A SYSTEMS STUDY OF THE
DYNAMIC BEEF MARKET
by
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A SYSTEMS STUDY OF THE
DYNAMIC BEEF MARKET

by

Jimmy Joe Jackson

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ABSTRACT

A causal model containing the important structure present within the beef industry is developed. The model produces the same long-term fluctuations in supply and price of beef as occurred during the period from 1950 to 1970. Parameter sensitivity testing demonstrates that the long-term fluctuations are caused by system structure and by decision makers within the industry, not by exogenous factors. The overall goal of this study is to formulate, test, and gain ranchers' implementation of improved policy guidelines.

The challenge for the future of modeling is determining effective methods for gaining adoption of any recommendations arising from a "global" model, a model where a great number of decision makers are aggregated together. Decision makers must be confident that adopting new policies will improve their performance, independent of adoption by others; otherwise, implementation of recommendations is difficult.

A new policy guideline for determining the percentage of heifers to retain for breeding is proposed. In the new policy, when profits are high, the percentage of heifers withheld is low. This is the major difference in the proposed policy as the current practice is to withhold a high percentage.

To insure that the proposed policy is beneficial regardless of adoption rate, a second beef herd sector was added. Testing the new policy with 1950 to 1970 data demonstrated that it improved profits for those ranchers adopting
it. Changing the model to conform to 1974-1994 conditions and retesting the new policy demonstrated once more that it would be beneficial for ranchers to adopt the new policy.

Thesis Supervisor: John Henize

Title: Assistant Professor of Management
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CHAPTER I
INTRODUCTION

The Problem

During the spring and summer of 1973, the spotlight of national attention was focused upon the beef market and the upward spiraling beef prices. Consumer attention has focused only upon the tip of the iceberg of the problems that have plagued the beef industry for many decades. Since at least 1896, the beef market has been characterized by significant long-term fluctuations (Figure I-1) in the supply and price of beef.

Ranchers have recognized these fluctuations within the beef industry as a significant problem for many years. However, many ranchers believe that the oscillations are caused by a general conspiracy among the large meat packers and buyers. This presumption is generated by beef prices tending to peak when ranchers have the fewest animals to sell; when they have many animals to sell, the price is low. Few ranchers believe that these problems are caused by the beef industry structure in conjunction with their herd size decision making.
The Purpose of the Study

The purpose of this study is twofold. First, to develop a model that is capable of explaining the long-term fluctuations. Second, to develop a model which can be used to test the profitability for those ranchers who adopt "improved" policy guidelines in making their herd size decisions. Thus, the model will not be just descriptive, but will also be a useful aid in gaining implementation of better policies.

Caution must be exercised in defining implementation for any "global" model, a model in which many decision makers are aggregated together. A suggested policy may

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provide improvement if all decision makers adopt the policy; however, less than 100 percent adoption may cause the policy to be ineffective or counterproductive. Thus, there should be no restriction which would make it necessary for all ranchers to adopt the new policies in order to make the guidelines profitable for adopters.

Methodology

Systems Dynamics\(^2\) is a philosophy of systems behavior which seeks the cause of complex behavior in the feedback loops contained within the system. Systems Dynamics and its accompanying computer language, Dynamo,\(^3\) will be utilized because the beef industry contains many complex interrelationships. Systems Dynamics and Dynamo are understandable to a layman. This greatly increases his confidence in any model built, which, in turn, makes implementation easier to achieve.


Before proceeding with a description of the model's general structure, a brief review of past beef-market research is presented.

Review of Past Models

There have been many excellent attempts at general verbal descriptions of the dynamics involved within the beef market. One of the better verbal descriptions was by Maki, who said:

Several factors are frequently cited as determinants of the cattle cycle, namely, the biological makeup of beef herds, the management practices of ranchers and feedlot operators and the method of making future market estimates. It is, however, the producer response to price fluctuations in terms of changing the number of cattle on hand, particularly breeding stock, that actually generates the cattle cycle. For example, an increase in feeder prices leads to increases in beef cattle numbers, not only in heifers and steers, but also -- a year and one-half later on the average -- in calves. The change in steer inventories leads to an increase in commercial slaughter during the following 12-month period, while the change in heifer inventories contributes to a corresponding increase in beef cow numbers a year later. The change in commercial slaughter immediately results in a drop in slaughter steer prices. Feeder prices are directly associated with slaughter prices. Thus falling steer prices are followed by a lower feeder market.

Meanwhile, the increase in beef cow inventories generates a decline in commercial cattle slaughter two years after the initial increase in the feeder market. Because beef cows and heifers are withheld
from slaughter in response to an initial increase in feeder prices, beef production must decline temporarily. Consequently, both slaughter steer and feeder prices must increase. Thus, the price changes in the third year tend to counterbalance the price changes in the second year. The beef cycle, however, still maintains its positive relation to the initial change in feeder price. The change in beef cow numbers results, therefore, in an increase in calf inventories. The increase in calf inventories, in turn, results in an increase in steer and heifer inventories. Meanwhile, the inventory changes lead to further changes in commercial slaughter. Eventually, the production and price cycles turn around and start moving in opposite directions from whence they started. Thus, the cattle cycle of about six to eight years duration is generated by a complex of factors that influence the long-run make-up of the beef economy.¹

Besides verbal descriptions, others have endeavored to develop causal flow diagrams that show the interrelationships in a more explicit manner. One such example is shown in Figure II-1, which was developed by the Department of Agriculture. Even though dynamic since it is time related, it mainly contains feed forward relationships and does not represent many of the feedback relationships which this study hypothesizes to exist in the relevant system. Thus, the model has little explanatory power of long-term fluctuations, since the primary feedback within the beef industry has long-term effects.

Early models, mainly by agricultural economists, were only able to explain short-term behavior because they

Figure II-1: A Model of the U.S. Meat Economy

considered many variables to be exogenous that were, in fact, embedded in feedback processes. Meadows made an important contribution to the research of cyclical behavior in various commodity markets when he propagated that the greatest causes of the fluctuations within any commodity, including beef, were the feedback loops and decision makers comprising that commodity market. To show the applicability of his general commodity model, Meadows adjusted parameters for biological and managerial factors in three different commodities: hogs, beef, and chickens. He did not attempt validity testing and only demonstrated that his model when applied to the beef market had the same periodicity.

Overview of the General Structure

The model boundary has been defined to include the beef herd sector, feed lot sector, and the market interaction with consumers. These three sectors are hypothesized to be capable of explaining the long-term fluctuations observed within the beef market.

One could contend that the system boundary should be expanded to embody a hog sector because of the substitution effects of beef and pork. Since feed prices have a major influence upon decisions made by cattle and hog raisers, it could be asserted that a feed sector should be incorporated.

However, the fluctuation periodicity of these two factors is considerably shorter than that for beef; consequently, it is unlikely hogs or feed produce the longer term fluctuations.

The beef market has a "worse-before-better" performance which is characteristic of many dynamic systems. The short period market supply is negative (backward-bending supply curve) rather than positive.\(^4\) With an increase in price, ranchers withhold cattle from market to increase their breeding herds. Of course, reduced beef supply causes further price increases. The supply relationship, coupled with the long delay times in heifers becoming cows, gestation period, calf growing period, and feeding time, causes much of the dynamic behavior.

The feed lot sector is simply a delay. Because of biological factors relating to weight gain per pound of feed, it is difficult for the feeding time to be economically varied more than a few days.\(^5\) In the past, the feed lot sector was a significant stabilizing influence within the beef industry. When profits were large, feed lots would expand thereby increasing the supply of beef; and, during bleak times, they would continue operation because marginal

\(^4\)Williams and Stout, p. 536.

revenues normally were greater than marginal costs. This ratchet effect expanded the percentage of cattle fed in feed lots from 51 percent in 1950 to approximately 90 percent currently.  

The consumer sector assumes that what is produced in a period is also consumed in that same period. Thus, per capita consumption equals per capita production. Therefore, the function of the market is to determine the market clearing price in each period. It is asserted that an individual's expenditure for beef is a function of one's personal disposable income. Given consumption and expenditure, price is determined.

Figure II-2 is a causal loop model containing the important relationships that cause the long-term fluctuations. From this simple model, a more detailed model is developed in Chapter III.

Emphasis of this Study

Although the beef market has been studied for a long time by many people and with great effort, few efforts have had an implementation orientation; none of the studies have resulted in policy change. So far, research has centered upon improved understanding of the beef market and better

---

Figure II-2: Causal Flow Diagram of the Beef Market

Population

- \rightarrow

Average Slaughter Rate

+ \rightarrow Per Capita Consumption

Animals in Feed Lots

+ \rightarrow % Heifers Kept For Breeding

Steers Ready For Market

+ \rightarrow Beef Cows

+ \rightarrow Personal Disposable Income

Per Capita Expenditure For Beef

- \rightarrow Beef Price

+ \rightarrow Profit

Heifers Ready For Market

+ \rightarrow Heifers Held For Breeding
methods for analyzing the industry. However, this study takes departure from previous studies in having as its objective improved profits for ranchers.

This goal implies that greater attention must be paid to validity testing (to increase ranchers' confidence), to proper selection of improved policies, and to adequate policy testing. Any recommended policy changes must be intuitive to ranchers, if not before at least after a simplistic explanation of the reasons for adopting the new policies. Also, ranchers must have confidence that these policies will improve their profits.
CHAPTER III
MODEL DESCRIPTION

Three methods of presentation—pictorial, verbal, and mathematical—will be utilized to enhance understanding of the model developed in this study.

Pictorial Description

The flow diagrams presented on the following two pages provide an overview of the model. They allow one the best perspectives of the structure which is important in causing the long-term oscillations within the beef market. When studying the detailed verbal and mathematical description which is in the next section, the flow diagrams should be referred to to enhance understanding of the system.

The numbers contained within the flow diagram symbols correspond to the sub-heading numbers used in the remainder of the chapter and also to the equation numbers.\(^1\) Appendix B contains an alphabetical listing and definition of all abbreviations.

