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ABSTRACT

SIMULATION OF THE CATTLE-CALVES SUB-SECTOR IN A DEVELOPED ECONOMY WITH SPECIAL REFERENCE TO THE CANADIAN CATTLE HERD

By

John James Meek

Cattle prices and cattle numbers in Canada have historically demonstrated a regular cyclical time pattern; recently this pattern has become more irregular. This cycle results in fluctuating incomes to producers, fluctuating prices to consumers, and fluctuating contributions to the foreign trade sector. While these fluctuations might have been tolerated in an earlier age, modern society demands more stability, more growth, and more management.

In order to predict supply or prescriptive right actions, descriptive knowledge of the dynamics of cattle production and trade is required. The purpose of this dissertation is to contribute both descriptive knowledge and analytical tools that may subsequently be employed in prescriptive and predictive applications as well as in future descriptive analyses.

The study has three basic objectives; these objectives are realized concurrently rather than sequentially. The first objective is to identify the structure and develop a model of the Canadian cattle herd consistent with specified design parameters. The second is to

identify, assemble, and explicitly evaluate such data, official and otherwise, as are required to build and validate the model. Thirdly, the model must be tested and found to be valid by specific validation criteria. The third objective includes generation of plausible disaggregations of published population and slaughter data.

This study was conducted as an element of the sector modeling program of the Economics Branch, Agriculture Canada. While the cattle herd model is designed to interact with other models in this program, it is also designed to provide useful answers independent of these other models. Specifically, the model reflects the supply side of the cattle-calves sub-sector. Modeling of the price determination mechanism, the trade mechanism, and the wheat-feed grain sub-sector are left to the other models with the cattle herd model taking prices and trade flows as given.

The cattle herd model is based on the biological growth and production processes as experienced and practiced in Canada. In addition, the cattle herd is separated into its dairy, beef, male and female components. Three geographic regions are recognized; Eastern and Western Canada are modeled explicitly while the third region, the rest of the world, is treated implicitly through the exogenously determined or given trade flows.

The herd is further disaggregated to recognize function, production process, and age. The basic functional choice is recognized through allocation of breeding age cattle to either the breeding herd (investment) or to the feedlot for subsequent slaughter (consumption).

Two feeding processes are modeled: the first simulates a low energy ration such as might be experienced with high roughage feeding; the second employs a high energy ration simulating feedlot feeding-finishing. Finally, the model recognizes age by subdividing calves into ages one to three months, four to six months, and six to twelve months. Further age subdivision is recognized through the above functions and processes.

While many aspects of cattle production and marketing are behavioral, three were isolated for explicit modeling. All others are left for subsequent model development. As investment-disinvestment in the breeding herd is central to the study of cattle herd dynamics, cow and bull cull flows and cow and bull replacement flows are estimated econometrically. In addition, the flow of calf slaughter is estimated in similar manner.

In order to conveniently adapt the behavioral models to the cattle herd model, a statistical "excess price" model was developed. This latter model is developed from simultaneous supply-demand equations to abstract from "own" price producing a single equation with quantity as the endogenous variable.

The excess price model proved to be a good predictor of quantity (flows) but was a disappointing estimator of sign. That is, the estimated sign of the regression coefficients differed from the predicted sign in a high proportion of instances.

The technique employed to model the cattle herd is that of generalized simulation. This technique encompasses the system science approach to problem solving. The system science approach is an iterative, learning one where concepts or values initially held to be true may subsequently be found to be false or not useful in the context of the study. Should this occur, then a return to a prior stage of the investigation is required. Four tests of objectivity were used as validation criteria; the first two were applied continually throughout the study. These tests are: consistency with observed and possibly recorded experience, logical internal consistency of the concepts used, interpersonal transmissibility of the concepts used and results produced, and workability of the model in the solution of practical problems.

Three basic versions of the cattle herd simulator, CATSIM, were built. They differ basically in the method of calculating investment and disinvestment in the breeding herd. The most advanced version, CATSIM3, employs the behavioral models to estimate these flows. Two other models were built. The first, MATRIX, is used to estimate endogenous variables for the behavioral models from known published data using simplifying assumptions. The second, RECON, is used to evaluate the various published data series and other information descriptive of the cattle herd. This second model is based on a single identity.

The most substantive results of this study are contained in the structure, parameter estimates, and assumptions of the models. A basic purpose of this study was to develop general models and evaluate historic cattle data in order to solve future practical problems. This objective was met.

While meeting this basic objective, several useful results were obtained concurrently. MATRIX provided highly plausible estimates of dairy and beef cow slaughter and replacement flows for both Eastern and Western Canada. Eastern and Western bull cull and replacement flows are also estimated as well as beef and dairy calf slaughter flows. These estimates are produced for the years 1958 to 1972 inclusive.

RECON provided valuable insights into the validity of official cattle-calves statistics for the period 1959 to 1972. In addition, the model provided an opportunity to test certain beliefs about the cattle herd, cattle production and cattle trade. The assumptions made to disaggregate the official data in order to build MATRIX, RECON, and CATSIM, served to accent the deficiency of the official data.

Model CATSIM embodies all of the descriptive knowledge of the cattle herd that was assembled. This model generated quarterly population and slaughter flows for the years 1958 to 1972 inclusive. These estimates were demonstrated to be highly credible when compared to the historic official data. These data disaggregations are a significant result.

All models serve to highlight deficiencies in the descriptive knowledge of the Canadian cattle herd. Model sensitivity to certain model elements served to rank the importance of the missing elements. While all models developed in this study may immediately be adapted to solve practical problems of the cattle-calves sub-sector, a concurrent effect must be made to alleviate these noted deficiencies.

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CHAPTER I

INTRODUCTION

The livestock sub-sector is a major element in the Canadian agriculture economy. Vast expanses of range lands and apparent ample supplies of feed grains coupled with a growing domestic and world demand for red meat should make livestock, and cattle in particular, a growth sub-sector. But an anomaly appears to be developing. Over the past several years, Canada has been losing its self sufficiency in beef and in fact has incurred several successive trade deficits.

This thesis does not intend to examine Canada's comparative advantage in the production of red meat or beef; its objective is much more modest. This study intends to expand or make a contribution to the growing stock of knowledge concerning the dynamics of the Canadian cattle herd. More specifically, it intends to provide both descriptive knowledge and analytical tools that may aid in future prescriptive and predictive applications as well as further descriptive analysis.

The Problem Setting

The agricultural situation in Canada in the early 1970's could have been described as: (1) unacceptably low net farm income, (2) unstable income (product prices), (3) uncertainty as to the future, and,

(4) inadequate production planning leading to chronic mismatching of supply with demand.

The internal economic situation is aggravated by the fact that Canada is a trading nation thus highly interdependent with the world economy. In the agricultural sector alone, it is estimated that 25-30 percent of the nation's total agricultural production is exported. Thus, while current commodity shortages occur largely outside her borders, these shortages (as well as gluts) are felt internally through the international trade sector. These periodic and often unpredictable shocks tend to confound long and intermediate range internal planning. The most vulnerable agricultural sub-sectors are wheat and feed grains as these commodities are largely produced to meet an often volatile international market.

This inability is transmitted through various linkages to other sub-sectors, notably livestock, and in fact to other sectors. The situation is aggravated by the fact that wheat, feed grain and livestock production (beef and to a lesser extent hogs) is concentrated regionally in the Prairie Provinces. Because this region, and especially Saskatchewan, is highly dependent on agriculture, the regional economy is prone to unacceptable fluctuations. Fluctuations in the Prairie agricultural economy are transmitted nationwide through balance of payments, the producer durable goods sector, and especially the food element in the consumption sector. While these fluctuations might have been tolerated in an earlier age, modern society demands more stability, more growth, and more management.

One noteworthy result of the combined events of the past several years has been the unprecedented trend of growing trade deficits in beef and veal. While trade in these commodities showed a very slight surplus in 1969 and 1970, the deficits became increasingly large into 1973; this is in contrast to substantial trade surpluses in prior years. This situation has been aggravated by continuing declines in the dairy herd in virtually all parts of Canada with the prospects of deficits in milk and dairy products appearing as matters of some real concern.

As in most developed countries, the right course of action to pursue concerning the domestic and international agricultural situation has been a preoccupation of government, university, and industry personnel for some 50 years. While the problem has taken many forms through depression, war, and post-war periods, a problem still exists.

A most significant study in this regard was produced by the recent (1969) Canadian Task Force on Agriculture.[1] It stated the following hierarchy of values for agriculture.

First level	• Higher national income per capita; all Canadians must have at least a minimum standard of living
Second level	• Functional balance of payments • Higher net farm income • Full employment • Reasonably stable prices
Third level	• Stable farm income • Lower cost of production and marketing • Increased mobility of labor out of agriculture.

[1] Canadian Agriculture in the 70's, Report of the Federal Task Force in Agriculture, Ottawa, Queen's Printer, 1969.

In addition to these values, it stated specific goals for the non-dairy livestock sub-sectors. These specific goals are:

- that a target of 500,000 feeder cattle for export be set for 1980, and
- that enough beef and veal be produced in Canada to meet domestic consumption, and
- that all tariffs be removed on cattle and beef, and
- that Quebec and Ontario dairymen reconsider selling dairy calves as veal in order to market heavier veal or feeders, and
- that resources be diverted from grain production to cattle production, and
- that the Canadian Dairy Commission institution incentives for dairymen to move into beef production.

Since these recommendations were made, the world and domestic agricultural situation have switched from a surplus to a deficit position. Is this a permanent or temporary switch? How should Canada react domestically? In the face of uncertainty and fluctuations, what is the best long and short run resource allocation policy?

The Study Context

Government, especially at the federal level, must take the lead in ensuring the well being of all Canadians through thoughtful and appropriate policies and programs effectively implemented in a timely fashion. To this end, the Economics Branch of Agriculture Canada has been and is providing increasingly effective input into policy and program planning for the agriculture and food sector.

To aid the Branch policy advisors, the Branch has been developing an interactive set of agricultural sub-sector models. These include:

- feed grain models
- oil seed models
- beef models
- dairy models
- hog models
- production adjustment models.

In certain instances, several models have been or are being developed for one sub-sector. In the case of the beef sub-sector, at least two models have been developed.

The first of these is a short run linear programming model that was initially designed to interact with the feed grains and oil seeds models. In this model, the cow herd is considered as fixed, however, the progeny are allowed to move at several critical stages of the production process. The initial application of this model was to assist in the development of a national feed grains policy.[1]

A second beef model is being developed at the University of Guelph.[2] This model is a quadratic programming application that considers cattle production, trade, beef and veal consumption, and

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[1]An interim feed grain policy was implemented in August 1973, and replaced by a more permanent policy in August 1974. Both policies were developed with assistance from Economics Branch models.

[2]G. L. MacAuley, unpublished Ph.D. dissertation, University of Guelph (forthcoming).

price determination among three regions, Canada East, Canada West, and United States. While this model is basically a transportation model, the production, and especially the behavioral elements, are well developed.

A third study, a simple cattle herd simulator, was begun in mid-1973 to examine the consistency of Canada's statistical data base, related to cattle and calves. This study was curtailed before the completion due to subsequent staff shortages. This third study has been incorporated as an important part of this dissertation.

This dissertation research is being conducted as an integral part of the sector modeling program of the Economics Branch, Agriculture Canada. It has been designed with general purposes in mind that require something less than a general equilibrium model. While encompassing the simulator mentioned above, an early attempt was made to ensure general compatibility with the Guelph quadratic programming model.

