand Head	3
CALFCRP	Calf Crop	Thousand Head	2
CATDD	Cattle Death Loss, Not Calves or Cows	Thousand Head	1
CATOFD	Cattle on Feed, Total	Thousand Head	2
CATOFRMS	Cattle and Calves on Farms, Jan. 1	Thousand Head	2
CATPL	Cattle Placed on Feed	Thousand Head	1
CCEXP	Cow-Calf Expenses	Dollars per Cow	5
CCREPT	Cow-Calf Receipts	Dollars per Cow	5
COW$	Omaha Utility Cow Price	Dollars per Cwt.	2
FDEXP	Feedlot Expenses	Dollars per Cwt. of Weight Gain	5
KCS$	Steer Price, 600-700 Pounds, Kansas City	Dollars per Cwt.	2
S&H$	Steer Price, 900-1100 Pounds, Choice, Omaha	Dollars per Cwt.	2
SAHFDSL	Steer and Heifer Fed Slaughter	Thousand Head	2
SAHNFSL	Steer and Heifer Non-Fed Slaughter	Thousand Head	2
TBCOWSL	Total Beef Cow Slaughter	Thousand Head	1

Variable	Definition	Units	Source
EXOGENOUS			
A	Carcass to Retail Weight Conversion Factor	Percent	1
BEXPRT	Beef Exports	Million Pounds	2
BIMPRT	Beef Imports	Million Pounds	2
BULL#	Bulls on Farms, Jan. 1	Thousand Head	3
BULLSL	Bull and Stag Slaughter	Thousand Head	2
CALFSL	Calf Slaughter	Thousand Head	2
CATBAL	Balance for Cattle and Calves on Farms	Thousand Head	2
CATEX	Cattle Exports	Thousand Head	2
CATIM	Cattle Imports	Thousand Head	2
CATLOSS	Cattle on Feed Death Loss	Thousand Head	1
CORN$	Season Average Corn Price	Dollars per Bushel	3
CPI	Consumer Price Index (All Items less Food)	Index, 1982=100	4
CRET$	Broiler Retail Price	Dollars per Pound	2
D801	Dummy Variable for 1980 and 1981	1 in 80-81, otherwise 0	1
D812	Dummy Variable for 1981 and 1982	1 in 81-82, otherwise 0	1
DCOW#	Dairy Cows on Farms, Jan. 1	Thousand Head	2
DUMxx	Dummy Variable for Year 19xx	1 in 19xx, otherwise 0	1
DYHEBRD	Dairy Heifers Bred	Thousand Head	1
F&UI	Producer Price Index, Industrial Commodities, Fuel and Related Products and Power	Index, 1982=100	4
HAY$	Hay Price, Season Average Price	Dollars per Ton	3
INCOME	Consumer Expenditures for Food	Billion Dollars	4
INTRAT	Interest Rate, Commercial Paper, 6 Months	Percent	4
POP	U.S. Population	Million People	4
PPI	Producer Price Index, All Commodities	Index, 1982=100	4
PRET$	Pork Retail Price	Dollars per Pound	2
S75678	Shift for Years 1975 thru 1978	1 in 75-78, otherwise 0	1

Variable	Definition	Units	Source
SHIFTxx	Shift Variable in Year 19xx	1 from Year 19xx forward, otherwise 0	1
SMEAL$	Soybean Meal Price, Decatur, 44% Protein	Dollars per Ton	3
STREND	Stochastic Trend Approximation		1
TDCOWSL	Total Dairy Cow Slaughter	Thousand Head	1
TREND	Trend Variable	1 in 1965; 2 in 1966, ...	1
W	Mean Temperature and Mean Precipitation, December-May	Fahrenheit Degrees/ Inches	3
WAG$	Compensation per Employee per Week, Agriculture, Forestry, and Fisheries	Dollars per Week	4

SOURCES:
1) Derived Series

2) United States Department of Agriculture. Livestock and Meat Statistics, 1984-88. SBN-784. Econ. Res. Serv., Washington D.C., Sep. 1989.

3) United States Department of Agriculture. Agricultural Statistics, 1988. U.S. G.P.O., Washington D.C., 1988.

4) Economic Report of the President, 1989. Council of Economic Advisors, U.S. G.P.O., Washington D.C., 1989.

5) United States Department of Agriculture. Economic Indicators of the Farm Sector. Costs of Production -- Livestock and Dairy, 1989. ECIFS 9-1, Econ. Res. Serv., Washington D.C., August 1990.