Verbal and Mathematical Description

This section is subdivided by number and name of each component as shown in the flow diagrams on pages 22 and 23.

\(^1\)Appendix A contains a complete listing of the equations, including the necessary control statements.
Figure III-1: Beef Herd Sector

Average Slaughter Rate (ASH, 21)

HS 15 Heifers Slaughter

DECT Decision Time

Steers Ready For Market (SFRM, 17)

HFRF Heifers Ready For Market

D3 HFRMR 4 AMR Heifers Ready For Market H. mo

Survival Rate SR

D3 BHH Birth Rate 9 Heifers mo

GRH Gestation Rate Heifers

AMBH Average Months Between Heifers

PHKB 12 % Heifers Kept for Breeding

(PPLF, 16) Percentage Feed Lot Fed

Animals in Feed Lots (AFL, 20)

HFFS 14 Heifers Fed For Slaughter

DECT Decision Time

HFB Heifers For Breeding 15

Feed Price Index (FPI, 10)

PI 11 Profit Index

(BPI, 26) Beef Price Index

NH Normal Herd

RFA 9 Relative Feed Per Animal

AH 8 Average Herd

HAT Herd Averaging Time

BC 1 Beef Cows

CSR Cow Slaughter Rate

(ASR, 21) Average Slaughter Rate

ACL Average Cow Lifetime
Figure III-2: Feed Lot and Consumer Sectors

- Personal Disposable Income Index (PDII, 25)
- Disposable Income Multiplier (DIM)
- Population Index (POPI, 24)
- APCC 23 Actual Per Capita Consumption
- Normal Slaughter Rate (NSR)
- Dairy Animal Slaughter Rate (DASR, 21)
- Slaughter Rate Smoothing Time (ST)
- BPI 27 Beef Price Index
- (KWR, 28) Korean War Factor

- PCEF 25 Per Capita Expenditure For Beef
- Profit Index (PI, 11)

- D3 FASH 20 APT
  Fed Animal Slaughter Rate mo
- AFL Animals in Feed Lots
- SFFS 18 Steers Fed For Slaughter
- (MFFS, 14) Heifers Fed For Slaughter
- SHFM 17 Steers Ready For Market
- (HRFM, 5) Heifers Ready For Market
- (PPLF, 16) Percentage Feed Lot Fed
- DECT Decision Time
- (HS, 15) Heifer Slaughter Rate
- ASR 22 Average Slaughter Rate
- CSR, 7 Cow Slaughter Rate
- SS 19 Steers Slaughter
followed by a verbal description, and the dynamo equations and abbreviation definitions.

1. Beef Cows

Beef cows is formulated as a regular level equation with an inflow of heifers becoming cows and an outflow of cow slaughter rate. All level equations require initial conditions. In this model, initial conditions are based upon an index system. The beef cow index represents percent of 1950's value; consequently, the initial condition for cows is 100.

\[ L \quad BC.K = BC.J + DT \cdot (HBC.JK - CSR.JK) \]

\[ N \quad BC = IBC \]

\[ C \quad IBC = 100 \]

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<tr>
<td>HBC</td>
<td>HEIFERS BECOMING COWS</td>
</tr>
<tr>
<td>CSR</td>
<td>COW SLAUGHTER RATE</td>
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<tr>
<td>IBC</td>
<td>INITIAL BEEF COWS</td>
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2. Gestation Rate Heifers

The gestation rate of heifers is determined by beef cows divided by the average months between heifers. Since cows have, on the average, one calf per year with a 50 percent chance of it being a heifer, the average months between heifers is 24.\(^2\) There are seasonal differences in the

\(^2\)This information was provided by several Texas ranchers.
calving rate; however, these have little influence upon the long-term oscillations since their periodicity is only one year.

\[ \text{R: } \text{GRH.KL=BC.K/AMBH} \]

\[ \text{C: } \text{AMBH=24 MONTHS} \]

3. Birth Rate Heifers

The birth rate of heifers is simply the gestation rate of heifers delayed by gestation time of 9 months. An average of 10 percent of all conceptions end in either miscarriage or death before marketing. This is represented by multiplying the normal birth rate by a survival rate of .9. It could be disaggregated and applied to both birth rate and marketings; however, aggregation is easier and does not effect model performance.

\[ \text{R: } \text{BRH.KL=SR*DELAY}_3(\text{GRH.JK,GT}) \]

\[ \text{C: } \text{SR=.9} \]

\[ \text{C: } \text{GT=9 MONTHS} \]

- \text{BRH - BIRTH RATE HEIFERS}
- \text{SR - SURVIVAL RATE}
- \text{GRH - GESTATION RATE HEIFERS}
- \text{GT - GESTATION TIME}

---


4. Heifers Ready For Market Rate

Heifers ready for market rate is the birth rate of heifers delayed by the average time from birth to marketing of 7 months.

\[ HRFMR.KL = DELAY(3 \cdot BRH.JK, AMT) \]

\[ AMT = 7 \text{ MONTHS} \]

- **HRFMR** - HEIFERS READY FOR MARKET RATE
- **BRH** - BIRTH RATE HEIFERS
- **AMT** - AVERAGE MARKETING TIME

5. Heifers Ready For Market

Heifers ready for market represents the seven month old heifers which ranchers are choosing to retain for breeding or for marketing to feed lots and slaughter plants.

\[ HRFM.K = HRFM.J + DT \cdot (HRFMR.JK - HFB.JK - HFFS.JK - HS.JK) \]

\[ HRFM = IBC \cdot SR/AMBH \]

- **HRFM** - HEIFERS READY FOR MARKET
- **HRFMR** - HEIFERS READY FOR MARKET RATE
- **HFB** - HEIFERS FOR BREEDING
- **HFFS** - HEIFERS FED FOR SLAUGHTER
- **HS** - HEIFERS SLAUGHTERED
- **IBC** - INITIAL BEEF COWS
- **SR** - SURVIVAL RATE
- **AMBH** - AVERAGE MONTHS BETWEEN HEIFERS

6. Heifers Becoming Cows

Heifers become cows after a total two-year\(^5\) aging process. This is 16 months after they could have been sold for feeding or slaughter.

\(^5\)This is the U.S.D.A. definition. Since U.S.D.A. data is used for comparison to the model results, their definition was used.
HBC.KL = DELAYP(HFB.JK, ADT, HHFB.K)
C
ADI = 16 MONTHS

HBC - HEIFERS BECOMING COWS
HFB - HEIFERS FOR BREEDING
ADT - AVERAGE DELAY TIME IN BECOMING COWS
HHFB - HEIFERS HELD FOR BREEDING

7. Cow Slaughter Rate

The number of cows divided by the average cow lifetime yields the cow slaughter rate. It is debatable whether the cow slaughter rate is independent of price since some ranchers cull cows when prices are high and other ranchers retain their older cows to have another calf before culling because of the high calf prices. The data appears to indicate that the influences of these two groups of ranchers offset each other; however, the effect of certain exogenous factors, such as weather, makes it difficult to ascertain.

CSR.KL = BC.K/ACL
C
ACL = 100

CSR - COW SLAUGHTER RATE
BC - BEEF COWS
ACL - AVERAGE COW LIFETIME

8. Average Herd

This variable is an exponential average of beef cows and heifers being held for breeding. Calves were not included since they consume an insignificant amount of feed and since ranchers normally include only cows, heifers, and bulls in their total when their herd size is requested. Bulls have not been included in the model because less than one percent of all male calves are retained for breeding and
because bulls have essentially no effect on the dynamics of the system since fluctuations in their number are less than that of cows because the ratio of cows/bull can be and is varied. The 12 month averaging time was chosen since range condition and feeding are yearly cycles. This averaging time will be tested to determine if model behavior is sensitive to its selection since its value is not known with certainty.

\[ L_{AH.K} = AH.J + DT \times (HHFB.J + BC.J - AH.J) / HAT \]
\[ C_{HAT} = 12 \text{ MONTHS} \]
\[ N_{AH} = IBC + (ADT \times HFBI) \]

- \( AH \): AVERAGE HERD
- \( HHFB \): HEIFERS HELD FOR BREEDING
- \( BC \): BEEF COWS
- \( HAT \): HERD AVERAGING TIME
- \( IBC \): INITIAL BEEF COWS
- \( ADT \): AVERAGE DELAY TIME IN BECOMING COWS
- \( HFBI \): HEIFERS FOR BREEDING INITIAL

9. Relative Feed Per Animal

The supplemental feed per animal that ranchers must provide is a nonlinear function of the average herd size. Initially, ranchers may have to feed slightly more per animal during the winter months, then lengthen their winter feeding period, and, finally, have to feed some during the dry summer months. This relationship is graphically represented in Figure III-3. The ratio of normal herd to average herd corresponds to range carrying capacity. For instance, .5 would be equivalent to having twice as many animals as the normal (1950) carrying capacity. Normal herd is
equal to the initial value of average herd; thus, the 1950 ratio is 1.

\[ \text{RFAT} = \frac{3}{2.2/1.6/1.2/1.9/0.8} \]

\[ \text{NH} = \text{AH} \]

**Figure III-3: Relative Feed Per Animal Graph**

10. Feed Price Index

An important exogenous input to the model is feed prices. The index is an average of grain, roughage, and concentrated protein prices \(1950 = 1^6\) weighted by the proportions used for range herd rations. The uncertainty of

future feed prices makes it necessary to demonstrate that any policy recommendations are improvements independent of what occurs to feed prices.

\[
\begin{align*}
A & = \text{TABHL}(FPIT, \text{TIME.K/12,0,20,1}) \\
I & = \text{FPIT} = 1/1.09/1.02/0.98/0.94/0.89/0.86/0.87/0.85/0.85/ \\
X & = 0.86/0.90/0.90/0.92/0.94/0.89/0.89/0.91/0.94
\end{align*}
\]