In addition, it is planned that subsequent to this dissertation research, the developed models are to be adapted to meet specific descriptive, predictive, and evaluative needs of the Economics Branch. Some anticipated applications are discussed briefly in the next section.

The Problem Statement

The problem that is confronted in the dissertation is the conceptualization and construction of a dynamic demographic model of the Canadian cattle herd. This model is conceptualized and constructed according to the terms of reference and design criteria stated below.

were initially established in consultation with the Economics Branch in light of current and expected future research and policy requirements. These terms of reference and design criteria are discussed below.

The model that is developed in this study is partial equilibrium when operated independently of the other Branch models. While it is intended that it be operated interactively with other models, it is to be useful without this interaction. In other words, it is designed as a component, but a self-contained component.

The model is based on the biological growth and production process as experienced and practiced in Canada. In addition to this basic departure from prior models,[1] the model separates cattle into beef and dairy components, constituting a second major departure. In turn, each of these have a separate male and female component.[2]

The model has three geographic elements, two modeled explicitly, and the third implied. The two explicit regions are Canada East and Canada West. The third region is the rest of the world and is treated implicitly through the trade component. In Canada, the major trading partner in cattle and calves ~~in~~ is the United States.

In addition to the above disaggregation of the herd, the herd is further subdivided in terms of the (1) age and/or (2) function,

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[1]Most models of the beef or cattle sub-sector are based on and tied to available published statistical data as their main, and usually only, source of information. Most models of the beef sub-sector emphasize beef cattle. Reference to the dairy herd as a very significant source of beef is generally treated tangentially.

[2]Most models fail to distinguish between steer and heifer beef, cow beef and bull beef; however, veal is normally treated as a separate commodity.

and/or (3) process. The basic functional choice is recognized through allocation of breeding age cattle to either (1) the breeding herd or (2) the feedlot and slaughter.

The variation in production process is recognized through two separate and distinct feeding rations. The first process utilizes a low energy ration where cattle are grown on grass, hay and other roughage; this process may or may not be terminated by a short finishing period. The second process involves a high energy, high caloric intake ration, such as would be experienced by cattle on full feed in a feedlot. This process assumes that the animal is both grown and finished in such an environment. Some combination of these two processes should approximate the actual Canadian experience. In addition, this element of the model allows for a changing combination of the two processes over time.

The model is designed to subdivide calves into ages 1-3 months, 4-6 months, and 6-12 months. This subdivision is reasonably consistent with the cattle production and marketing process as practiced in Canada.

The major behavioral aspects of the model include: (1) calf slaughter rate, (2) cow and bull cull rate, and (3) cow and bull replacement rate. These major flow elements drive the model and provide it with its basic cyclical and trend nature.

The models developed in this thesis, as previously mentioned, are partial equilibrium. Specifically, the following mechanisms have <u>not</u> been developed:

- the price determination mechanism for beef and veal and for cattle, and
- the trade mechanism for cattle, calves and beef, either internal or external to Canada, and

- the major sub-sector which is both competitive and complementary in production has not been modeled, namely, the wheat and feed grain sub-sector.

In the first two instances, the model developed by MacAuley[1] generates the emitted prices and flows; the output and input matrices of this and the MacAuley model are designed in such a manner that there is potential for the two to be operated interactively. In the third instance, the international grain market provides a major influence on domestic grain price. Because the influence is largely unidirectional, the grain prices, stocks, and outlook can be treated as exogenous to cattle production.

The major outputs of the model are (1) a time series of cattle population numbers by age, function, and process cohorts and (2) a time series of slaughter cattle and calf numbers by sex, function, and process.[2]

The stock values (population cohorts) are determined by a set of flow variables. These flow variables include:

1. calf slaughter rate
2. cow and bull cull rate
3. cow and bull replacement rate
4. export rate
5. import rate

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[1]MacAuley, op. cit.

[2]Official Statistics Canada (STATCAN) livestock statistics list seven cattle-calves categories biannually for both Eastern and Western Canada; this model produces 25 categories quarterly. In addition, STATCAN produces six slaughter categories; this model can generate at least 11 for both East and West.

6. birth rate
7. death rate
8. feeding-finishing rate.

Numbers 1, 2, and 3 are pure behavioral variables. Econometric techniques are used to arrive at parameter estimates. Prices, including cattle prices, are exogenous to the model. Prices provide a feedback mechanism for the cattle production process, and are an element of interaction with other models.

Numbers 4 and 5 are taken as exogenous, and provide a second level of interaction with other models. Exports and imports are interpreted to mean interregional as well as foreign trade.

Numbers 6, 7, and to a lesser extent 8, are basically biological Technology and environmental influences are of major significance. The impact of economics, especially relative prices and price expectations, have an effect on 6 and 7; their influence on 8 is marked. This latter area is not explored in this study but must be given top priority in future model development.[1]

Major design criteria involve flexibility to meet future and possibly unanticipated applications. In the extreme, this requirement can invoke undue cumbersomeness. To avoid this result, flexibility features are avoided if they prove to be mildly cumbersome.

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[1]The events in the cattle industry during 1973-74 have demonstrated that producers can and do alter feeding-finishing rate in the face of major price adjustment and price uncertainty. This unusual instability leads to further price instability and uncertainty.

At the design stage and during model development, specific applications were not known with certainty. This in major part was due to the fact that problems to be addressed, and thus applications, occur in the future. However, several general types of applications were identified. The model is designed:

1. to analyze and evaluate existing data series (while this is part of the existing study, additional interaction with statisticians and researchers is planned), and

2. to analyze and assess the impacts on the cattle-calf sub-sector of changing:
   - biological parameters,
   - production processes,
   - flows values such as exports and imports, and

3. to use the model in an optimum control mode to determine optimal or alternate paths that may lead to present targets such as projected domestic or export demand, and

4. to operate in a forecasting mode, and

5. to operate interactively with researchers in order to heighten their descriptive knowledge and understanding of the sub-sector.

These applications are not exhaustive. Since the model is based on the biological reproduction and growth process and since one anticipated application set involves the evaluation of changes in biological parameters and production processes, the model must incorporate basic biological parameters and processes.

The evaluation mentioned above would be expected to include (1) breeding herd size, (2) breeding herd maintenance, (3) progeny feed intake, and (4) beef and veal output. The basic biological parameters that are indicated include:

1. live birth rate
2. birth weight
3. birth distribution
4. heifer calving age
5. heifer calving distribution
6. weaning weight
7. rate of gain
8. carcass weight
9. carcass dressing percentage.

While all of these parameters are not modeled either explicitly or implicitly, the model must accommodate them with very little alteration. In addition, the model must be flexible enough to accommodate additional production and finishing processes beyond the high and low energy streams initially modeled.

Study Objectives

The purpose of this study is to develop a general simulator of the Canadian cattle herd that can subsequently be readily adapted to meet specific research needs of the Economics Branch and other Canadian institutions associated with the cattle-calves sub-sector. This main objective must be conducted concurrently with or subsequent to other prerequisite objectives which are included below.

The following specific objectives of this study are realized concurrently rather than sequentially. This concept is consistent with the systems analysis process to be described in the next chapter.

a. Data and Information assessment:

1) to identify and gather such data and information as required to support the hypothesized model, and

2) to attempt a reconciliation of these data and information in order to determine their accuracy.

b. Model Development:

1) to identify the structure and develop a general simulation of the Canadian cattle herd consistent with the hypothesized model, and

2) to identify, conceptualize, and estimate those behavioral and biological relationships that are found to be the model's critical parameter and flow variables, and

3) to identify and design into the model those critical elements that are consistent with expected applications and future development.

c. Model Testing and Validation:

1) to successfully "track" past population and slaughter data consistent with the simplifying assumptions used, and

2) to generate disaggregate historic population and slaughter data series and to generate replacement and cull data series that are held to be highly plausible.

Literature Review

The literature is particularly undeveloped with respect to the problem outlined above. While this is the case, certain related literature is available or is emerging. This related literature falls into five categories.

1. Simulations of agricultural sectors or sub-sectors.
2. Simulation techniques and components.

3. Econometric models of the cattle-feed grain sub-sectors.
4. Structure of the Canadian cattle-calves sub-sector.
5. Data description of this sub-sector.

A cattle herd model was incorporated as a component of the "Nigerian Model."[1] This component modeled both a "traditional" and a "modern" sector in an attempt to develop policy strategies and evaluate policy alternatives. The beef component employed calving rates, death rates, and various marketing strategies with the former two rates being functions of nutritional level. The "modern" beef component utilized a land allocation (allocation between crops and grazing) as a policy variable. The output of land allocated to grazing was a function of input expenditures on it. Supplemental feeding was used as a policy variable as well.

Posada[2] developed a somewhat similar model for the Northern Columbia beef industry. This industry appears to be a traditional economy; policy instruments include imposition and assimilation of more advanced technology. Credit and export incentives were also employed.

Both the Nigerian and the Posada models are explicitly oriented toward policy evaluation; consequently, the identification and modeling

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[1]This model and related study are reported in G. L. Johnson et al., A Generalized Simulation Approach to Agricultural Sector Analysis with Reference to Nigeria, East Lansing, Michigan State University, 1971.

[2]Alvaro Posada, "A Simulation Analysis of Policy for the Northern Columbia Beef Cattle Industry," unpublished Ph.D. dissertation, Michigan State University, 1974.

of output and policy variables become a major part of the model. Input demand, a crop element and a price determining element are included as part of both models. The Nigerian study modeled the non-agricultural sectors of the economy while Posada did not.

Both of the above studies model one or more sectors of the national economy. As a consequence, the models are highly aggregated; minimum detail is dictated only by policy and output variables that are found to be relevant. A more detailed sub-sector simulation was done by Hovav Talpaz.[1]

Talpaz developed a hog supply response model subject to both biological and economic constraints. This model tends to more explicitly model a sub-sector, the hog sub-sector, while taking the balance of the economy as exogenous. He states that "demand for hogs and the distribution and marketing system are beyond the scope of this model." The model does evaluate production response to an identified set of policy variables and ultimately recommendations are made for dampening the hog cycle.

Key variables in the Talpaz model are the hog-corn price ratio and volume (rate) of farrowing. The study has two parts. The first used econometric techniques to identify and estimate key model parameters. Specifically, a Fourier series application to a trigonometric time function is employed. The second uses a time-variant mixed

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[1]Hovav Talpaz, "Simulation Decomposition and Control of Multi-Frequency Dynamic System: The United States Hog Production Cycle," unpublished Ph.D. dissertation, Michigan State University, 1973.

difference equation system to simulate production supply response. A component model was developed to yield age and weight distributions for market hogs. The sow farrowing variable was found to be the major state variable while hog-corn price ratio represented the major input signal.

The components and techniques necessary to develop the Talpaz and Posada models, as well as other simulation models not discussed here,[1] can largely be attributed to T. J. Manetsch and his associates. These techniques and components were perfected in large part during the execution of the "Nigerian Project" and subsequent "Korean Project." The text, of which Manetsch is joint author, only reflects this knowledge in part.[2] Full credit must be given to lectures, seminars, and mimeographed material presented by him and his colleagues.

The next chapter deals explicitly and at length with the structure of the Canadian cattle industry and the data base descriptive of that industry. Specific sources and references are cited at that time. Chapter III cites references relevant for the development of the behavioral models.

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[1]One example is D. L. Forster, "The Effects of Selected Water Pollution Control Rules on the Simulation Behavior of Beef Feedlots, 1974-1985," unpublished Ph.D. dissertation, Michigan State University, 1974.