TABLE A.2. DATA

YEAR	ANONGR	BACK	BCONS	BCOW#	BHEIFBRD	BPERCAP
1965	40045.30	44093.99	19586	33400	4665.85	100.803
1966	40359.15	43751.05	20747	33500	4708.93	105.550
1967	40205.57	43481.76	21440	33770	5057.28	107.896
1968	40160.72	41059.01	22236	34570	5587.60	110.787
1969	38840.40	40843.42	22602	35490	5138.70	111.516
1970	40272.30	43877.11	23391	36689	5230.71	114.075
1971	41772.19	43648.87	23493	37878	6039.19	113.132
1972	42268.21	43891.26	24258	38810	6250.91	115.569
1973	43124.69	47313.12	23043	40932	8026.49	108.740
1974	46237.81	56871.31	24683	43182	7591.08	115.422
1975	51489.02	56452.56	25675	45712	6143.38	118.882
1976	48309.42	51876.38	27770	43901	5122.72	127.362
1977	47281.38	46784.86	27199	41443	4705.31	123.497
1978	43298.49	42258.81	26235	38738	3908.38	117.862
1979	40674.22	41254.23	23712	37062	5896.38	105.359
1980	39857.02	45169.39	23513	37107	4938.83	103.236
1981	42603.67	49377.93	23977	38773	3703.84	104.184
1982	45122.76	46230.66	24118	39230	4706.31	103.724
1983	43466.19	46168.65	24821	37940	3817.05	105.711
1984	43683.86	43615.22	25000	37484	3429.75	105.485
1985	41766.25	40305.91	25472	35406	4424.43	106.453
1986	38340.96	38520.53	25935	33753	3189.20	107.347
1987	37866.83	35618.73	25205	33945	4337.01	103.342
1988	34870.59	34321.98	25191	33183	4155.41	102.361
1989	34781.09	34066.04	24261	33515	4081.11	97.540

YEAR	BPROD	BRET$	BSTOCK	BSUPP	CALDD	CALFCRP	CATDD	CATOFD	CATOFRM
1965	18699	0.820	260	19937	2607	43922	909.30	9979	109000
1966	19695	0.844	307	21137	2424	43537	905.15	10582	108862
1967	20183	0.846	275	21803	2512	43803	820.58	11268	108783
1968	20845	0.887	296	22620	2485	44315	811.73	11417	109371
1969	21126	0.986	353	23037	2591	45177	811.40	12534	110015
1970	21685	1.017	338	23830	2714	45871	851.30	13190	112369
1971	21904	1.081	366	23976	2808	46738	887.20	12770	114578
1972	22413	1.187	367	24739	3346	47682	1021.21	13912	117862
1973	21278	1.421	448	23635	4388	49194	1310.69	14432	121539
1974	23137	1.463	402	25200	4104	50873	1188.82	13643	127788
1975	23975	1.548	350	26135	4596	50183	1542.02	10170	132028
1976	25969	1.482	464	28392	3369	47384	996.42	12941	127980
1977	25279	1.484	316	27682	4000	45931	1213.39	12580	122810
1978	24241	1.819	405	26854	3860	43818	1195.49	13472	116375
1979	21447	2.263	459	24386	3700	42596	1182.22	13274	110864
1980	21643	2.376	432	24166	3618	44938	1077.03	12221	111242
1981	22389	2.387	335	24564	3359	44666	955.67	11598	114351
1982	22536	2.425	388	24811	3586	44200	1089.76	10618	115444
1983	23243	2.381	429	25562	3617	43885	1142.20	12051	115001
1984	23598	2.396	472	25850	3591	42470	1144.86	11594	113360
1985	23728	2.326	420	26271	3345	41050	1008.25	12453	109582
1986	24371	2.307	412	26919	3280	41182	1044.97	11731	105378
1987	23566	2.425	386	26247	3100	40152	1033.84	11277	102118
1988	23589	2.547	422	26354	3000	40588	973.59	11872	99622
1989	23138	2.699	326	25715	3053	40142	731.10	11440	99180