FPI - FEED PRICE INDEX
FPIT - FEED PRICE INDEX TABLE

11. Profit Index

The profit index is a ratio of beef price to ranchers' costs, which are composed of four types: fixed costs, costs that are a function of relative feed per animal, feed costs, and other variable costs. Fixed costs vary inversely proportional to the herd size. Several costs vary proportionally to the amount of feeding done, such as labor involved in feeding and equipment operation expenses. Also grouped in this general category are range improvement activities such as fertilization, tree control, spraying, etc. It is assumed these will be done when economical, and this assumption was included in the construction of Figure III-3. The importance of feeding costs is apparent. Other variable costs include veterinary costs, marketing costs, etc. The


way the index is formed, a profit index of .9 represents a point where ranchers are receiving a "fair rate" of return and the herd size is in momentary equilibrium.

\[ P_{i,k} = B_{i,k}/((A_1*NH)/AH_{i,k}) + 1 + (A_2*RFA_{i,k}) + (A_3*RFA_{i,k} \times F_{i,k}) \]

\( A_1 = .4 \)
\( A_2 = .2 \)
\( A_3 = .3 \)

<table>
<thead>
<tr>
<th>PI</th>
<th>PROFIT INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPI</td>
<td>BEEF PRICE INDEX</td>
</tr>
<tr>
<td>A1</td>
<td>1950 FIXED COSTS PERCENTAGE</td>
</tr>
<tr>
<td>NH</td>
<td>NORMAL HERD</td>
</tr>
<tr>
<td>AH</td>
<td>AVERAGE HERD</td>
</tr>
<tr>
<td>A2</td>
<td>1950 COSTS THAT ARE A FUNCTION OF RFA</td>
</tr>
<tr>
<td>RFA</td>
<td>RELATIVE FEED PER ANIMAL</td>
</tr>
<tr>
<td>A3</td>
<td>1950 FEED COSTS PERCENTAGE</td>
</tr>
<tr>
<td>FPI</td>
<td>FEED PRICE INDEX</td>
</tr>
</tbody>
</table>

12. Percentage Heifers Kept for Breeding

With a "fair" rate of return (profit index of .9), ranchers will withhold 26 percent of their heifers. This percent is the zero herd growth percent which is defined by the biological constraints of the system. As profitability increases, the percent withheld for breeding increases rapidly and then increases at a reduced rate. Ranchers can and will increase their withholdings of heifers because of the lure of high profits and their conclusion that they can easily add a few more animals to their herd. However, after a point, further increases are smaller because ranchers may be having cash flow problems, time is required to expand facilities for a significant increase in herd size, and marginal heifers being withheld are of poorer quality and are
less likely to become profitable cows. This relationship is presented in Figure III-4.

A \[ \text{PHKB.K} = \text{TABLE}(\text{PTHKB}, \text{PI.K}, .6, 1.4, 1) \]

\[ \text{PTHKB} = .1 / .15 / .18 / .26 / .46 / .51 / .65 / .75 / .8 \]

- **PHKB** - PERCENTAGE HEIFERS KEPT FOR BREEDING
- **PTHKB** - PERCENTAGE TABLE HEIFERS KEPT FOR BREEDING
- **PI** - PROFIT INDEX

Figure III-4: Percent Heifers Kept for Breeding Graph

13. Heifers for Breeding

Heifers for breeding is the percentage withheld times the heifers available. There is a short delay time while ranchers make the physical choice of which particular heifers to retain for breeding purposes.

\[ \text{HFB.KL} = \text{HRFM.K} \times \text{PHKB.K} / \text{DECT} \]

\[ \text{DECT} = 1 \]

\[ \text{HFB} = \text{HPBI} \times \text{IBC} \]

\[ \text{HPBI} = .018 \]

- **HFB** - HEIFERS FOR BREEDING
- **HRFM** - HEIFERS READY FOR MARKET
- **PHKB** - PERCENTAGE HEIFERS KEPT FOR BREEDING

Those heifers not held for breeding are either slaughtered or placed in feed lots to be fed for slaughter. The same decision delay time exists in this process as in the selection of heifers for breeding.

\[ HFFS.KL = HHFM.K * (1 - PHKB.K)^*PFLF.K / DECT \]
\[ HS.KL = HHFM.K * (1 - PFLF.K)^*(1 - PHKB.K) / DECT \]

\( HFFS \) - Heifers Fed for Slaughter
\( HRFM \) - Heifers Ready for Market
\( PHKB \) - Percentage Heifers Kept for Breeding
\( PFLF \) - Percent Feed Lot Fed
\( DECT \) - Decision Time
\( HS \) - Heifers Slaughtered

16. Percent Feed Lot Fed

The percent feed lot fed is modeled as an exogenous variable even though it would have been considered an integral part of any model constructed a few years ago. However, it appears that the percent can be taken as a constant of approximately ninety percent. In the past, this percentage has exhibited a ratchet movement. When profits were favorable, feed lot operations were expanded; when prices were depressed, the percentage did not decrease because feed lot operators, in general, were covering their variable costs even if they were not meeting their fixed costs. Thus, they continued operations on the same scale as before profits decreased.
The strong development of grain feeding of cattle since 1950 has caused the supply of cattle available for feeding to be rapidly utilized. The industry now uses nearly all of the beef cattle and many of the dairy animals that hold a potential for grain feeding before slaughter. This accounts for the large increase in production without a corresponding increase in herd size, which is portrayed in Figure III-5. However, future increases in the supply of cattle...
meat must now come from expansion of breeding herds. This greater reliance upon a long-term adjustment process can be expected to cause larger fluctuations in the price and supply of beef, if present policies continue.

\[
\begin{align*}
A &= PFLF.K = TABHL(PFLFT, TIME.K/12, 0, 20, 1) \\
A &= .827/.850
\end{align*}
\]

PFLF - PERCENT FEED LOT FED
PFLFT - PERCENT FEED LOT FED TABLE

17. Steers Ready for Market

Until now steers have been unmentioned even though they are an integral part of the beef industry. Steers are affected by the same biological and structural processes as heifers until being ready for market. It would be possible to formulate the same structure for steers as for heifers; however, an easier method is to set steers ready for slaughter equal to heifers ready for slaughter.

\[
A = SRFM.K = HRFM.K
\]

SRFM - STEERS READY FOR MARKET
HFRM - HEIFERS READY FOR MARKET


The construction of these two equations is identical to the equations for heifers fed for slaughter and heifers slaughtered.

\[10^{U.S.D.A., Cattle Feeding in the United States, p. 5.}\]
20. Fed Animal Slaughter Rate

The fed animal slaughter rate is a composite of heifers and steers fed for slaughter delayed by average feeding time. As noted in Chapter I, feeding time is considerably more constant than most people believe, especially in the short term. Once a feed lot operator has placed an animal on a particular feeding schedule, altering the schedule will decrease its efficiency. Five months is considered, on average, to be the optimal feeding time. If profits are favorable, feeding time can not be extended because of lack of physical facilities; and reducing feeding time when profits are depressed will increase the fixed cost per pound of gain.

\[ S_{FFS} = S_{RFM} \cdot P_{LF F} + (1 - DECT) \]

\[ S_{SS} = S_{RFM} \cdot (1 - P_{LF F}) \]

\[ S_{FFS} - STEERS FED FOR SLAUGHTER \]
\[ S_{RFM} - STEERS READY FOR MARKET \]
\[ P_{LF F} - PERCENTAGE FEED LOT FED \]
\[ DECT - DECISION TIME \]
\[ S_{SS} - STEERS SLAUGHTERED \]

---

21. Dairy Animal Slaughter Rate

There has been a major shift in the relative numbers of beef animals and dairy animals in this country. While beef cows increased 50 percent since 1950, dairy cows have decreased 40 percent (Figure III-6). Dairy calves are considered to be less efficient feeders than beef calves; as a

result, few are placed in feed lots. Normally, dairy calves will weigh several hundred pounds when slaughtered. The slaughter of culled dairy cows also represents a significant quantity of meat. Additionally, during the 1950's and 1960's, dairy herds were being reduced causing an even greater slaughter rate. The dairy animal slaughter rate is a composite of these various factors. Dairy animal slaughter is included since it was important (10% of the total slaughter in 1950), even though it is no longer important (2% in 1972).

The average slaughter rate combines the instantaneous slaughter rates. It is based upon relative weights with a fed animal equalling 1, a calf being 60 percent of that weight, and a cow equalling 150 percent of that weight. This combined rate is averaged because there are many factors that can influence the rate in the short term, but not


the longer term. Examples are weather that affects marketings, holidays affecting markets and packers, inventory changes, and, to a certain extent, seasonality. The smoothing time was picked rather arbitrarily and must be tested to determine if the model is sensitive to its selection.

\[
\begin{align*}
\text{L} & \quad \text{ASH.K} = \text{ASH.J} + \text{DT} \times (\text{FASR.JK} + 1.5 \times \text{CSR.JK} + 0.6 \times (\text{HS.JK} + \text{SS.JK})) \\
\text{X} & \quad + \frac{\text{DASH.JK} - \text{ASH.J}}{\text{ST}} \\
\text{N} & \quad \text{ASH} = 6.822 \\
\text{C} & \quad \text{ST} = 9 \text{ MONTHS}
\end{align*}
\]

ASH - AVERAGE SLAUGHTER RATE
FASR - FED ANIMAL SLAUGHTER RATE
CSR - COW SLAUGHTER RATE
HS - HEIFERS SLAUGHTERED
SS - STEERS SLAUGHTERED
DASH - DAIRY ANIMAL SLAUGHTER RATE
ST - SLAUGHTER RATE SMOOTHING TIME

23. Actual Per Capita Consumption

Production of beef per capita and per capita consumption of beef in the United States necessarily are very closely related. Because beef is perishable, storage stocks are small and do not serve as an effective price buffer. Average cold storage inventory represents about 7 days of supply, does not vary much, and is poorly correlated with price. It is reasonable to conclude that, to a large extent, inventory changes are caused by exogenous factors such as

15 John T. Larsen, p. 3.
16 Willard F. Williams and Thomas T. Stout, p. 95.
holidays, day of the week, weather affecting retail sales, etc., and not by any active decision making by packers.