[2]T. J. Manetsch and G. L. Park, Systems Analysis and Simulation with Application to Economic and Social Systems, East Lansing: Michigan State University, 1973.

Dissertation Organization

The dissertation is organized in such a manner as to provide a general statement of the problem and a specific set of objectives in this present chapter. This chapter has also provided a description of the context in which the study is being conducted as well as a discussion of what is being attempted and what is being left to related models.

Chapter II discusses the background necessary to proceed to the detail of Chapters III, IV, and V. Specifically, Chapter II discusses the system science simulation approach to problem solving, provides a historical description of the cattle-calves sub-sector and a discussion of the currently available statistical data base. In addition, the theoretical economic model underlying the cattle-calves sub-sector is discussed in detail.

Chapter III develops the behavior models required for the simulation model and provides parameter estimates for the latter model. In addition, the model MATRIX is discussed. This model is required to generate an estimated matrix of endogenous variables for the above behavioral models.

The statistical data bases concerning cattle and calves is felt to be less than desirably consistent. Chapter IV discusses a model called RECON that assists in isolating errors and biases in these data series. The implications for both this study and others are considered.

Chapter V discusses the development of the cattle herd simulator, CATSIM. The building of this simulator requires a second set of estimated parameters. These parameters are obtained from sources other than statistical analysis. They fall into two basic categories: the first concerns the basic biological relationships, and the second involves data base disaggregation. A third set is suggested but left to a subsequent study, that is, the statistical estimation of these two former sets.

Chapter VI provides an evaluation of CATSIM under various operating conditions. Three basic versions of CATSIM are developed. CATSIM 1 operates the basic model under a set of strict and somewhat unrealistic assumptions concerning the rate of breeding herd replacement; CATSIM 2 relaxes that assumption. CATSIM 3 utilizes behavior models to generate replacement rates and certain other critical rates.

The final chapter, Chapter VII, summarizes the study and discusses the modifications required to adapt the model to anticipated applications. Aspects of the model that require further development are also discussed.

CHAPTER II

METHODOLOGY

The development of a cattle herd simulator, together with its integral behavior elements, requires a description of the sub-sector, a description of the sub-sector's context, and a theoretical basis for analysis. An understanding of the technique of analysis is required as well. It is the purpose of Chapter II to provide this necessary foundation.

The first section, The Systems Science Approach to Problem Solving, considers systems science simulation as a problem-solving technique useful for investigating both the normative and the non-normative aspects of problems. It should be noted that while the first section discusses the total method or approach, this dissertation covers only the first few steps of that approach. The steps involving application are left to future studies, some of which are being developed concurrently and in coordination with this study.

The second section, The Cattle Sub-Sector, provides a historical, verbal, and graphical sketch of the Canadian cattle herd, while the third section, The Statistical Data Base, discusses the statistical base descriptive of that herd. It should be stressed that the description of the herd is recorded largely in terms of stock and flow data

series that are proving to be inadequate, incomplete, incompatible, and possibly, in error.

The final section, The Economic Model, develops the economics relevant to describing the cattle herd. Special attention is paid to investment and disinvestment in the basic breeding herd and to the relationship between the cattle-calves sub-sector and the wheat-feed grain sub-sector. It is a basic contention of this dissertation that analysis of investment/disinvestment provides a chief indicator of fed cattle supply 24-36 months hence.

The Systems Science Approach to Problem Solving

The word simulation conjures up a wide variety of concepts or techniques in the minds of those who contemplate it. Lack of concensus or existence of misunderstanding leads to unwarranted confusion. The concept of systems science simulation used in this dissertation follows closely the one developed and applied by G. L. Johnson and his associates at Michigan State University.[1]

The systems science simulation approach is general with respect to technique; thus it may use single or simultaneous equation models, LP, and NLP models, input/output tables, PPB and capital budgeting

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[1]For further elaboration refer to: (a) G. L. Johnson et al., op. cit., pp. 25-37; G. L. Johnson et al., Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985, East Lansing, Michigan State University, 1972, pp. 32-46; and M. L. Hayenga, T. J. Manetsch, and A. N. Halter, "Computer Simulation as a Planning Tool in Developing Economics," American Journal of Agricultural Economics 50:1755-1759, Dec. 1968.

techniques, or any number of other more specialized techniques. Each is eligible for inclusion at that point at which each is more appropriate. The approach is also general with respect to data use and data sources. Thus, both time series and cross section data are often employed. Statistical estimation procedures may be used to obtain parameter estimates. Another source of data, used extensively in this dissertation, is informed judgment or data of a judgmental nature implying a Bayesian approach. The method employed in this study utilizes the techniques developed by systems scientists as well as the concept of a system now used generally by most disciplines. While the systems science simulation approach to systems design and analysis was originally developed by electrical engineers, it is increasingly finding favor in a diverse group of disciplines. It is also finding favor in multi-disciplinary problem oriented research as the systems approach allows the diversity to be handled in a comprehensive and coordinated manner, with the logic that is common to all disciplines.

Thus, generalized systems science simulation is flexible with respect to kinds and sources of information and technique. The mechanical and logical nature of the process allows adaptation to a wide variety of modes, including projection, optimization, and optimum control. It has also been found useful in a normative policy making mode where the following preconditions for optimization, not being present, have hampered or even precluded appropriate use of specialized techniques. The preconditions for optimization are as follows:

1. A common denominator for the "goods" and "bads" is present.
2. This common denominator is comparable among those individuals or groups affected.
3. The order, or second order condition, is apparent before optimization takes place.
4. A specific decision rule for selection of the optimum is available.

The generalized systems science simulation approach continues to be flexible in application; this is important when all possible applications are not known a priori.

The systems science approach to simulation is an iterative, learning process. While many, if not most, economists "talk systems," very few actually "do systems." This study provides an example of "doing systems," of laying out the system in explicit detail and simulating the components. The systems approach to accomplishing this task has the appeal of Baysian statistics, that is, it appeals to the logic and thought process of the non-economist or non-econometrician. It accomplishes this by formalizing the learning and corrective process that is the method of all scientists and in fact all entities that learn when reacting to stimuli.

A very simple system is presented diagramatically in Figure 1. Three types of problems can be identified with such a system.

1. Synthetic or design problems: given desired output and expected input, design the system to produce the desired output, e.g., a pollution control device for internal combustion motors.
2. Analysis problem: given input variables of the system, find the output variables, e.g., prediction of national crop yields, or the daily weather.
3. Identification problem: given measured input and output variables, find the relation between them.

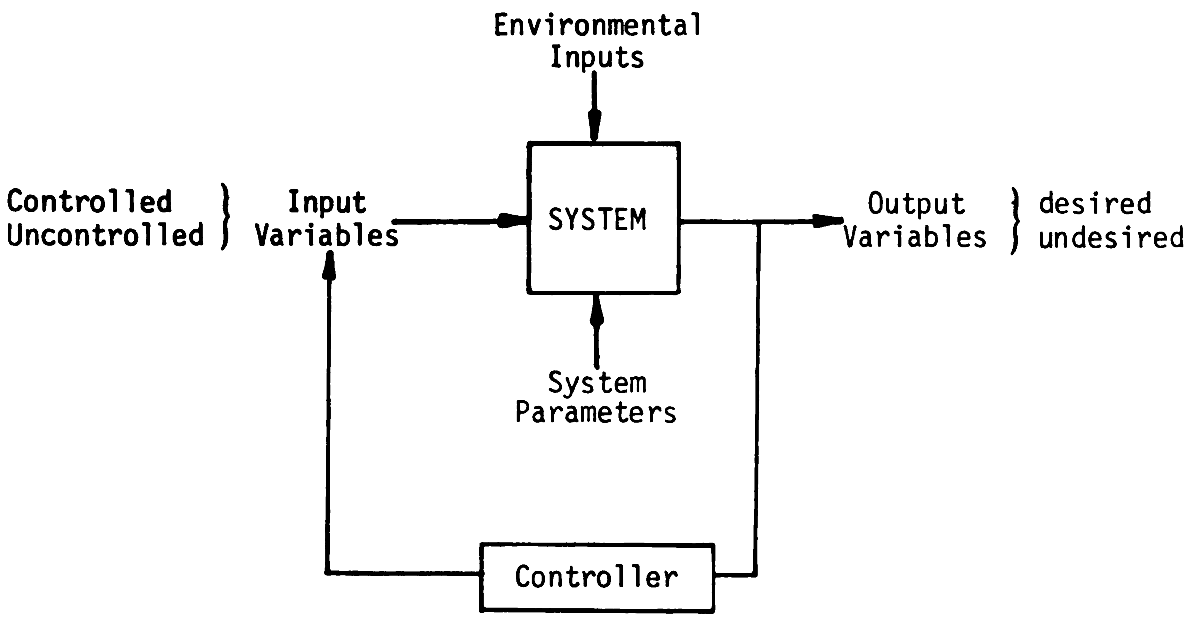

Figure 1. A simple system with feedback

The identification problem basically is the one of concern in this study. In final application, however, the model will deal with problems of analysis, or even design.

The systems analysis approach uses an iterative, learning, problem investigating approach in dealing with all three types of problems. Figure 2 provides a general overview of this process.

This study basically includes stages 1 through 3. At each stage interaction takes place between the model builder(s) and the model user. In a policy evaluation mode, the ultimate model user becomes the policy or decision maker.