YEAR	CATPL	CCEXP	CCREPT	COW$	FDEXP	KCS$	S&H$
1965	21697.46	.	.	14.43	.	24.12	24.99
1966	23198.67	.	.	17.83	.	27.43	25.71
1967	23991.54	.	.	17.22	.	26.68	25.29
1968	26935.11	.	.	17.94	.	27.92	26.87
1969	27717.28	.	.	20.29	.	31.78	29.45
1970	27428.38	.	.	21.34	.	33.70	29.36
1971	29509.53	.	.	21.62	.	34.87	32.39
1972	30550.64	114.08	140.39	25.21	13.25	41.40	35.78
1973	27428.38	136.92	174.42	32.82	20.18	53.17	44.54
1974	22508.52	148.38	126.75	25.56	25.61	37.88	41.89
1975	26304.88	161.79	119.03	21.09	24.40	33.91	44.61
1976	27077.42	173.37	134.73	25.31	23.58	39.40	39.11
1977	29303.02	164.31	146.91	25.32	20.69	40.18	40.38
1978	30034.90	188.85	244.55	36.78	19.57	58.78	52.34
1979	26582.01	231.16	352.30	50.10	22.63	83.08	67.75
1980	25348.30	251.89	306.91	45.72	25.44	75.23	66.96
1981	24770.50	265.18	260.64	41.92	28.32	66.24	63.84
1982	28512.29	267.20	255.49	39.95	25.81	64.82	64.22
1983	27413.40	268.80	247.18	39.35	28.21	63.70	62.52
1984	28811.89	276.53	258.78	39.81	28.47	65.29	64.84
1985	27534.31	265.44	254.39	38.32	25.12	64.56	58.37
1986	27885.27	253.74	265.47	37.19	27.10	62.79	57.75
1987	29175.69	259.62	311.25	44.83	25.84	71.00	65.12
1988	28472.70	295.15	350.90	46.55	31.60	83.67	69.54
1989	28496.24	.	.	47.82	.	86.20	72.52

YEAR	SAHFDSL	SAHNFSL	TBCOWSL	BEXPRT	BIMPRT	BULL#	BULLSL
1965	19675	4920	4068.70	91	923	2180	502
1966	20995	5101	.3893.35	83	182	2150	519
1967	22273	4796	3402.38	88	313	2155	469
1968	24056	3972	3618.73	88	500	2195	543
1969	25248	2824	3856.25	82	615	2220	582
1970	26054	2606	3399.36	01	792	2272	578
1971	26437	2450	3730.53	17	734	2328	633
1972	28032	1414	3335.04	14	960	2377	645
1973	26423	680	3386.93	44	990	2467	676
1974	24509	4484	4848.76	15	615	2643	820
1975	21813	6997	8716.40	10	758	2985	1097
1976	25667	5912	7942.87	58	073	2845	998
1977	26494	5120	7206.07	67	939	2664	903
1978	28268	2434	5800.24	14	297	2538	798
1979	25896	1553	3307.45	16	405	2403	629
1980	24313	2745	3673.77	20	064	2492	724
1981	24130	3691	3900.24	52	743	2547	775
1982	25214	2769	4405.39	05	939	2611	818
1983	26077	2492	4593.21	12	931	2609	808
1984	26068	2416	5332.79	77	823	2549	787
1985	26455	1964	4551.66	79	071	2411	759
1986	26515	2378	3726.14	73	129	2261	714
1987	26672	1919	3442.02	56	269	2204	689
1988	27042	1299	3507.26	41	379	2163	644
1989	26446	734	3462.68	28	155	2133	659

YEAR	CALFSL	CATBAL	CATEX	CATIM	CATLOSS	CORN$	CPI	CRET$
1965	7788	73	54	1128	1419.46	1.16	31.6	0.396
1966	6863	404	35	1100	1517.67	1.24	32.3	0.416
1967	6110	540	55	752	1569.54	1.03	33.4	0.387
1968	5616	372	36	1039	1762.11	1.08	34.9	0.408
1969	5011	881	39	1042	1813.28	1.16	36.8	0.434
1970	4203	-886	88	1168	1794.38	1.33	39.0	0.417
1971	3825	-180	93	991	1930.53	1.08	40.8	0.420
1972	3201	-626	104	1186	1998.64	1.57	42.0	0.427
1973	2404	-718	273	1039	1794.38	2.55	43.7	0.608
1974	3175	-359	204	568	1472.52	3.02	48.0	0.570
1975	5406	-562	196	389	1720.88	2.54	52.5	0.643
1976	5527	583	205	984	1771.42	2.15	56.0	0.611
1977	5692	681	107	1133	1917.02	2.02	59.6	0.619
1978	4302	-388	122	1253	1964.90	2.25	63.9	0.665
1979	2927	-352	66	732	1739.01	2.48	71.2	0.677
1980	2679	-236	66	681	1658.30	3.12	81.5	0.719
1981	2886	-955	88	680	1620.50	2.47	90.4	0.737
1982	3106	-897	58	1005	1865.29	2.55	96.3	0.716
1983	3162	-761	56	921	1793.40	3.21	99.7	0.728
1984	3367	-207	71	753	1884.89	2.63	104.0	0.814
1985	3455	-871	125	836	1801.31	2.23	108.0	0.763
1986	3478	303	108	1407	1824.27	1.50	109.8	0.835
1987	2902	-125	131	1200	1908.69	1.94	113.6	0.785
1988	2565	474	321	1332	1862.70	2.54	118.3	0.854
1989	2223	-459	169	1459	1864.24	2.30	123.7	0.927