In making the assertion, production equals consumption, it is necessary to assume that imports do not have a significant influence upon the domestic beef market. The assumption is not unreasonable since imports represent less than 10 percent of the beef consumption. Most beef imports are of the cheaper grades, such as canner and cutter. There is a high degree of negative correlation between imports and domestic canner and cutter slaughter (comprised almost exclusively of slaughtered cows). Therefore, it appears that imports have limited affect upon beef prices other than canner and cutter; there they tend to have a stabilizing influence.

\[ APCC.K = \frac{ASR.K}{(NSR \cdot POPI.K)} \]

\[ NSR = 6.822 \cdot IPC \]

\[ IPC = 1.04 \]

**APCC** - ACTUAL PER CAPITA CONSUMPTION  
**ASR** - AVERAGE SLAUGHTER RATE  
**NSR** - NORMAL SLAUGHTER RATE  
**POPI** - POPULATION INDEX  
**IPC** - INITIAL PRICE CONDITION

24. Population Index

The population (1950=1) is imputed for each year and is necessary in calculating the actual per capita consumption.

\[ POPI.K = \text{TABHL}(POPT, \text{TIME.K}/12, 0, 20, 1) \]

\[ POPT = 1/1.01/1.02/1.04/1.06/1.08/1.1/1.12/1.14/1.16/1.18/1.2/1.22/1.24/1.26/1.28/1.3/1.32/1.34/1.36/1.38/1.4 \]
25. Per Capita Expenditure for Beef

How do consumers decide their beef purchases? There have been many attempts to determine this though the result has been controversy, not an agreed upon answer. There is agreement that the elasticity of foods, taken together, is relatively low because food consumption can not vary greatly. However, the elasticity of any one food is greater than food in total because there are other foods that can substitute for it.

Unitary elasticity is assumed in this model since it is in general agreement with past studies. Thus, the per capita expenditure for beef is independent of price. Personal disposable income is a major determinant of an individual's expenditure for beef. As income increases, a person will buy more expensive cuts of beef, switch from cheaper meats to beef, and increase his total beef consumption.17

An ordinary least-squares regression of consumption times deflated beef prices (deflated by the U.S.D.A.'s food price index) versus per capita disposable income yielded expenditure = .98 + (.78 ± .13)(personal disposable income) with 95% confidence limits.

A \hspace{1cm} \text{PCEFB}.K=1+(\text{DIM} \times (\text{PDII}.K-1))
C \hspace{1cm} \text{DIM}=0.8

\text{PCEFB} \hspace{0.5cm} \text{PER CAPITA EXPENDITURE FOR BEEF}
\text{DIM} \hspace{0.5cm} \text{DISPOSABLE INCOME MULTIPLIER}
\text{PDII} \hspace{0.5cm} \text{PERSONAL DISPOSABLE INCOME INDEX}

26. 

Personal Disposable Income Index

This is an exogenous imput that is necessary for determining the per capita expenditure for beef.

A \hspace{1cm} \text{PDII}.K=\text{TABHL}(\text{PDIT}, \text{TIME}.k/12,0,20,1)
T \hspace{1cm} \text{PDIT}=1/1.01/1.02/1.06/1.05/1.11/1.14/1.15/1.13/1.16/1.18/1.22/1.24/1.3/1.36/1.46/1.5/1.51/1.54
A \hspace{1cm} \text{PDII} \hspace{0.5cm} \text{PERSONAL DISPOSABLE INCOME INDEX}
A \hspace{1cm} \text{PDIT} \hspace{0.5cm} \text{PERSONAL DISPOSABLE INCOME TABLE}

27. 

Beef Price Index

Given the preceeding assumptions, it becomes easy to determine the beef price. It is simply expenditures divided by consumption. For making a base run of the model from 1950 to 1970, it was necessary to include an additional factor for consumer behavior during the Korean War.

A \hspace{1cm} \text{BPI}.K=(\text{PCEFB}.K/\text{APCC}.K)+\text{KWF}.K

\text{BPI} \hspace{0.5cm} \text{BEEF PRICE INDEX}
\text{PCEFB} \hspace{0.5cm} \text{PER CAPITA EXPENDITURE FOR BEEF}
\text{APCC} \hspace{0.5cm} \text{ACTUAL PER CAPITA CONSUMPTION}
\text{KWF} \hspace{0.5cm} \text{KOREAN WAR FACTOR}

28. 

Korean War Factor

During World War II, there was beef rationing. Rationing was well remembered when the Korean War began. People began hoarding beef similar to 1973's occurrence prior
to the lifting of price controls on beef. Hoarding was made possible by the advent of the home freezer and larger refrigerators. This increased demand caused prices to soar during the early stages of the war. People continued to hold their extra amount of beef until it became apparent that rationing would not be necessary. Then they consumed their extra beef stocks which lowered their purchases and depressed beef prices. Events such as the Korean War or price controls are extremely difficult to predict, much less trying to predict consumer reaction to them. Accordingly, it should be re-emphasized that this model is not predictive, but rather a tool in formulating and implementing improved policies.

A  \[ K_{WF,K} = \text{TABHL}(\text{KWFT}, \text{TIME}, K/12, 0, 4, 1) \]

T  \[ \text{KWFT}=0/.15/.04/-17/0 \]

\[ \text{KWFT} \quad - \quad \text{KOREAN WAR FACTOR} \]

\[ \text{KWFT} \quad - \quad \text{KOREAN WAR FACTOR TABLE} \]
For a model to be useful, one must have confidence in the model. This implies the model should be examined for validity. Validity testing takes many forms; it is advantageous to use as many techniques as possible. Discussed in this chapter are model development, replicating past behavior, and sensitivity testing.

Model Development

Remembering that the purpose of validity testing is developing confidence in the model, it is readily apparent that validity testing is not just one stage of developing a model, but something that should be accomplished in all stages.

During model development, care must be taken that formulation of relationships is as meaningful as possible to the "customer." Considerable care must be taken in determining the parameters of the model because a misspecification of a parameter will undermine the confidence of the customer even though the model may not be sensitive to the parameter. Thus, the first portion of validity testing is insuring that each of the parts of the model are plausible
and reasonably accurate. This was strived for in Chapter III as much as possible.

**Replicating Past Behavior**

The next phase is attempting to replicate past behavior. This was alluded to several times in Chapter III, and the model developed there is the base run 1950-1970 model. Figure IV-1 shows the results of plotting two key variables, beef cows and beef price versus the actual beef cows and actual beef price. The model performs adequately in replicating the long-term fluctuations, especially in beef prices. The closeness of fit between model and actual beef cows is not as good as for prices, and understandably so. There are influences that were not included because they would not substantially influence model behavior, though they do have an effect upon the number of cows. The most important of these are the lighter selling weights of fed animals due to American consumers' preference for better quality meat.¹

Another test of validity is a consideration of the plausibility of as many time trajectories as possible. If the "customer" can observe the various relationships between variables within a model and believe that their behavior is plausible, his confidence with the model will be enhanced.

¹Anthony and Motes, p. 280.
Figure IV-1: Model Results Versus Actual Results
Figure IV-2: Base Run 1950-1970

Diagram showing the trends in beef price, average slaughter rate, steers ready for market, and beef cows over the years 1950 to 1970.
Figure IV-2 shows a different set of variables from the same 1950-1970 base run. Assuming he finds the basic components of the model acceptable, a rancher would be additionally convinced of the model's validity by the key variables' phase relationships. The model's beef price tends to move in the opposite direction of steers ready for market, which also occurs in the real system. This relationship causes many ranchers to believe in the conspiracy theory mentioned in Chapter I; and, yet, the same results were derived from a model of the structure of the beef market and the method ranchers use to determine their herd size.

Sensitivity Testing

The final stage of validity testing is sensitivity testing to determine how model behavior varies when parameter values are changed, particularly those that are impossible to measure accurately. Again, the purpose is to increase the customer's confidence. He may believe the model builder arbitrarily chose these parameters so the model would work and that any other reasonable selection would generate unacceptable model behavior.

Table IV-1 shows the average absolute deviation between the model's beef price and the actual beef price as a function of parameter selection. This measure was used
Table IV-1: Sensitivity Effect of Constants

<table>
<thead>
<tr>
<th>Constant and Base Run Value</th>
<th>Tested Value</th>
<th>Average Absolute Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Run Values</td>
<td></td>
<td>.06</td>
</tr>
<tr>
<td>Herd Averaging Time = 12</td>
<td>HAT=6</td>
<td>.06</td>
</tr>
<tr>
<td></td>
<td>HAT=18</td>
<td>.06</td>
</tr>
<tr>
<td>Relative Feed Per Animal</td>
<td>RFAT=3.5/2.5/1.8</td>
<td>.05</td>
</tr>
<tr>
<td>Table=3/2.2</td>
<td>/1.3/1/.9/.8</td>
<td></td>
</tr>
<tr>
<td>1.6/1.2/1/.9/8</td>
<td>RFAT=2.5/1.9/1.4</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>/1.1/1/.9/.8</td>
<td></td>
</tr>
<tr>
<td>A1 - 1950 Fixed Costs Per-</td>
<td>A1=.3, A3=.4</td>
<td>.06</td>
</tr>
<tr>
<td>centage = .4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2 - 1950 Costs That Are A</td>
<td>A2=.3, A3=.2</td>
<td>.05</td>
</tr>
<tr>
<td>Function of RFA = .2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3 - 1950 Feed Costs Per-</td>
<td>A1=.5, A2=.1</td>
<td>.10</td>
</tr>
<tr>
<td>centage = .3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slaughter Rate Smoothing</td>
<td>ST=6</td>
<td>.06</td>
</tr>
<tr>
<td>Time = 9</td>
<td>ST=12</td>
<td>.08</td>
</tr>
<tr>
<td>Disposable Income Multiplier</td>
<td>DIM=.65</td>
<td>.07</td>
</tr>
<tr>
<td>= .8</td>
<td>DIM=.95</td>
<td>.08</td>
</tr>
<tr>
<td>DT = .5</td>
<td>DT=.1</td>
<td>.06</td>
</tr>
</tbody>
</table>
since price is considered to be one of the most important variables within the model.