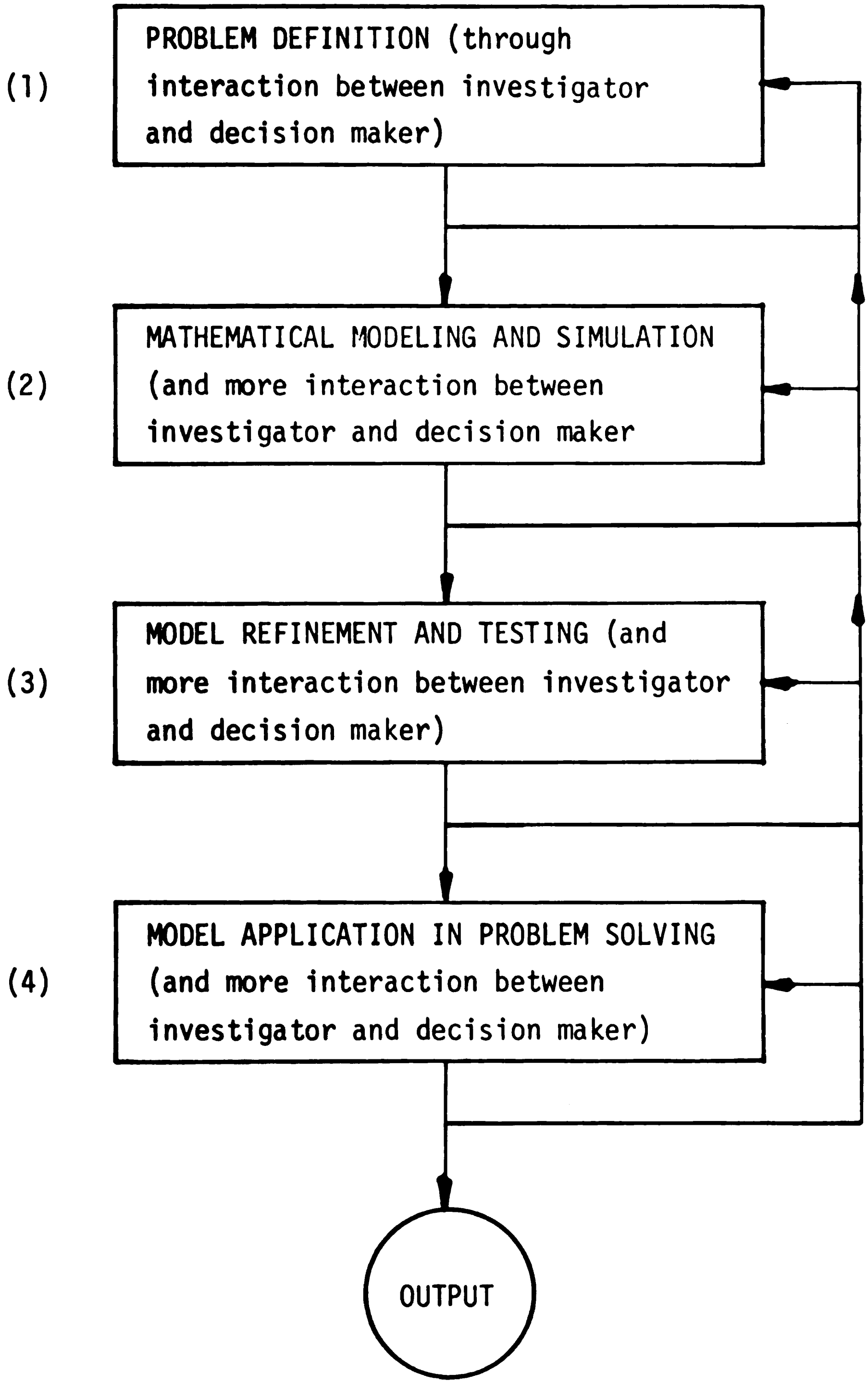

Figure 2. The systems simulation process

The method is iterative in that stage 1 takes place before stage 2, stage 2 prior to stage 3, etc. At each stage, however, new or conflicting information may be uncovered that partially or wholly negates information or concepts previously held to be true in earlier stages. Thus, any one step may have to be repeated, possibly several times. Similarly, new information may force a return to a prior step or, in fact, a return to step 1.

In addition to the possibility and process of uncovering new knowledge as the overall process takes place, the process accommodates the possibility of uncovering new problems that were not anticipated a priori. These new problems may force a return to a prior stage.

As previously mentioned, this study basically does not include stage 4. However, the foregoing applies to stage 4. Thus, in application, there still exists the critical interaction between model builder and model user. In fact, the human element is not seen as divorced from the process but as an integral part of the process. Thus, even in stage 4, the possibility of new knowledge or new problems may force a reversion to any prior stage. Consequently, the results of this study must be held tentatively.

The application of the systems simulation process to policy problems should be noted at this point. Models, including simulation models, normally are thought of as providing knowledge of a non-normative nature. An objective function is normally used to minimize a set of "bads" and to maximize a set of "goods." This objective function explicitly states what is "good" and what is "bad"; knowledge of the normative is clearly implied. But in policy problems very often it is knowledge of a normative nature that is missing; it is the normative knowledge that must be acquired.

To successfully optimize, the preconditions for optimization must be present. In many, if not most, policy applications, these preconditions are not present. In another parlance there is normally an absence of an explicit social welfare function. While the model provides a set or competing sets of production possibilities, no clear rule is present for evaluating these competing sets with respect to social welfare.

The problem may be expressed in terms of the lack of knowledge concerning the normative. Systems science simulation can aid in the learning and awareness heightening process by involving the policy maker in the total process from problem formulation to model application. The process forces the accumulation of normative and non-normative information germane to the eventual policy decision.

While the above discussion provides an overview of the general process, more specific steps are required before a problem may be approached, systemized, and eventually simulated. The process involves the following basic steps.

Feasibility Analysis

This step precedes the commencement of work on any project including this one. It corresponds in part to stage 1 of Figure 2 and includes the following self-explanatory steps:

- needs analysis
- system identification (in very general terms)
- problem formulation
- generation of the systems' concepts (a broad general list)
- determination of physical, social, and political relizability
- determination of economic feasibility
- generation of a subset of viable concepts.

System Modeling

This step receives the set of viable concepts as inputs, the working model is the output. It is basically an elaboration of stages 2 and 3 of Figure 2. This step involves:

- concept selection (the final subset)
- modeling of these concepts
- parameter estimation or approximation
- stability analysis
- sensitivity analysis.

From the subset of viable concepts, a further subset is selected that best appears to represent the system being modeled in light of the identified problem. The concepts are individually modeled to collectively produce the model of the system.

Systems modeling takes place in terms of the subset of concepts finally selected. This model represents a second level of abstraction from reality. The sequence is:

THE REAL WORD

↓

MATHEMATICAL MODEL

↓

SIMULATION MODEL

The mathematical model can be represented in terms of an exact block diagram. The elements in the exact block diagram are modeled in terms of system components[1] that in many cases have been developed in the past and are published in the form of specialized systems languages.[2]

Parameter estimation is a major element in the building of a simulator. These parameters may often be estimated statistically where adequate data are available. Where this is not possible, "guesstimates" and informed judgment provide a second source. In addition, the simulator itself may be deployed to produce parameter estimates with certain optimal properties.

If the model output simulates some set of "correct" values, then a formal optimization procedure may be employed to estimate parameter values. If some less precise concept of correctness is held or if highly plausible parameter estimates are available from other

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[1]Appendix B contains a detailed discussion of mathematical modeling, explains the symbols used in expressing the model in exact block diagram form, and discusses, as well, the principle system components used in this dissertation.

[2]An example is R. L. Llewellyn, FORDYN: An Industrial Dynamics Simulator, Raleigh, North Carolina State University, 1965.

sources, then an informal method of parameter adjustment or "fine tuning" may be employed.

Viability testing is the first stage of testing. At this stage, generated variable values are checked for correct sign and approximate magnitude. Validation involves a more detailed test and may include a comparison of simulated output with some known output, as in the case of this study.

Sensitivity analysis involves testing the sensitivity of the model to parameter changes. There are two basic reasons for this test. In the first case, the accuracy of sensitive parameter estimates is more critical than those of lower sensitivity. This test then gives some ordering to the allocation of further research resources. In the second instance, the ranking of policy parameters in terms of sensitivity can be very informative to decision makers.

Stability testing can take place concurrently with sensitivity testing. This test ensures that the model is stable over all reasonable combinations of parameter values. The dynamic properties of the model should approximate the observed dynamic properties of the system being modeled.

Validation

The actual process of validation is one of demonstrating that the model fails to be found invalid. Thus, the model may be incorrect in one or more aspects yet superficially appear to be valid. The model may be found incorrect in application; at this stage, corrections or revisions will be made in keeping with the systems process.

A simulation model, such as the one being developed in this study, uses information from a wide variety of sources. These include published statistical data, experimental data, as well as the informed judgment of a range of knowledgeable people. The reliability or accuracy of any or all of this information is open to question.

Unlike specialized techniques, the usual statistical tests do not always apply; where possible, they are used. In all cases, however, less sophisticated but nevertheless useful tests of objectivity are applied. These tests are applied consistently at each stage of model development in order to validate and verify the process that is taking place.

These tests of objectivity are:

1. consistency with observed and possibly recorded experience (correspondence),
2. logical internal consistency of the concepts used (coherence),
3. interpersonal transmissibility of the concepts used and the results produced, and
4. workability of the model in the solution of problems.[1]

More specifically, the model's output must be consistent with the official published cattle statistics and users evaluation of these statistics. Also, the process by which the model generates output must

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[1]The following two references are examples of those using objectivity as a validation and verification criterion. G. L. Johnson et al., Korean Agricultural Sector Analysis, pp. 43-45; and G. L. Johnson and C. Leroy Quance, The Overproduction Trap in U.S. Agriculture, Baltimore, The John Hopkins Press, 1972, pp. 44-48.

be consistent with generally held concepts of how the sub-sector functions.

The model must be able to reconcile those various bits of information used in its construction in such a manner as to successfully reproduce, or change, the commonly held view of the sub-sector. These include generation of short term fluctuations and long term trends. If the model lacks stability or does not reproduce trends and cycles then it fails to be consistent with the real world. In this case the model would fail the consistency (correspondence) test. If the model cannot reconcile the elements used in its construction then it (the model or the elements) fail the internal consistency (coherence) test.

The process, the parameter values, and the generated output, must be accepted by a wide range of individuals cognizant of the various aspects of the cattle sub-sector. This group would include animal scientists, livestock economists, livestock marketing experts, and other knowledgeable industry people. This is the interpersonal transmissibility test.

Finally, the model must demonstrate workability or prove to be insightful with respect to specific problems. This means that this model (or some future amended version) is only useful insofar as it can provide useful answers; for a wide range of problems it may be found to be inferior to some other methods or of no use whatsoever.

The process of objective validation and verification is never ending. The present stage of development of the model represents a

highly plausible representation of the system. Additional information at some future date may cause this model to be greatly modified or simply rejected.

Thus the model's validation will not generally be expressed in a set of well-known and accepted statistics but rather will take an objective truth in the minds of those scientists, policy makers, and others who wish to use it, understand its logic, and contemplate the validity and usefulness of its output.

The Cattle Sub-Sector

This section describes the cattle sub-sector in terms of its various dimensions. This sub-sector is in interaction with other sub-sectors and indeed with international influences through its foreign trade dimension; thus, it is ever changing. An attempt is made, consequently, to describe the sub-sector in dynamic terms with emphasis on the external influencing factors.

The Spatial Dimension

Canada is divided geographically by physical barriers running north and south, giving rise to separate and readily identifiable regions. Within each region, considerable similarity exists with respect to climate, population density, degree of industrialization, as well as political and social thinking. Generally, each region is made up of one or more provinces; statistical data collection is conducted on a basis consistent with these regions.

For the purpose of this study, two major regions will be identified, East and West. The major elements in the Western region, with respect to the cattle sub-sector, are the Prairies. In the East, Ontario and Quebec are of major significance.

Approximately 70 percent of Canada's population lives in the East, mainly in southern Ontario and Quebec, while the remaining 30 percent is spread rather thinly over the Prairies and concentrated in the Vancouver area of British Columbia.

In contrast, the June 1, 1972 Livestock Survey indicates that the West had 61.6 percent of the cattle population. This uneven distribution of human and cattle population gives some clue as to the direction of the internal trade in cattle and meat.

The relative distributions are even more distorted if the cattle population is split into its dairy and beef cattle components. Table 1 shows the June 1, 1972 distribution on a seven region basis. The West is shown to have the bulk (81%) of the beef cow herd, while the East has most of the dairy herd (79% of the nation's dairy cows).

Table 1 provides a static picture only; Figures 3 and 4 show the trend in dairy and beef cow numbers, both East and West, over the 1954-1972 period. In general, the dairy cow herd has declined over most of the period and continues to decline both in absolute numbers and as a proportion of the total herd. In contrast, beef cow numbers have been on the increase over this same period with irregularity in this rate being the greatest in the West.

Table 1. National distribution of cattle and calves, June 1, 1972, expressed as a proportion of the national total

	Bulls	Milk cows	Dairy heifers	Beef cows	beef heifers	Steers	Calves
Maritimes	.0274	.0457	.0512	.0137	.0127	.0228	.0236
Quebec	.1967	.4116	.3529	.0476	.0338	.0341	.0914
Ontario	.1446	.3329	.4101	.1237	.2396	.3746	.1772
EAST	.3687	.7902	.8140	.1849	.2932	.4314	.2922
Manitoba	.0829	.0480	.0467	.1071	.0825	.0885	.0940
Sask.	.2121	.0452	.0362	.2884	.2326	.1476	.2488
Alberta	.2892	.0805	.0629	.3670	.3453	.3036	.3212
B.C.	.0471	.0361	.0401	.0527	.0465	.0289	.0448
WEST	.6313	.2098	.1860	.8151	.7068	.5686	.7088

The Trend-Cycle or Time Dimension

Marshall[1] points out that official estimates of the numbers of cattle and calves in Canada have been kept since 1906. Over that period, milk cow numbers rose smoothly to peak in the mid-1930's and have fallen rather steadily since that date. On the other hand, cattle, other than milk cows, have trended upward irregularly since 1906.