YEAR	DCOW#	DYHEBRD	F&UI	INCOME	INTRAT	POP	PPI	PRET$
1965	15380	3115.0	13.80	101.0	4.38	194.3	32.30	0.652
1966	14490	2950.5	14.10	109.0	5.55	196.5	33.30	0.734
1967	13725	2856.0	14.40	112.3	5.10	198.7	33.40	0.666
1968	13115	2793.0	14.30	121.6	5.90	200.7	34.20	0.668
1969	12550	2716.0	14.60	130.5	7.83	202.6	35.60	0.736
1970	12091	2690.1	15.30	142.1	7.71	205.0	36.90	0.774
1971	11909	2679.6	16.60	147.5	5.11	207.6	38.10	0.698
1972	11776	2710.4	17.10	158.5	4.73	209.9	39.80	0.827
1973	11622	2758.7	19.40	176.1	8.15	211.9	45.00	1.092
1974	11297	2860.9	30.10	198.2	9.84	213.8	53.50	1.078
1975	11220	2769.2	35.40	218.7	6.32	215.9	58.40	1.346
1976	11071	2720.9	38.30	236.2	5.34	218.0	61.10	1.340
1977	10998	2727.2	43.60	255.9	5.61	220.2	64.90	1.254
1978	10896	2752.4	46.50	282.2	7.99	222.5	69.90	1.436
1979	10790	2910.6	58.90	317.3	10.91	225.0	78.70	1.441
1980	10758	3041.5	82.80	349.1	12.29	227.7	89.80	1.395
1981	10849	3172.4	100.20	376.5	14.76	230.1	98.00	1.524
1982	10986	3181.5	100.00	398.8	11.89	232.5	00.00	1.754
1983	11047	3173.1	95.90	421.9	8.89	234.8	01.30	1.698
1984	11059	3339.0	94.80	448.5	10.16	237.0	03.70	1.620
1985	10777	3751.6	91.40	471.6	8.01	239.2	03.20	1.620
1986	11116	3169.9	69.80	501.0	6.39	241.6	00.20	1.784
1987	10466	2885.4	70.20	526.4	6.85	243.9	02.80	1.884
1988	10311	2943.5	66.74	559.7	7.68	246.1	06.96	1.834
1989	10212	3003.7	72.38	594.9	9.60	248.7	12.71	1.829

YEAR	TDCOWSL	W	WAG$
1965	4005.30	0.061	19.97
1966	3662.65	0.055	22.64
1967	3354.63	0.053	23.87
1968	3224.28	0.062	25.44
1969	3063.75	0.062	29.09
1970	2716.64	0.060	32.01
1971	2644.47	0.052	33.43
1972	2656.96	0.059	34.55
1973	2861.07	0.075	41.38
1974	2666.25	0.064	47.11
1975	2841.60	0.071	51.99
1976	2676.14	0.053	60.65
1977	2657.93	0.052	65.88
1978	2669.76	0.064	71.11
1979	2622.55	0.075	80.28
1980	2658.23	0.058	86.03
1981	2741.76	0.048	88.54
1982	2946.61	0.065	96.09
1983	3003.80	0.074	97.68
1984	3289.22	0.065	103.31
1985	2838.34	0.054	113.18
1986	4234.86	0.049	119.14
1987	3167.98	0.060	127.86
1988	2829.74	0.060	134.43
1989	2853.32	0.060	141.19