The table indicates there were only two parameters to which the model was very sensitive: relative feed per animal table and one particular set of costs factors. It is unlikely either of these parameters would have a value in the sensitive range. If the relative feed per animal function was this flat, it would be advantageous for ranchers to eliminate their range land and feed their herds their entire food intake. Since ranchers do not do this, it is safe to assume that it is uneconomical.

Rejecting high fixed costs (A1) is more difficult. There are times and places where ranchers do have fixed costs this high, if one considers ranchers to be solely in the ranching business. However, ranchers are cognizant of the land boom that has been occurring during the past several decades and realize that part of their business is land holding for a profit. Since the majority of a rancher's fixed costs are land holding costs, the effective fixed costs for his beef operation are less than they might initially appear.

This chapter has shown that the model can be considered valid and can now be employed in testing new policies.
CHAPTER V
POLICY RECOMMENDATIONS

A policy is proposed which should improve ranchers' profitability. Evaluation criteria are developed with particular attention paid to the less-than-100-percent-adoption problem. Then the policy is tested using 1950-1970 data and plausible data for 1974-1994.

Proposed Policy

The ranchers' key decision is the number of heifers to withhold for breeding. In the past, ranchers have over-reacted to price changes. When profits were relatively high, ranchers withheld a large percentage of heifers while ignoring the certainty of supply increases which will force prices downward. Their behavior during periods of low prices was the opposite though with the same oblivion to competitive response through reduction of supply.

Thus, one policy recommendation would be: withhold few heifers when prices are high and withhold many when prices are low. There are other influences which would make the possibility of implementation of this policy remote. The most important is that during periods of low prices, the rancher may be having a severe cash flow problem. Therefore, it appears that a policy recommendation which would have a chance of implementation would be a bell-shaped curve such as one of those portrayed in Figure V-1.
Evaluation Criteria

To determine if a new policy is an improvement, criteria must be developed to evaluate it. As mentioned in Chapter I, the goal is profit improvement. Consequently, it is necessary to measure the change in profits from adopting a new policy. Profit is determined by summing the animals sold (cows sell for approximately 50% more than 7 month old calves) times the profit per animal. As mentioned before, .9 is the breakeven profit index; therefore, subtracting .9 from the profit index yields a profit per animal index. Dividing this by the initial number of cows in a sector yields a normalized profit.
The challenge for the future of modeling is determining effective methods for gaining adoption of any recommendations arising from a "global" model, a model where a great number of decision makers are aggregated together. Decision makers must be confident that adopting new policies will improve their performance, independent of adoption by others; otherwise, implementation of recommendations is difficult.

To insure that the proposed policy is beneficial regardless of adoption rate, a second beef herd sector,\(^1\) identical to the one in the basic model, was added. To represent varying degrees of policy acceptance, all that is necessary is to vary the initial values of beef cows in each of the two sectors. For example, starting with an index of 80 cows in the old sector and a 20 cows index in the new sector would represent 20 percent adoption of the new policy. The sum of the initial conditions must equal 100.

**New Policy Results 1950-1970**

Table V-1 contains the results for what would have happened during 1950-1970 had each of the policies (as shown in Figure V-1) been adopted in 1950. In addition, it shows the influence of adoption rate on profitability.

The results indicate that the tested new policies do indeed improve profits for ranchers. They also improve

\(^1\)Appendix C contains a listing of this two beef herd sector model.
profits regardless of the percent adopting the new policies. As more ranchers adopt any of the new policies, the profits of all ranchers are increased. In addition, everyone concerned benefits because as the percent adopting the new policies increases, the amplitude of the price fluctuations decreases.\(^2\)

**Table V-1: New Policy Profits 1950-1970**

<table>
<thead>
<tr>
<th>% Adopters</th>
<th>Policy 1</th>
<th>Policy 2</th>
<th>Policy 3</th>
<th>Policy 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.56</td>
<td>1.56</td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>99</td>
<td>2.14</td>
<td>2.13</td>
<td>2.10</td>
<td>2.07</td>
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<tr>
<td>99</td>
<td>2.14</td>
<td>2.13</td>
<td>2.10</td>
<td>2.07</td>
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<tr>
<td>80</td>
<td>2.28</td>
<td>1.57</td>
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<td>1.57</td>
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<tr>
<td>80</td>
<td>2.28</td>
<td>1.57</td>
<td>1.57</td>
<td>1.57</td>
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<tr>
<td>50</td>
<td>2.63</td>
<td>2.60</td>
<td>2.57</td>
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<td>50</td>
<td>2.63</td>
<td>2.60</td>
<td>2.57</td>
<td>2.54</td>
</tr>
<tr>
<td>50</td>
<td>1.99</td>
<td>1.97</td>
<td>1.94</td>
<td>1.92</td>
</tr>
<tr>
<td>20</td>
<td>3.81</td>
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<tr>
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</table>

**New Policy Results 1974-1994**

Not only is it necessary to show that the new policies are an improvement, using a past period's data, but it is also necessary to show that they will most likely be an improvement over current policies during future periods. To

\(^2\)Above 80% adoption, exponentially increasing prices can occur with no correcting action countering it. However, the probability of ever obtaining the necessary agreement to have this high an adoption rate is so remote that this outcome can be ignored.
Table V-2: New Policy Profits 1974-1994

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<td>.43</td>
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<td>.56</td>
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<td>80</td>
<td>.84</td>
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<td>.56</td>
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<td>50</td>
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<td>.75</td>
<td>.64</td>
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<td>.59</td>
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<td>20</td>
<td>.92</td>
<td>.75</td>
<td>.63</td>
</tr>
<tr>
<td>Adopters^4</td>
<td>99</td>
<td>1.80</td>
<td>1.58</td>
<td>1.36</td>
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<tr>
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<td>99</td>
<td>.61</td>
<td>.46</td>
<td>.33</td>
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</table>

accomplish this, several changes were made in the constants and table functions as suggested in Chapter IV. ³

Most of the changes are straightforward and were mentioned in the applicable sections of Chapter III. However, a key variable to ranchers is feed prices, which are difficult to determine. Therefore, several different feed price inputs were used to examine the influence of feed prices on policy selection.

³A listing of this model is contained in Appendix D.

⁴These runs are identical to the other set with 1% adoption, except there is a noise factor included in the feed price equation with a standard deviation of .1.

⁵The four policies, as shown in Figure V-1, all produced similar results. All mention of new policy henceforth will be referring to policy 1 as shown in that Figure.
Table V-2 shows the relationships among profits, feed price increase, and percentage adoption. The feed price increase is formulated as a ramp increase (the number shown in the Table is the 1994 price deflated by the consumer price index with 1974=1). In addition, runs were made containing noise to determine if policy selection was sensitive to noise.

The new policy is not as advantageous during 1974-1994 as it was during 1950-1970. The difference is a result of the fixed percentage of animals being feed lot fed, the fixed dairy animal slaughter rate, and primarily increasing feed prices. This combination of factors causes long periods of reduced beef prices. These periods decrease the effectiveness of the new policy in shifting marketings from low price periods to high price periods.

In the future, increased adoption reduces the profitability of adopters and increases the profitability of non-adopters. Increased feed costs cause lower profitability for both sets of ranchers, though the adopters' profits are decreased to a greater extent. It is apparent that if reality is represented by the northwest corner of Table V-2, it is advantageous for a rancher to adopt the new policy.

The study recommends the utilization of the new policy even though it is possible for adoption to reduce profitability, as Table V-2 indicates. However, the probability of
having greater than 20 percent adoption is remote and it is unlikely that feed prices will increase greatly. Therefore, it appears that it is profitable for ranchers to adopt the new policies.

When dealing with agricultural policy, it is important to consider possible political or consumer reaction to changes. Because price fluctuations are dampened as percent adoption increases, adopting the new policy would reduce consumer awareness of beef price changes. The average cost of beef is slightly increased, though this will generally be unnoticed by consumers. The reduced price fluctuations benefit everyone since they reduce the risks and uncertainties inherent to the beef industry.

As was shown in Table V-1, the four policies performed almost identically. This is because the general shape of the decision function (Figure V-1) was the same for each. Thus, one does not need to be exact in the policy specification, which makes it much easier for ranchers to use the revised policy. A verbal description of the policy would be: Withhold as many heifers as possible contingent upon cash flow problems when prices are low; when prices are

---

6 This model was initialized with 1974's high feed prices. Prices will most likely decrease due to competitive response. This is a deflated index; and during the period 1950-1970, there was a decrease. It appears that a 40 percent increase by 1994 is a good estimate of the maximum increase.
average, increase heifer withholdings to one-third of those available; and when prices are very high, do not withhold heifers. Adopting this verbal policy should increase a rancher’s profitability.
CHAPTER VI
CONCLUSION

Implications of the Study

This study has shown that Systems Dynamics and Dynamo are excellent tools in analyzing a complex feedback system. Most past studies have concentrated upon the estimation of the price elasticities of supply and demand. This study demonstrates the beef system is insensitive to most parameters. Since structure is the most important determinant of the system behavior, the emphasis should be upon the structure of the system. The purpose of constructing the model was policy selection. Since the ranking of policies was independent of parameter selection within a broad range, accurate parameter estimation is not cost effective.