Marshal goes on to say that these irregularities in cattle numbers, the so-called cattle cycle, is basically a phenomenon of the beef cattle population and thus most pronounced in the West. He identifies the following cycles for cattle other than milk cows.

[1]R. G. Marshall, Variations in Canadian Cattle Inventories and Marketing, Department of Agricultural Economics, Ontario Agricultural College, Guelph, 1964.

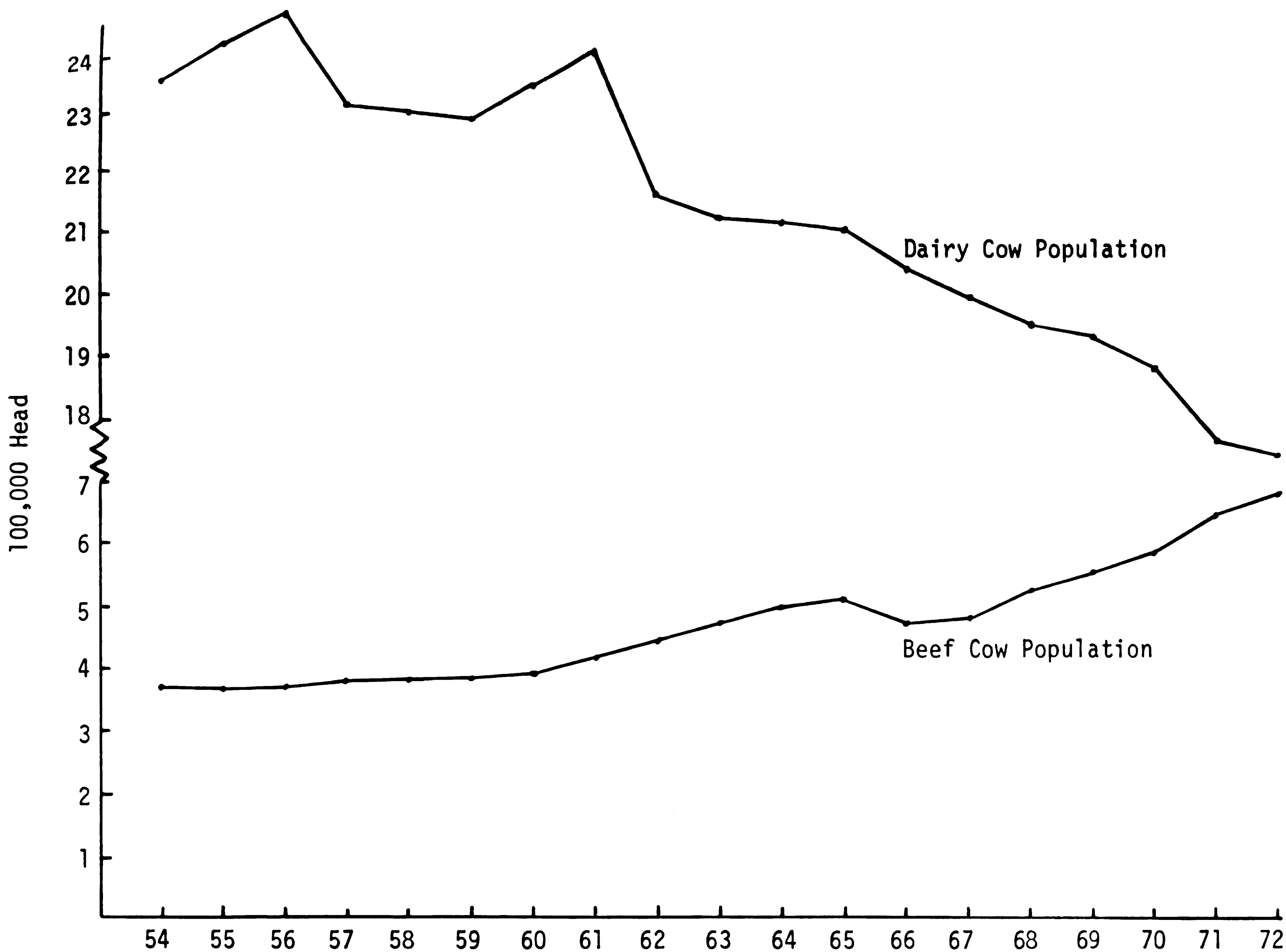

Figure 3. Eastern Cow Population, June 1, 1954-1972.

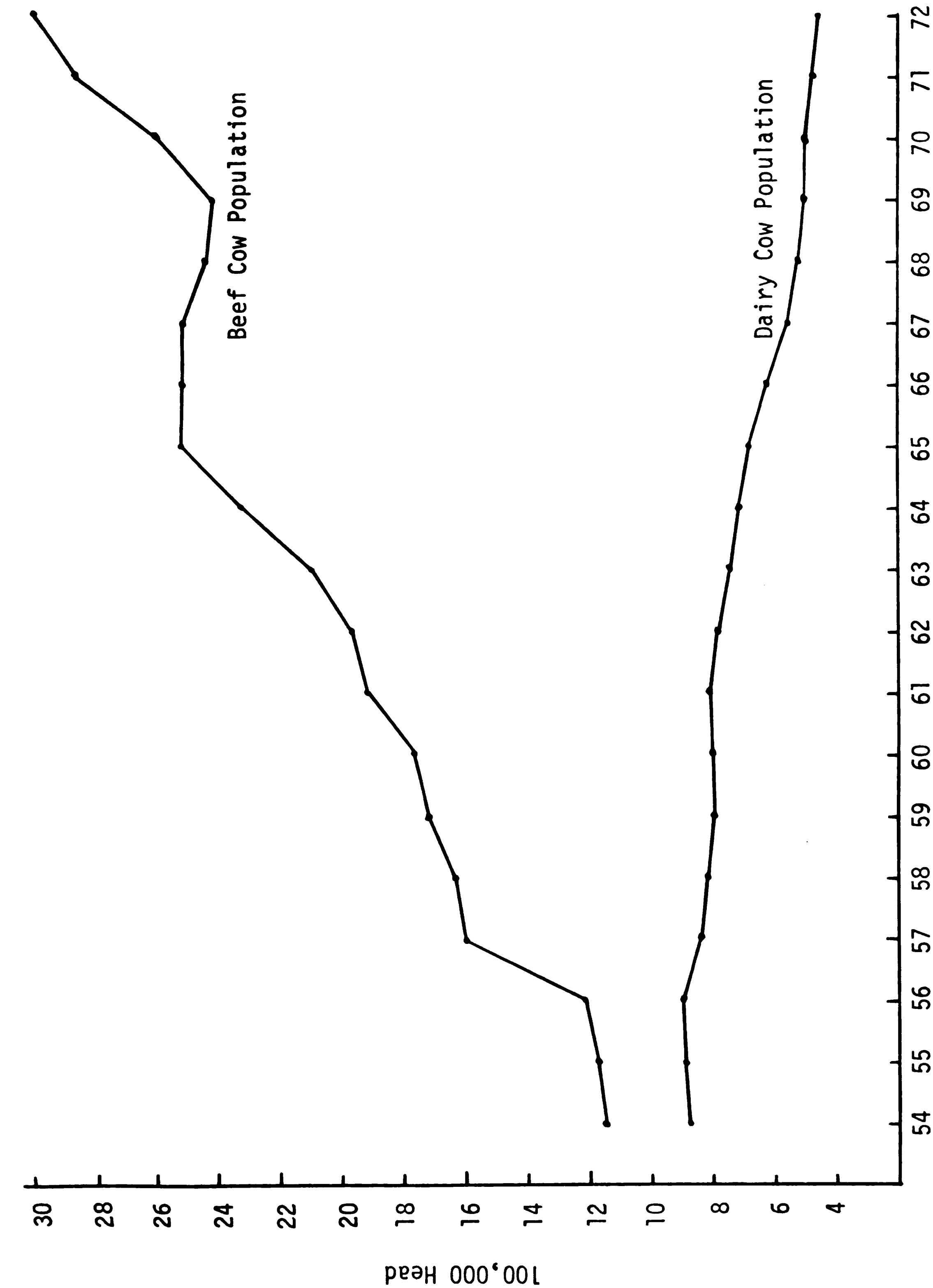

Figure 4. Western Cow Population, June 1, 1954-1972.

1911-1928	upswing 1911-1919 downswing 1919-1928	8 years 9 years
1928-1939	upswing 1928-1933 downswing 1933-1939	5 years 6 years
1939-1950	upswing 1939-1945 downswing 1945-1950	6 years 5 years
1950-1963	uncompleted 12 year upswing (one year decline in 1958)	

Subsequent analysis shows that the last continued until 1965. A four year down turn followed that bottomed out in 1969. An upswing has been in progress since that date.

Marshall has been tempted to say that the "conventional" cattle cycle (as occurring 1911-1950) has not been in evidence since 1950. He states, "this apparent deviation from the historical cyclical pattern over recent years, both in terms of timing and magnitude, would appear to negate the automatic properties of the cattle cycle as seemed apparent in the earlier years."[1]

Petrie characterizes the cattle cycle in terms of slaughter, and from peak to peak.[2]

1945-1957	downswing 1945-1950 upswing 1951-1957	6 years 6 years
1957-1965	downswing 1957-1958 upswing 1959-1965	1½ years ½ years
1965-1969	downswing 1965-1969	3½ years

[1]Marshall, op. cit., p. 11.

[2]T. Petrie, "Analysis of Seasonal, Cyclical and Trend Variations in the Prices and Output of Cattle and Hogs in Canada," unpublished Master's thesis, Saskatoon, University of Saskatchewan, 1971.

Marshall discounts the 1957-1958 downswing as being a product of high exports, therefore, low domestic slaughter. Beef cow members continued to increase during this period.

Both Marshall and Petrie note that the cyclical motion in cattle numbers, generally, is a western beef cattle phenomenon. Petrie goes on to give three basic reasons for this cyclical motion.

1. Producer response to short term conditions. This would include the drought in the thirties, the outbreak of foot and mouth disease in Saskatchewan in 1952, and the drought in 1961.

2. Exports as a response to relative international prices, especially U.S. cattle prices. A low period of exports are noted between 1952-1956 and 1967-1972. The intervening period 1958-1966 generally was a period of high exports.

3. Wheat--the competitive condition of livestock in the Western economy. If wheat exports and prices are average to high, resources are traditionally withdrawn from cattle production in the West. The years 1963-1967 saw high wheat exports and low carryover. Conditions changed during 1968-1970 as exports were reduced and carryover reached unprecedented levels.

Summarizing both Marshall and Petrie, the following events had a significant impact on the Western beef cattle population.

1937-1940	drought
1941-1945	government policy to divert excess grain to livestock
1945-1950	high western grain sales
1950-1962	high grain carryover especially wheat
1963-1967	high wheat sales
1967-1970	high wheat carryover
1970-	government policy to divert excess resources to livestock.