The goal of this study was determining policy guidelines that are usable by ranchers and which increase their profits. This has been accomplished, though the task of gaining ranchers' implementation remains. The most advantageous channels of communication and the most appropriate methods of presentation should be determined in order to evoke the largest consideration and adoption of the recommended policy.
Extensions of the Study

Not only can the model be used for examining ranchers' policies, but also for testing government policies that may affect the beef industry. For example, it would be possible to test the influence of increasing government expenditures for beef upon the amplitude of the price fluctuations and upon the average price of beef. This could be accomplished by including an exogenous input to beef expenditures. Beef input quota policy could be tested similarly by including inputs as an exogenous input to the average slaughter rate.

This study has shown that designing a model of the beef industry is relatively easy and that it is possible to make meaningful policy recommendations using the model. However, the techniques necessary to achieve implementation, especially of a "global" model, are poorly understood and deserve increased attention in the future.
BIBLIOGRAPHY


BIBLIOGRAPHY cont.


### Appendix A: Basic Model Equations

**Appendix A:**

<table>
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<tr>
<th>Equation</th>
<th>Description</th>
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<tr>
<td>( BC \cdot K = BC \cdot J + DT \cdot (HBC \cdot JK - CSR \cdot JK) ) BEEF COWS</td>
<td>1</td>
</tr>
<tr>
<td>( BC = 100 ) BEEF COWS</td>
<td>2</td>
</tr>
<tr>
<td>( GRH \cdot KL = BC \cdot K / AMBH ) GESTATION RATE HEIFERS</td>
<td>3</td>
</tr>
<tr>
<td>AMBH = 24 MONTHS AV. MONTHS BETWEEN HEIFERS</td>
<td>3</td>
</tr>
<tr>
<td>( BRH \cdot KL = SR \cdot DELAY3(\text{GRH} \cdot JK, GT) ) BIRTH RATE HEIFERS</td>
<td>3</td>
</tr>
<tr>
<td>( SR = .9 ) SURVIVAL RATE</td>
<td>3</td>
</tr>
<tr>
<td>( GT = 9 ) MONTHS GESTATION TIME</td>
<td>3</td>
</tr>
<tr>
<td>( HRFM \cdot KL = DELAY3(\text{BRH} \cdot JK, AMT) ) HEIFERS READY FOR MARKET RATE</td>
<td>3</td>
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<tr>
<td>AMT = 7 MONTHS AV. MARKETING TIME</td>
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<tr>
<td>( HRFM \cdot K = HRFM \cdot J + DT \cdot (HRFM \cdot JK - HFB \cdot JK - HFFS \cdot JK - HS \cdot JK) ) HEIFERS READY MARKET</td>
<td>3</td>
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<tr>
<td>HRFM = 3.75</td>
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<tr>
<td>( HBC \cdot KL = DELAYP(HFB \cdot JK, ACT, HHFP \cdot K) ) HEIFERS BECOMING COWS</td>
<td>3</td>
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<tr>
<td>ADT = 16 MONTHS AV. DELAY TIME IN BECOMING COWS</td>
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<tr>
<td>CSR \cdot KL = BC \cdot K / ACL COW SLAUGHTER RATE</td>
<td>3</td>
</tr>
<tr>
<td>ACL = 100 MONTHS AV. COW LIFETIME</td>
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<tr>
<td>( AH \cdot K = AH \cdot J + DT \cdot (HHFB \cdot J + BC \cdot J - AH \cdot J) ) / HAT AVERAGE HERD</td>
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<tr>
<td>AH = 100 * (16 * HFB)</td>
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<td>HAT = 12 MONTHS HERD AVERAGING TIME</td>
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<tr>
<td>( RFAT = 1 / 1.09 / 1.02 / 1.01 / 0.9 / 0.8 ) RELATIVE FEED PER ANIMAL</td>
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<tr>
<td>( NH = 100 + (16 * HFB) ) NORMAL HERD</td>
<td>3</td>
</tr>
<tr>
<td>( EPIT = \text{TABLE}(\text{EPIT}, \text{TIME}, K / 12, 0, 0, 20, 1) ) FEED PRICE INDEX</td>
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<tr>
<td>( \text{EPIT} = 1 / 1.09 / 1.02 / 1.01 / 0.9 / 0.8 ) RELATIVE FEED PER ANIMAL TABLE</td>
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<td>( NH = 100 + (16 * HFB) ) NORMAL HERD</td>
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<tr>
<td>( PHKB \cdot K = \text{TABLE}(PHKB, PI \cdot K, 12 / 1.09 / 1.02 / 1.01 / 0.9 / 0.8) ) % HEIFERS KEPT FOR BREEDING</td>
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</tr>
<tr>
<td>( PHKB = 1.15 / 1.18 / 1.26 / 1.46 / 1.51 / 1.65 / 1.75 / 1.8 ) % TABLE HEIFERS KEPT BREEDING</td>
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</table>
HFB*KL=HRFM*K*PHKB.K/DECT HEIFERS FOR BREEDING
HFB=HFB1
HFB1=1.8
DECT=1 MONTH DECISION TIME
HFFS.KL=HRFM.K*(1-PHKB.K)*PFLF.K/DECT HEIFERS FED FOR SLAUGHTER
HS.KL=HRFM.K*(1-PFLF.K)*(1-PHKB.K)/DECT HEIFERS SLAUGHTERED

FEED LOT SECTOR

PFLF.K=TABHL(PFLFT,TIME.K/12,0,20,1) % FEED LOT FED
SRFM.K=HRFM.K STEERS READY FOR MARKET
SFFS.KL=SRFM.K*PFLF.K/DECT STEERS FED FOR SLAUGHTER
SS.KL=SRFM.K*(1-PFLF.K)/DECT STEERS SLAUGHTERED
FASR.KL=DELAYP(SFFS.JK+HFFS.JK,AFT,AFL.K) FED ANIMAL SLAUGHTER RATE
AFT=5 MONTHS ANIMAL FEEDING TIME
ASR.K=ASR.J+DT*(FASR.JK+5*CSR.JK+6*(HS.JK+SS.JK)+DASR.JK
=ASR.J)/ST AVERAGE SLAUGHTER RATE
ASR=(7.5-HFB1)*.514+1.5+1.2916*(7.5-HFB1)+.73
ST=9 MONTHS SMOOTHING TIME

CONSUMER SECTOR

APCC.K=ASR.K/(NSR*POPI.K) ACTUAL PER CAPITA CONSUMPTION
NSR=((7.5-HFB1)*.514+1.5+1.2916*(7.5-HFB1)+.73)*IPC NORMAL SLAUGHTER
IPC=1.04
DAS.K=TABLE(DASRT,TIME.K/12,0,20,1) DAIRY ANIMAL SLAUGHTER
.56/.53/.5/.47/.46/.45
DASR.KL=DAS.K/1
POPI.K=TABHL(POPT,TIME.K/12,0,20,1) POPULATION INDEX
POPT=1/1.01/1.02/1.04/1.06/1.08/1.1/1.12/1.14/1.16/1.19/1.21/1.22
1.24/1.26/1.28/1.3/1.32/1.33/1.34 POPULATION TABLE
PCEF.R.K=1+(DIM*(POII.K-1)) PER CAPITA EXPENDITURE FOR BEEF
DIM=.8 DISPOSABLE INCOME MULTIPLIER
PDII.K=TARHL(PDIT,TIME,K/12,C,20,1) PERSONAL DISPOSABLE INCOME INDEX 25
PDIT=1/1.01/1.02/1.06/1.05/1.11/1.14/1.15/1.13/1.16/1.16/1.18/
1.22/1.24/1.3/1.36/1.4/1.46/1.5/1.51/1.54 PERSONAL DISPOSABLE INCOME TABLE 26
BPI.K=(PCEF8.K/APCC.K)+KWF.K BEEF PRICE INDEX
KWF.K=TARHL(KWFT,TIME,K/12,C,4,1)
KWFT=0/.15/.04/-1.17/0

NOTE
SUPPLEMENTAL EQUATIONS
NOTE
ABC.K=TABHL(ABCT,TIME,K/12,0,20,1) ACTUAL BEEF COWS
ABCT=100/110/125/139/149/153/151/146/144/150/154/163/171/183/196
/204/206/204/212/216/224 ACTUAL BEEF COW TABLE
ABP.K=TARHL(BPT,TIME,K/12,0,20,1) ACTUAL BEEF PRICES
BPT=1.12/1.33/1.23/.91/.94/.84/.86/.91/.01/1.03/.97/.91/1.03/.88
/.85/.97/.96/.95/1.03/1.21 BEEF PRICE TABLE
ADR.KL=FIGE(BPI,K-ABP.K,ABP,K-BPI,K,BPI,K,ABP,K) ABSOLUTE DEVIATION RATE
ADS.K=ADS.J+(DT*ADR.JK) ABSOLUTE DEVIATION SUM
ADS=0
AADS.K=ADS.K/TIME,K AVERAGE ABSOLUTE DEVIATION SUM

NOTE
CONTROL STATEMENTS
NOTE
PRINT 11RFA/21PHKB/3)SRFM/4)AFL/5)ASR/6)BPI/7)PI/8)ADR/9)ADS/10)AADS/
X 11)HHFB/12)BC/13)HFB/14)HBC
C PRTPER=12
C PLOT BC=C,ABC=B(0,240)/BPI=P,ABP=A(0,16)
PLOT SRFM=5(S(0,8)/BPI=P,PI=1(0,1,6)/BC=C(0,240)/ASR=6(0,14)
C PLTPER=8
C DT=.5
C LENGTH=240
RUN BASE RUN 1950 - 1970
## Appendix B: Definitions

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<td>Slaughter Rate Smoothing Time</td>
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</table>
A SYSTEMS STUDY OF THE DYNAMIC BEEF MARKET