The recent rise in cattle numbers has in part been sparked by diversification (into livestock) programs sponsored by several provincial governments, as well as the 1970 Lower Inventories for Tomorrow (LIFT) program of the Federal government.

Thus, to Petrie's list might be added a fourth item, government programs. These items are in addition to and superimposed on the traditional cobweb model of the cattle cycle. Figure 7 attempts to show the progress through 1958-1972 of births, calf exports, calf slaughters, while Figure 5 relates cow-heifer slaughter to calf births and steer slaughter.

The Trade Dimension

Boswell,[1] Boswell and MacEachern,[2] and Marshall[3] provide a panorama of the changing cattle trade pattern in North America, especially as it affects Canada.

Cattle export statistics divide non-dairy, non-breeding stock exports into three weight classes: less than 200 pounds, 200-700 pounds, and over 700 pounds. While these categories will be treated in some

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[1]A. M. Boswell, "The Changing Economic Profile of Canada's Beef and Veal Trade," Canadian Farm Economics 8(5):1-14, Oct. 1973.

[2]A. M. Boswell and G. A. MacEachern, "Determinants of Change in the North American Feeder Cattle Economy," Canadian Journal of Agricultural Economics, 15(1):53-65, 1967.

[3]R. G. Marshall, An Assessment of Current and Prospective Trade Patterns, Supply and Demand Situations for Cattle and Beef, Hogs and Pork, with Reference to Canada's Position in the North American Market, Department of Agricultural Economics, University of Guelph, 1968.

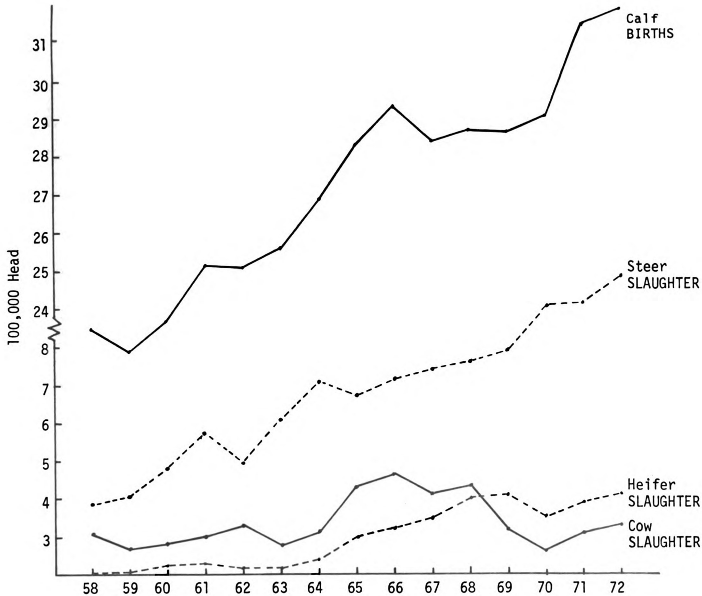

Figure 5. Western Cattle SLAUGHTER and Calf BIRTHS, 1958-1972.

detail later in this chapter, the intent of this discussion is to provide some appreciation of the changing nature of trade flows.[1]

Calves under 200 pounds flow from Eastern Canada (mainly Quebec, and to a lesser extent Ontario) into New York, Michigan, and the New England States. A recent occurrence has been the shipment of calves to Europe, especially to Greece and Italy. These calves are destined for veal slaughter and are primarily excess male calves from the dairy herd. This flow occurs primarily in the March-June period. Figure 6 demonstrates how this flow has gradually increased over the 1956-1972 period.

Cattle exports in the 200-700 pounds range are primarily feeder calves from Western Canada moving to feedlots in North-Central and northern United States. These calves are, for the most part, 6-8 months of age and in the 400-500 pound weight range. Historically a large percentage have been heifers due to differential steer-heifer price margins between the two countries. Figure 7 shows this flow, while irregular, it has been of major significance over the 1956-1968 period. Of recent years, this flow has virtually stopped due to relative conditions between the sub-sectors in the two countries.

The third major category is hard to specify. It can contain heavy feeder cattle, fed cattle or cows, primarily low quality cows for manufacturing purposes. This category is believed to contain a fairly

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[1]Since Canadian trade in cattle cannot be divorced from the U.S. cattle industry, knowledge of the changing U.S. pattern is helpful. One useful reference is <u>The Interregional Structure of the American Beef Industry in 1975 and 1980</u>, Publication B-708, Oklahoma State University, July 1973.

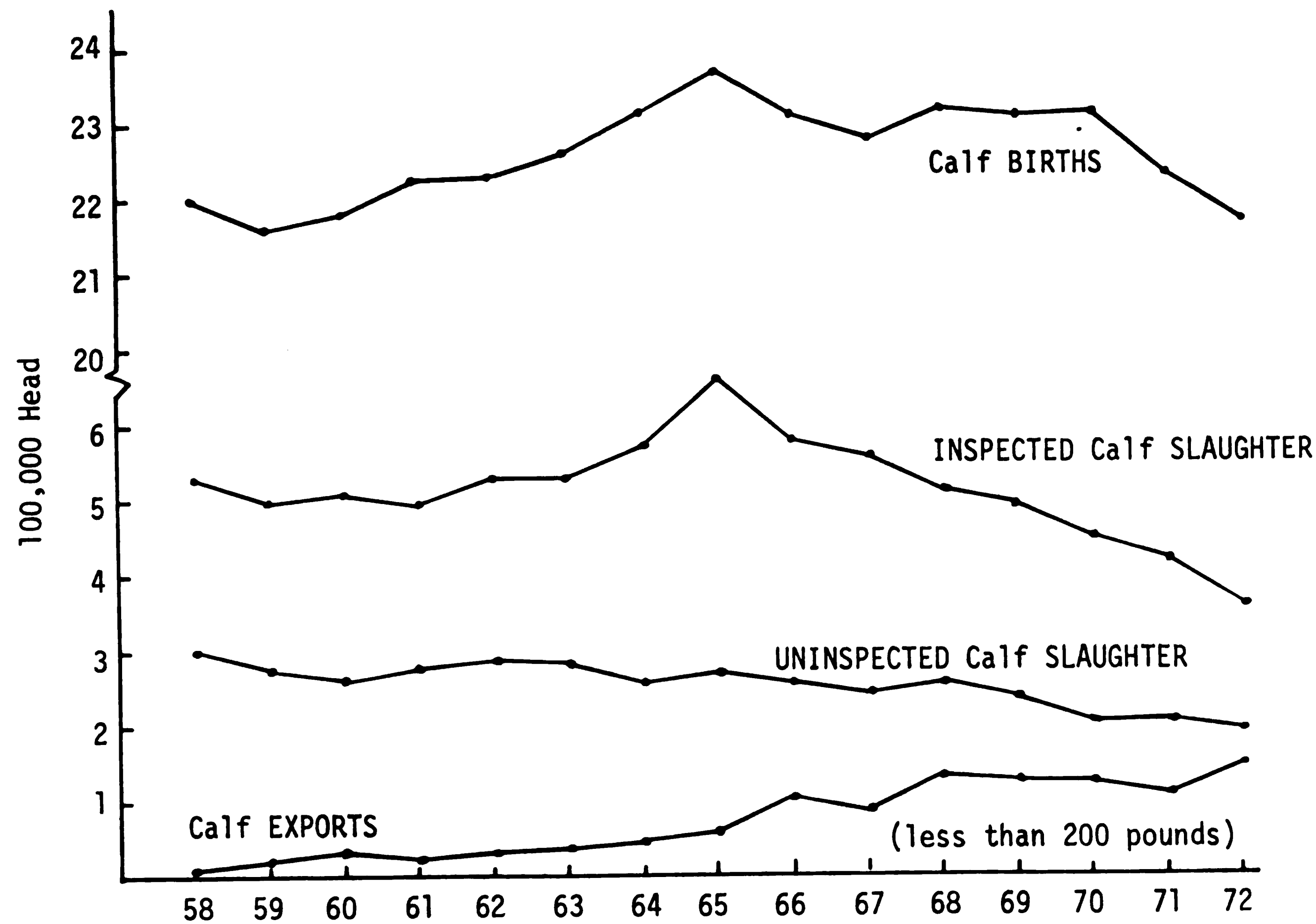

Figure 6. Eastern Calf BIRTHS, EXPORTS, and SLAUGHTER, 1958-1972.

steady flow of the latter class of cow. Flows of heavy feeder cattle are irregular, mainly from the West and occur in response to price differentials, again, mainly from Western Canada.

The flow of breeding stock, both export and import, is small, except for dairy cows and heifers. A significant export market persistently exists for both purebred and grade dairy females. These flows originate primarily in Eastern Canada.

Cattle imports are primarily heavy finished cattle for immediate slaughter. This flow is intermittent and in response to relative price differences. The import (or export) response is due in large part to an "import margin" (or export margin). This margin is believed to be made up of tariff plus transport plus shrink. It is usually calculated when both prices are in Canadian dollars.

The Internal Flow Dimension

The major internal flow of cattle is from West to East. Because of the difference between the cattle/people geographic distribution, either cattle or beef must move East. Over the past 16 years both flows have increased. From Figure 7 it can be seen that calves shipped East increased during the 1957-1967 period, with a slight tapering off to 1971. The latter period was consistent with the adverse Prairie grain economy.

The movement of cattle (over 550 and 575 pounds)[1] from West to East has been significant and relatively steady at the annual rate of

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[1]The statistics are collected in terms of a 550 pound upper limit for heifers while a 575 pound upper limit is used for steers.