BC*JK=BC*J+DT*(HBC*JK-CSR*JK) BEEF COWS
BC=IBC
IBC=99 INITIAL BEEF COWS
GRH*KL=BC*K/AMBH GESTATION RATE HEifers
AMBH=24 MONTHS AV. MONTHS BETWEEN HEifers
BRH*KL=SR*DELAY3(GRH*JK,GT) BIRTH RATE HEifers
SR=.9 SURVIVAL RATE
GT=9 MONTHS GESTATION TIME
HIFM*KL=DELAY3(BRH*JK,AMT) HEifers READY FOR MARKET RATE
AMT=7 MONTHS AV. MARKETING TIME
HIFM*K=HIFM*J+DT*(HIFM*K-HFB*JK-HFFS*JK-HS*JK) HEifers READY MARKET
HIFM=.0375*IBC
HBC*KL=DELAYP(HFB*JK,ADT,HFFB*K) HEifers BECOMING COWS
ADT=16 MONTHS AV. DELAY TIME IN BECOMING COWS
CSR*KL=BC*K/ACL COW SLAUGHTER RATE
ACL=100 MONTHS AV. COW LIFETIME
AH*JK=AH*J+DT*(HFB*J+BC*J-AH*J)/HAT AVERAGE HERD
AH=IBC+(ADT*HFBI*IBC)
HAT=12 MONTHS HERD AVERAGING TIME
RFA*K=TABLE(RFAT,NH/AH*K,0,1,5,25) RELATIVE FEED PER ANIMAL
RFAT=3/2.0/1.6/1.2/1.0/9/8 RELATIVE FEED PER ANIMAL TABLE
NH=IBC+(ADT*HFBI*IBC) NORMAL HERD
FPI*K=TABHL(FPIT,TIME*K/12,0,20,1) FEED PRICE INDEX
FPIT=1/1.09/1.02/1.93/1.94/1.95/1.96/1.97/1.98/1.99/1.92
/1.94/.99/1.01/1.02/1.03 FEED PRICE INDEX TABLE
A1=.4 1950 FIXED COSTS %
A2=.2 1950 COSTS THAT ARE A FUNCTION OF RFA
A3=.3 1950 FEED COSTS %
PHKB*K=TABLE(PTHKB,P1*K,.8,.15,.18,.26,.46,.51,.65,.75,.8) % HEifers KEPT FOR BREEDING

Appendix C: Equations Two Beef Herd Sector Model
<table>
<thead>
<tr>
<th>NOTE</th>
<th>SECOND BEEF HERD SECTOR</th>
<th>101</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>BCX.K=BCX.J+DT*(HBCX.JK-CSRX.JK) BEEF COWS X</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>BCX=PAX</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>PAX=1% ADOPTING X</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>GRHX.KL=BCX.K/AMBH CESSION RATE HEIFERS X</td>
<td>102</td>
</tr>
<tr>
<td>R</td>
<td>BRHX.KL=SR*DELAY3(GRHX.JK,GT) BIRTH RATE HEIFERS X</td>
<td>103</td>
</tr>
<tr>
<td>R</td>
<td>HRFRMX.KL=DELAY3(BRHX.JK,AMT) HEIFERS READY FOR MARKET RATE X</td>
<td>104</td>
</tr>
<tr>
<td>L</td>
<td>HRFRMX.KL=HFRMX.J+DT*(HFRMX.JK-HFBX.JK-HFSX.JK-HSX.JK)</td>
<td>105</td>
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<tr>
<td>NOTE</td>
<td>HEIFERS READY FOR MARKET X</td>
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</tr>
<tr>
<td>N</td>
<td>HRFRMX=0.0375*PAX</td>
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<tr>
<td>R</td>
<td>HBCX.KL=DELAYP(HFRX.JK,ADT,HFBX.K) HEIFERS BECOMING COWS X</td>
<td>106</td>
</tr>
<tr>
<td>L</td>
<td>CSRX.KL=BCX.K/ACL COW SLAUGHTER RATE X</td>
<td>107</td>
</tr>
<tr>
<td>N</td>
<td>AHX.K=AHX.J+DT*(HFBX.J+BCX.J-AHX.J)/HAT AVERAGE HERD X</td>
<td>108</td>
</tr>
<tr>
<td>N</td>
<td>AHX=PAX*(ADT*HFRMX)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>RFAX.K=TABLE(RFAT,NHX/AHX,K,0.5,25) RELATIVE FEED PER ANIMAL X</td>
<td>109</td>
</tr>
<tr>
<td>N</td>
<td>NHX=PAX+(ADT*HFBX)</td>
<td></td>
</tr>
<tr>
<td>NOTE</td>
<td>PROFIT INDEX X</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>PHKBX=TABLE(PTHKBX,PIX.K,6,1,4,1) % HEIFERS KEPT FOR BREEDING X</td>
<td>112</td>
</tr>
<tr>
<td>T</td>
<td>PTHKBX=20/20/25/35/35/30/25/30/10/0</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>HRFRMX.KL=HFRMX.K*PHKBX.K/DECT HEIFERS FOR BREEDING X</td>
<td>113</td>
</tr>
<tr>
<td>R</td>
<td>HFBX=HFB1*PAX</td>
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</tr>
<tr>
<td>R</td>
<td>HFFS K=HFRMX.K*(1-PHKBX.K)*PFLF.K/FED FOR SLAUGHTER</td>
<td>114</td>
</tr>
<tr>
<td>R</td>
<td>HSX.KL=HFRMX.K*(1-PHKBX.K)*(1-PFLF.K)/DECT HEIFERS SLAUGHTER</td>
<td>115</td>
</tr>
<tr>
<td>NOTE</td>
<td>FEED LOT SECTOR</td>
<td></td>
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</tbody>
</table>
A

PFLF.K=TABH(L(PFLF.TIME.K/12,.0,20.1) % FEED LOT FED
X
PFLF=514/595/631/532/515/539/535/525/602/664/644/675/
X
X
SRFM.K=HRFM.K+HRFM.X.K STEERS READY FOR MARKET
X
SFFS.KL=SRFM.K*PFLF.K/DECT STEERS FED FOR SLAUGHTER
X
SS.KL=SRFM.K*1-PFLF.K)/DECT STEERS SLAUGHTERED
X
FASR.KL=DELAYP(SFFS.JK+HFFS.JK+HFFX.JK,AFT,AFL.K)

NOTE

FED ANIMAL SLAUGHTER RATE
AFT=5 MONTHS ANIMAL FEEDING TIME
DASR.KL=TABLE(DASRT.TIME.K/12,.0,20.1) DAIRY ANIMAL SLAUGHTER RATE
X
X
ASR.K=ASR.J+DT*(FASR.JK+1.5*(CSR.JK+CSR.X.JK)+6*(HS.JK+HSX.JK+
X
SS.JK)+DASR.JK-ASR.J)/ST AVERAGE SLAUGHTER RATE
X
ASR=6.822
X
ST=9 MONTHS SMOOTHING TIME

NOTE

CONSUMER SECTOR
NOTE

APCC.K=ASR.K/(NSR*POPI.K) ACTUAL PER CAPITA CONSUMPTION
X
NSR=6.822*IPC NORMAL SLAUGHTER RATE
X
IPC=1.04
X
POPI.K=TABLE(POPT.TIME.K/12,.0,20.1) POPULATION INDEX
X
POPT=1/1.01/1.02/1.04/1.05/1.06/1.1/1.1/1.12/1.14/1.16/1.19/1.21/1.22
X
/1.24/1.26/1.28/1.3/1.31/1.33/1.34 POPULATION TABLE
X
PCEFB.K=1+(DIM*(POII.K-1)) PER CAPITA EXPENDITURE FOR BEEF
X
DIM=.8 DISPOSABLE INCOME MULTIPLIER
X
POII.K=TABLE(PDIT.TIME.K/12,.0,20.1) PERSONAL DISPOSABLE INCOME INDEX
X
PDIT=1/1.01/1.02/1.03/1.05/1.1/1.1/1.1/1.12/1.14/1.16/1.16/1.18/
X
1.22/1.24/1.3/1.36/1.4/1.46/1.5/1.5/1.54 PERSONAL DISPOSABLE INCOME TABLE
X
BPI.K=(PCEFB.K/APCC.K)+KWF.K BEEF PRICE INDEX
X
KWF.K=TABLE(KWFT.TIME.K/12,.0,4.1) KOREAN WAR FACTOR
X
KWFT=0/.15/.04/-17/.0 KOREAN WAR FACTOR TABLE