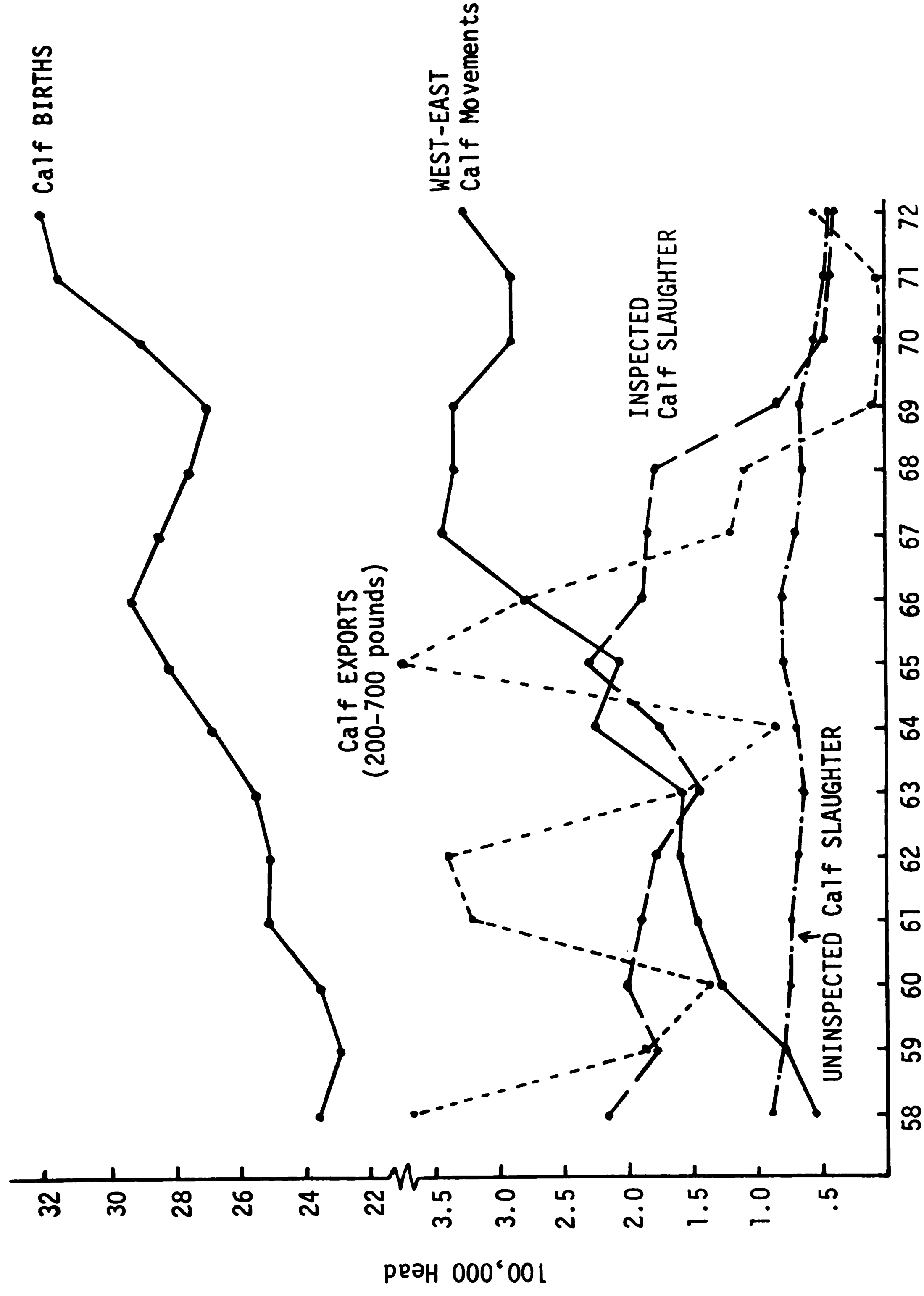

Figure 7. Western Calf BIRTHS, EXPORTS and SLAUGHTER, 1958-1972.

115,000-230,000 head per year. Most of these cattle are for immediate slaughter; however, some may be placed on feed for an additional finishing period.

Figure 8 shows that an increasing proportion of the Canadian slaughter takes place in the West. Since 1965, the East has generally suffered an absolute, as well as proportionate, slaughter decline.

In general, the cattle sub-sector has shifted from East to West. Both the beef cow herd and cattle on feed have expanded rapidly in the West. This has been accompanied by substantially increased Western slaughter, particularly since 1965.

The Calf Slaughter Dimension

An important aspect of cattle production is the slaughter of calves. This slaughter reduces the potential beef supply from a given calf crop. In addition, it adversely affects the ability to expand (should some of the slaughter be female).

In the West, both inspected and uninspected calf slaughter rates have generally declined since 1957, except for a slight increase in the 1962-1965 period when the grain economy was buoyant. Since 1968, calf slaughter has declined to less than 3 percent of total calf crop. Even in 1957, a peak year, calf slaughter was only 14 percent of the total calf crop. Figure 7 portrays Western calf slaughter.

In the East, calf slaughter is still of major significance although declining, generally, over the 1957-1972 period. In 1957, calf slaughter was about 42 percent of the calf crop, in 1972, 15 percent. The calf slaughter is believed to originate largely from

Figure 8. Total INSPECTED Cattle SLAUGHTER, 1958-1972.

the dairy herd and is about 70 percent male. It should be noted that in both East and West, uninspected has been a growing proportion of total calf slaughter, although declining absolutely. Eastern calf slaughter is shown in Figure 6.

The Seasonal Dimension

Annual calving distributions are difficult to determine exactly; however, reasonable estimates suggest a fairly uniform quarterly distribution in the East where the dairy herd predominates. In the West, 70-75 percent of the calf births occur before June 1st and probably the majority of these in the preceding three months.

Petrie's study[1] provides the best evidence of cattle slaughter. He notes peaks in slaughterings (all steers, heifers, cows, bulls) in March, June, and September, with the October-December period being slightly above average. The rest of the months experience slightly below average slaughterings. He attributes the March-June, and to a lesser extent September slaughtering peaks to fed cattle from feedlots. The October-December peak is made up of a higher proportion of lower quality cattle, likely cattle finished on grass. The September peak is due to a convergence of marketings of all cattle classes including cull cows. In general, he states, the seasonal pattern has not appreciably changed for 14 years (1956-1969).

The seasonal pattern of calf slaughter has also been consistent over the past 16 years. In the East, calf slaughter peaks in spring and

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[1]Petrie, op. cit.

early summer, reflecting the large number of veal dairy calves being made available. In the West, calf slaughter peaks during the fall as heavier calves are slaughtered.

The Statistical Data Base

The data that makes up the data base are collected and published by several agencies and divisions within agencies. This data base was assembled by bringing together the relevant published (and unpublished) data series from these several and diverse sources.[1]

These data are used in this study in several ways:

1. as stock and flow variables for the various component models,
2. as standards against which the various model's output may be compared, and
3. as hypotheses.

This third point may need some elaboration. One study objective is to "attempt a reconciliation of these data . . . in order to determine their accuracy." In this regard, the data are not assumed

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[1]As each of these agencies may publish in one or more statistical journals, and indeed publish each other's data, several publications are listed covering this data base: Agriculture Canada, Livestock Market Review, Ottawa, Queen's Printer, various issues; Agriculture Canada, Livestock and Meat Trade Report, Ottawa, Queen's Printer, various issues; Statistics Canada, Dairy Review, Ottawa, Queen's Printer, various issues; Statistics Canada, Livestock and Animal Product Statistics, Ottawa, Queen's Printer, various issues; Statistics Canada, Quarterly Bulletin of Agricultural Statistics, Ottawa, Queen's Printer, various issues; Statistics Canada, Report on Livestock Surveys Cattle, Sheep, Horses, Ottawa, Queen's Printer, various issues; and Statistics Canada, Trade of Canada, Ottawa, Queen's Printer, various issues.

to be accurate; rather, it is held as a hypothesis that is either accepted or rejected. Chapter IV deals specifically with this data reconciliation.

The balance of this section provides a brief description of the content of each data series incorporated into the data base. In addition, the collecting agency is listed. The content of each of these data series has been tentatively determined by referring to published articles and the personal comments of knowledgeable individuals as well as from personal knowledge of these data series. In keeping with the concept of data as a hypothesis, it is recognized at the outset that subsequent findings may lead to a revised understanding of the context of various data series.

The Livestock Survey[2]

Historically and for the period under consideration, Statistics Canada (STATCAN) has published a June 1 and December 1 livestock census. These data series are the basic reference for the stock variables.

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[2]From this point onward, except where noted, a specific notational convention will be used to emphasize the stock and flow variables that are major elements in this study. This convention is as follows:

- flow values and rates will be capitalized, i.e., BIRTH Rate and SLAUGHTER. Modifiers will have the first letter capitalized only.
- stock values will be written with the first letters only capitalized, i.e., Cow Population and Steers.

When words are used to describe age cohorts or functions of cattle or in any other context, this convention will not be used. Examples are modifiers of process or distribution, i.e., birth distribution and slaughter process. Table 2 provides a list of the stock and flow variables referenced in the balance of this dissertation. These variables include the published statistical data as well as those variables used to describe the various models.

Table 2. The stock and flow variable notational convention[a]

A. FLOW values and rates. These values and rates are capitalized; all modifiers of FLOWS have only the first letter capitalized.

BIRTHS and modified by Calf, Cow, and Heifer BIRTH Rate and modified by Cow and Heifers	
DEATHS DEATH Rate	with various modifiers such as Beef, Dairy, Male, Female, and age identification
SLAUGHTER, CULL SLAUGHTER Rate, CULL Rate INSPECTED SLAUGHTER	with various modifiers
UNINSPECTED SLAUGHTER	with various modifiers
also sub-categories	Farm Killed and Eaten Farm Killed and Sold
Cattle for SLAUGHTER Cattle for Local SLAUGHTER Cattle for Immediate SLAUGHTER	and with other modifiers
IMPORTS Purebred IMPORTS Other IMPORTS	
EXPORTS Purebred EXPORTS Other Dairy EXPORTS EXPORTS, Cattle Under 200 Pounds EXPORTS, Cattle 200-700 Pounds EXPORTS, Cattle Over 700 Pounds	
REPLACEMENTS REPLACEMENT Rate	with various modifiers
IN FLOW	
OUT FLOW	
Cows MILKED Yesterday Cows and Heifers to FRESHEN This Month MILK Cows BUTCHERED This Month	
WEST-EAST Movement with modifiers	Cattle-Calf Cattle Calf
also sub-categories	to FEEDLOT to STOCKYARDS to SLAUGHTER

[a]A specific notational convention is employed in this study to indicate which of three possible meanings are attached to words that are often used in three different contexts. These words are used to describe stock and flow variables, as well as to modify processes, distributions, and prices. This table provides a list of the elements in these three groups in order to aid the reader in comprehending this study.

Table 2--Continued

B. Stock values. These values have only their first letter capitalized; this applies as well to all modifiers.

Calf, Calves Weaned Calves Vealer Calves Stock or Stocker Calves	with modifiers such as Beef, Dairy, Male, Female, and age identification
Heifers, Heifer Population Bred Heifers Open Heifers Replacement Heifers First Calf Heifers Slaughter Heifers	with modifiers Beef and Dairy
Steers, Steer Population Slaughter Steers	with modifiers Beef and Dairy
Yearlings, Steers, Heifers Feeder Cattle, Steers, Heifers Finished Cattle, Steers, Heifers	
Herd Cattle Herd Cattle Population Breeding Herd	with various modifiers
Cows, Cow Population Brood Cows Mature Cows Cull Cows	with various modifiers
Bulls, Bull Population Replacement Bulls Cull Bulls	with various modifiers
Number of Farms Reporting Total Cows and Heifers for Milk--Two Years and Over Cows and Heifers in Calf	

C. Processes, delays, distributions, and prices. Modifiers of these are not capitalized.

Processes:	birth death slaughter growth feeding, finishing, feeding-finishing gestation production calving replacement breeding weaning	Distributions:	birth, calving death slaughter, cull replacement
		Prices:	slaughter steers canner and cutter cows stock calves veal calves hogs
Delays			

Calves, Under 1 Year Old	This time series represents both Male and Female, Dairy and Beef Calves. While this and all other Livestock Survey data are published by Province, for the purposes of this study Provincial totals have been aggregated to form an Eastern and Western total.
Steers, 1 Year Old or Older	These data represent both Dairy and Beef Steers.
Beef Heifers	These data are described as Female stock 1 to 2 years of age being raised for replacements and those for slaughter. As is the case with Steers, no attempt is made to differentiate those on feed from the balance over most of this time period (1958-1972).
Beef Cows	This figure is described as Female stock 2 years old and older, kept mainly for beef purposes.
Dairy Heifers	These data are described as Female stock 1 to 2 years being raised mainly for milk purposes.
Dairy Cows	These are described as Female stock 2 years old and older kept mainly for milk purposes.
Bulls, 1 Year Old or Older	These data summarize both Beef and Dairy Bulls.

Calves Born Survey

STATCAN publishes semi-annual estimates of Calf BIRTHS. The June 1 figure represents an estimate of the Calf Crop from December 1 of the previous year until June 1 of the current year. Similarly, the December 1 figure represents the accumulated Calf Crop from June 1 to December 1. Calves born include both Beef and Dairy Calves.

INSPECTED Cattle SLAUGHTER

These data are collected and published by the Livestock Division, Production and Marketing Branch, Agriculture Canada. Because these data are collected daily by on-site federal government inspectors, a good deal of credibility is attached to them.