NOTE

SUPPLEMENTAL EQUATIONS
R   P. KL = (((HRFM.K*(2-PHKB.K))+(1.5*(BC.K/ACL)))*(PI.K-.9))/IBC PROFIT RATE
L   SP.K=SP.J+DT*P.JK SUM OF PROFITS
N   SP=0
R   PX.KL = (((HRFMX.K*(2-PHKBX.K))+(1.5*(BCX.K/ACL)))*(PIX.K-.9))/PAX
NOTE PROFIT RATE X
L   SPX=SPX.J+DT*PX.JK SUM OF PROFITS X
N   SPX=0
NOTE CONTROL STATEMENTS
NOTE PRINT 1)RFA/2)RFAX/3)PHKB/4)PHKRX/5)SRFM/6)AFL/7)ASR/8)RPI/9)APCC/
X   10)PI/11)PIX/12)AH/13)AHX/14)PCEFB
PRINT 1)HHFB/2)HHF8X/3)BC/4)BCX/5)HFR/6)HFBX/7)HRC/
X   8)HRCX/9)P/10)PX/11)SP/12)SPX
C   PRTPER=12
C   DT=.5
C   LENGTH=240
RUN RUN 12 WITH SECOND BEEF HERO SECTOR
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<tr>
<th>NOTE</th>
<th>A SYSTEMS STUDY OF THE DYNAMIC BEEF MARKET</th>
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<tbody>
<tr>
<td>NOTE</td>
<td>BEEF HERD SECTOR</td>
</tr>
<tr>
<td>L</td>
<td>BC.K = BC.J + DT*(HBC.JK - CSR.JK) BEEF COWS</td>
</tr>
<tr>
<td>N</td>
<td>BC = IBC</td>
</tr>
<tr>
<td>C</td>
<td>IBC = 99 INITIAL BEEF COWS</td>
</tr>
<tr>
<td>R</td>
<td>GRH.KL = BC.K/AMBH GESTATION RATE HEIFERS</td>
</tr>
<tr>
<td>C</td>
<td>AMBH = 24 MONTHS AV. MONTHS BETWEEN HEIFERS</td>
</tr>
<tr>
<td>R</td>
<td>BRH.KL = SR*DELAY3(GRH.JK, GT) BIRTH RATE HEIFERS</td>
</tr>
<tr>
<td>C</td>
<td>SR = .9 SURVIVAL RATE</td>
</tr>
<tr>
<td>C</td>
<td>GT = 9 MONTHS GESTATION TIME</td>
</tr>
<tr>
<td>R</td>
<td>HRFMR.KL = DELAY3(BRH.JK, AMT) HEIFERS READY FOR MARKET RATE</td>
</tr>
<tr>
<td>C</td>
<td>AMT = 7 MONTHS AV. MARKETING TIME</td>
</tr>
<tr>
<td>L</td>
<td>HRFM.K = HRFM.J + DT*(HRFM.JK-HFB.JK-HFFS.JK-HS.JK) HEIFERS READY MARKET</td>
</tr>
<tr>
<td>N</td>
<td>HFC = .0375*IBC</td>
</tr>
<tr>
<td>R</td>
<td>HFC.KL = DELAY3(HFB.JK, ADT, HFB.K) HEIFERS BECOMING COWS</td>
</tr>
<tr>
<td>C</td>
<td>ADT = 16 MONTHS AV. DELAY TIME IN BECOMING COWS</td>
</tr>
<tr>
<td>C</td>
<td>CSR.KL = BC.K/ACL COW SLAUGHTER RATE</td>
</tr>
<tr>
<td>C</td>
<td>ACL = 100 MONTHS AV. COW LIFETIME</td>
</tr>
<tr>
<td>L</td>
<td>AH.K = AH.J + DT*(HFB.J + BC.J - AH.J)/HAT AVERAGE HERD</td>
</tr>
<tr>
<td>N</td>
<td>AH = IBC + (ACT<em>HFB</em>I BC)</td>
</tr>
<tr>
<td>C</td>
<td>HAT = 12 MONTHS HERD AVERAGING TIME</td>
</tr>
<tr>
<td>A</td>
<td>RFA.K = TABLE(RFAT, NH/AH.K, 0.15, .25) RELATIVE FEED PER ANIMAL</td>
</tr>
<tr>
<td>T</td>
<td>RFAT = 3/2.2/1.6/1.2/1.9/.8 RELATIVE FEED PER ANIMAL TABLE</td>
</tr>
<tr>
<td>N</td>
<td>NH = IBC + (ACT<em>HFB</em>I BC) NORMAL HERD</td>
</tr>
<tr>
<td>A</td>
<td>FPI.K = (NORMR(1, SD)) * (1 + TIME.K/FPIF) FEED PRICE INDEX</td>
</tr>
<tr>
<td>C</td>
<td>SD = 0 STANDARD DEVIATION</td>
</tr>
<tr>
<td>C</td>
<td>FPIF = 600</td>
</tr>
<tr>
<td>C</td>
<td>PI.K = BPI.K/(((A1<em>NH)/AH.K) + .1 + (A2</em>RFA.K)+(A3<em>RFA.K</em>FPI.K)) PROFIT INDEX</td>
</tr>
<tr>
<td>A</td>
<td>A1 = .3 1974 FIXED COSTS %</td>
</tr>
<tr>
<td>C</td>
<td>A2 = .2 1974 COSTS THAT ARE A FUNCTION OF RFA</td>
</tr>
<tr>
<td>C</td>
<td>A3 = .4 1974 FEED COSTS %</td>
</tr>
<tr>
<td>A</td>
<td>PKHKB.K = TABLE(PTHKB*PI.K, 6.1, 4.1) % HEIFERS KEPT FOR BREEDING</td>
</tr>
<tr>
<td>T</td>
<td>PTHKB = .1/.15/.18/.26/.46/.51/.65/.75/.8 % TABLE HEIFERS KEPT BREEDING</td>
</tr>
</tbody>
</table>
HFB.KL=HRFM.K*PHKB.K/DECT HEIFERS FOR BREEDING
HFB=HFB1*IBC
HFB1=.018 HEIFERS FOR BREEDING INITIAL %
DECT=1 MONTH DECISION TIME
HFFS.KL=HRFM.K*(1-PHKB.K)*PFLF.K/DECT HEIFERS FED FOR SLAUGHTER
HS.KL=HRFM.K*(1-PFLF.K)*(1-PHKB.K)/DECT HEIFERS SLAUGHTERED

NOTE
SECOND BEEF HERD SECTOR

BCX.K=BCX.J+DT*(HBCX.JK-CSRX.JK) BEEF COWS X
BCX=PAX
PAX=1% ADOPTING X

GRHX.KL=BCX.K/AMBL GESTATION RATE HEIFERS X
BRHX.KL=SR*DELAY3(GRHX.JK,GT) BIRTH RATE HEIFERS X
HRFMRX.KL=DELAY3(BRHX.JK,AMT) HEIFERS READY FOR MARKET RATE X
HRFMX.K=HRFMX.J+DT*(HRFMRX.JK-HFBX.JK-HFFSX.JK-HSX.JK)

NOTE
HEIFERS READY FOR MARKET X
HRFMX=0.375*PAX
HBCX.KL=DELAYP(HFBX.JK,ADT,HFFBX.K) HEIFERS BECOMING COWS X
CSRX.KL=BCX.K/ACL COW SLAUGHTER RATE X

AHX,K=AHX.J+DT*(HFBX.J+BCX.J-AHX.J)/MAT AVERAGE HERD X

AHX=PAX*(ADT*HFB1*PAX)

RFAK.K=TABLE(RFAT,NHX/AHX.K,0,1,5,.25) RELATIVE FEED PER ANIMAL X
NHX=PAX*(ADT*HFB1*PAX) NORMAL HERD X

NOTE
PROFIT INDEX X

PHKBX.K=TABLE(PTHKBX,PIX.K,6,1.4,.1) % HEIFERS KEPT FOR BREEDING X
HFBX.KL=HRFMX.K*PHKBX.K/DECT HEIFERS FOR BREEDING X
HFBX=HFB1*PAX
HFFSX.KL=HRFMX.K*(1-PHKBX.K)*PFLF.K/DECT HEIFERS FED FOR SLAUGHTER
HSX.KL=HRFMX.K*(1-PHKBX.K)*(1-PFLF.K)/DECT HEIFERS SLAUGHTERED X

NOTE
FEED LOT SECTOR

NOTE
PFLF,K=PFGLF % Feed Lot Fed
FPFLF=.9 Fixed Percentage Feed Lot Fed
SRFM,K=HRF.M,K+HRM.X,K Steers Ready for Market
SFFS,KL=SRFM,K*PFLLF,K/DECT Steers Fed for Slaughter
SS,KL=SRFM,K*(1-PFLLF,K)/DECT Steers Slaughtered
FASR,KL=DELAY(SFFS,KJ+HFFS,JK+HFFSX,JK,AFT,AFL,K)

NOTE
FED ANIMAL SLAUGHTER RATE
AFT=5 MONTHS ANIMAL FEEDING TIME
DASR,KL=FDASR DAIRY ANIMAL SLAUGHTER RATE
FCASR=.4 FIXED DAIRY ANIMAL SLAUGHTER RATE
ASR,K=ASR,J+DT*(FASR,JK+1.5*(CSR,JK+CSRX,JK)+.6*(HS,JK+HSX,JK+
SS,JK)+DASR,JK-ASR,J)/ST AVERAGE SLAUGHTER RATE
ASR=7.264
ST=9 MONTHS SMOOTHING TIME

NOTE
CONSUMER SECTOR

APCC,K=ASR,K/NSR*POPI.K) ACTUAL PER CAPITA CONSUMPTION
NSR=7.264*IPC NORMAL SLAUGHTER RATE
IPC=1.1 INITIAL PRICE CONDITION
POPI,K=1+(TIME.K/600) POPULATION INDEX
PCEF.B,K=1+(DIMX(PDII.K-1)) PER CAPITA EXPENDITURE FOR BEEF
DIM=.8 DISPOSABLE INCOME MULTIPLIER
PDII,K=EXP(TIME.K*LOGN(1.016)) PERSONAL DISPOSABLE INCOME INDEX
BPI.K=PCEF.B.K/APCC.K BEEF PRICE INDEX

SUPPLEMENTAL EQUATIONS

P,K=((HRF.M,K*(2-PHKB.K))+(1.5*(BC.K/ACL)))*(PI,K-.9))/IBC PROFIT RATE
SP.K=SP.J+DT*PJK SUM OF PROFITS
SP=0
PX,KL=((HRF.M,K*(2-PHKB.K))+(1.5*(BCX.K/ACL)))*(PIX.K-.9))/PAX
NOTE
PROFIT RATE X

SPX.K=SPX.J+DT*PX.JK SUM OF PROFITS X
SPX=0
NOTE: CONTROL STATEMENTS
NOTE
PRINT 1)RFA/2)RFAX/3)PHKB/4)PHK8X/5)SRFM/6)AFL/7)ASR/8)BPI/9)APCC/
X 10)PI/11)PIX/12)AH/13)AHX/14)PCER
PRINT 1)HHFB/2)HHFBX/3)HC/4)BCX/5)HFB/6)HFBX/7)HBC/
X 8)HBCX/9)P/10)PX/11)SP/12)SPX/13)FPI
C PRTPER=12
C CT=.5
C LENGTH=240
RUN RUN 22 1974 - 1994 WITH NEW POLICIES