SLAUGHTER, Male Calves SLAUGHTER, Female Calves	This rather broad category includes animals from light Vealers to heavy Butcher Calves. An examination of carcass weight reveals a low of 100-110 pounds in April-May to a high of 165-185 pounds in November. Western Female Calf SLAUGHTER historically peaked in the fourth quarter raising average carcass weight. Thus SLAUGHTER Calves might be expected to range from 200-450 pounds and from 3-6 months of age. While Calf SLAUGHTER is primarily thought of as Male Dairy Calves, historically there has been significant Female Calf SLAUGHTER in both Eastern and Western Canada.
SLAUGHTER, Steers SLAUGHTER, Heifers SLAUGHTER, Cows SLAUGHTER, Bulls	No attempt has been made to separate these categories into their Beef and Dairy components. The definition of Heifers and Cows does not necessarily conform to the age cohorts previously described for the STATCAN Livestock Survey. In addition, no attempt has been made to calculate carcass weight for each of these four categories. An examination of an aggregate carcass weight reveals that it has risen from about 525 pounds in 1958 to about 575 pounds in 1972. During this period, the proportion of Steers and Heifers on feed has risen. This undoubtedly has raised both live slaughter weight and dressing percentage.

WEST-EAST Cattle-Calf Movement

Like INSPECTED SLAUGHTER these data are collected and published weekly by the Livestock Division, Production and Marketing Branch, Agriculture Canada. These data refer only to those Cattle and Calves shipped East by rail. It is believed that most are shipped by rail with the balance by truck. Thus, these data represent a lower bound.

	Cattle Movement for:
SLAUGHTER	These are assumed to be Finished Cattle for Immediate SLAUGHTER.
FEEDLOT STOCKYARDS	These are assumed to be Feeder Cattle, over 550/575 pounds[1] to be placed in a feedlot mainly--some may go to grass.
	Calf Movement for:
SLAUGHTER	These are assumed to be Calves for Immediate SLAUGHTER--they are likely above average weight and age for Slaughter Calves.
FEEDLOT STOCKYARDS	These Calves are assumed to be below 550/575 pounds[2] and may go directly to a feedlot or to grass depending on season and prices.

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[1]The statistics are compiled in terms of 550 pounds for Heifers and 575 pounds for Steers.

[2]Ibid.

Dairy Correspondents Survey

Monthly data is collected by STATCAN from a sample of dairy farmers. The sample data has been adjusted to correspond to STATCAN's June 1 and December 1 Livestock Survey by Economics Branch personnel.

The self explanatory headings are as follows:

- Numbers of Farms Reporting
- Total Cows and Heifers for Milk--Two Years and Over
- Cows MILKED Yesterday
- Cows and Heifers in Calf
- Cows and Heifers to FRESHEN This Month
- Milk Cows BUTCHERED This Month

UNINSPECTED Cattle SLAUGHTER

These data are not published, however, they are compiled on a provincial basis by the Agricultural Division of STATCAN for their own internal use. Certain of these data were made available to the author on a quarterly basis with the balance on an annual basis. These data are compiled only on a cattle/calves basis.

UNINSPECTED SLAUGHTER falls into two categories: slaughter in plants and slaughter on the farm.[1] The former data are estimates of slaughter in packing plants not inspected by federal inspectors although they may be inspected for one or more reasons by provincial, municipal, or other federal authorities.

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[1]From this point onward both categories will be included in UNINSPECTED SLAUGHTER unless otherwise stated.

Cattle	In the West, this SLAUGHTER is about 5 percent of total Cattle SLAUGHTER, while in the East, it is about 20-25 percent; it is reasonably stable in both cases.
Calf	In the West, this SLAUGHTER is about 20-25 percent of total Calf SLAUGHTER; however, this total has fallen drastically over the 1958-1972 period. In the East, this SLAUGHTER is also 20-25 percent of total Calf SLAUGHTER. In contrast, Eastern Calf SLAUGHTER has remained relatively high, although only about half its earlier (1958) rate. This reduction in Eastern UNINSPECTED Calf SLAUGHTER is mainly attributed to major reductions in Quebec.
Farm Killed and Sold, Farm Killed and Eaten	These data represent estimates of animals that are slaughtered, butchered, and possibly sold by the farmer in such a manner as to not pass through a packing plant. The number of Farm Killed Cattle has remained fairly steady at about 130,000 head in the East and 70,000-100,000 head in the West. The numbers of Farm Killed Calves has dropped from 130,000 to 80,000 head in the East and from 60,000 to 25,000 head in the West.

The types of Cattle in this latter category are not readily apparent. One assumption might be that the Calf portion is distributed by sex and quarter, as is INSPECTED Calf SLAUGHTER. It also might be assumed that Farm Killed Cattle may be distributed fairly evenly among quarters. It might intuitively be expected that Cows and Heifers would make up a higher proportion of Farm Killed and UNINSPECTED SLAUGHTER than INSPECTED SLAUGHTER. Thus, one tentative distribution might be Cows (1/3), Heifers (1/3), and Steers (1/3). They might also be divided between Beef and Dairy, roughly in proportion to the incidence of Beef and Dairy in the total Herd.

IMPORT Data

The most reliable trade data is believed to be collected by the External Affairs Division of STATCAN and published in Trade of Canada. Data prior to 1969 data were readily available only on an annual basis. From 1969 forward, monthly data were available.

Purebred IMPORTS	This category includes both Dairy and NES (Beef) Cattle as well as Males and Females.[1] For the purpose of this model, all Purebred IMPORTS AND EXPORTS are assumed to be Cattle of at least two years. The breakdown into Beef and Dairy occurred only with the 1969-1972 data.
Other IMPORTS	This category contains largely Cattle for Immediate SLAUGHTER. They are assumed to be primarily Steers.

With all IMPORTS, the statistics are compiled at the Port of Entry. If these data are used as though destination coincided with the Port of Entry, some error may be introduced.

EXPORT Data

As with IMPORTS, only annual aggregate data is available prior to 1969. For 1969 and forward, these same statistics are available on a monthly basis.

- Annual Purebred

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[1]Not elsewhere specified. This element of the various EXPORT and IMPORT data name is dropped elsewhere in this dissertation in order to shorten the name; the context provides ample identification.

- Annual Purebred Dairy
- Annual Purebred NES.[1]

These data are not divided into Dairy and Beef components prior to 1966. In addition, no division is made into Male and Female. One possible guide to disaggregation is data published by the Livestock Division, Marketing and Trade Branch, Agriculture Canada. Using 1973 data from this source, Purebred NES (Beef) appears to run 60 percent Bulls in the West and 10 percent in the East. Purebred Dairy is less than 10 percent Bulls, East and West. Purebred Cattle appear to be almost 95 percent or better Beef in the West and 10 percent in the East (prior to 1972).

Dairy, NES, Weight 200 Pounds and Up[2]	This category is assumed to be Dairy Cows and Heifers that are not Purebred. For the purpose of this study, it will be assumed that all Cattle in this category are 2 years or over.
Cattle, NES, Weight Less Than 200 Pounds	This category is assumed to include very young Male Dairy Calves. These Calves are shipped largely from Quebec and Ontario to New York and other adjacent American states, with greatest flow occurring in the March to June period.
Cattle, NES, Weight 200-700 Pounds	These Cattle are largely shipped from the West to the North Central United States. One estimate is that they are 58-67 percent Female and are shipped mainly in October and November.

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[1] Ibid.

[2] Shortened to Other Dairy EXPORTS elsewhere in this dissertation.

Cattle, NES, Weight Over 700 Pounds	This category contains everything from Feeder and Slaughter Cows to Slaughter Steers and Heifers. One knowledgeable official has stated that it is primarily Cows; when relative prices place Canada on an export basis, the increase in this category is largely Slaughter Steers and Heifers. A review of Agriculture Canada's figures show that most Eastern Cattle in this category are for slaughter, with the numbers being reasonably stable, therefore, they are likely Cows. The Western pattern varies widely.

The above annual categories are also given on a monthly basis for 1969 and onward. This monthly basis provides a distribution for disaggregating the annual data prior to 1969.

The Economic Model

At any point in time, the size and composition of the Canadian Cattle Herd can be taken as given. This Herd represents the net effect of all past adjustments to price, institutional and biological conditions as well as those expected to prevail in the future.

The Breeding Herd, in terms of Cows and Bulls is viewed as a stock of capital. This stock of capital is a productive input in the production function for Calves and thus beef. The relative prices for inputs and products determine an optimum flow of services required from that stock, or abstracting from the user cost problem, determine the optimum size of that stock of capital.

Consideration of the Breeding Herd as a stock of capital that is an input to the production of beef from Slaughter Cattle differs from conventional capital theory. It differs in that net investment or disinvestment in the Cattle Herd directly affects beef supplies and, thus, relevant prices and, in turn, the optimum stock.

The optimum stock and the production functions are markedly influenced by the price of inputs and especially inputs that are produced with largely the same set of resources. The input in question is feed grain.

A Cattle Herd simultaneous equation model may be described in the following oversimplified terms.[1]

- A production function for Slaughter Cattle:[2]

(1) SLAUGHTER CATTLE = f_1 (land, labor, BREEDING STOCK, GRAIN, other capital, non-farm inputs, technology).

- Beef supply function:

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[1]While these equations will not be discussed immediately or directly, they are intended to facilitate the discussion which follows. They have no other purpose.

Many similar, but more comprehensive models of the cattle-feed grain sub-sector have been developed. One example is S. N. Kulshreshtha, A. G. Wilson, and D. N. Brown, An Econometric Analysis of the Canadian Cattle-Calves Economy, Department of Agricultural Economics, Saskatoon, University of Saskatchewan, 1971; and J. W. Freebain, "Some Adaptive Control Models for the Analysis of Economic Policy: United States Beef Trade Policy," unpublished Ph.D. dissertation, University of California, 1972.

Teigen provides a critical analysis of five such studies in his Ph.D. dissertation. L. D. Teigen, "Costs, Loss and Forecasting Error: An Evaluation of Models for Beef Prices," unpublished Ph.D. dissertation, Michigan State University, 1973.

[2]The notation for these equations is as follows: variables written with upper case letters are endogenous to the model, those written in lower case are exogenous.

(2) FED BEEF = f_2 (SLAUGHTER CATTLE, EXPORTS, IMPORTS, P_a, P_s, GRAIN PRICES)[1]

(3) NON-FED BEEF = f_3 (SLAUGHTER CATTLE, CULL CATTLE, IMPORTS, EXPORTS, GRAIN PRICES).

- Breeding Herd investment functions:

(4) REPLACEMENTS = f_4 (land, labor, SLAUGHTER CATTLE, P_a, P_s, $MVP_{BREEDING\ STOCK}$).

(5) CULLS = f_5 (land, labor, P_a, P_s, $MVP_{BREEDING\ STOCK}$).

(6) $d\,\dfrac{\text{BREEDING HERD}}{dt}$ = REPLACEMENTS - CULLS.

- Beef demand functions:

(7) $PRICE'_a$ = f_7 (NON-FED BEEF, FED BEEF, price of substitutes, income).

(8) $PRICE'_s$ = f_8 (NON-FED BEEF, FED BEEF, price of substitutes, income).

- Farm price functions:

(9) P_a = f_9 ($PRICE'_a$, processing and retailing cost, price of by-products).

(10) P_s = f_{10} ($PRICE'_s$, processing and retailing costs, price of by-products).

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[1] P_a and P_s are defined in the following pages.

• EXPORTS and IMPORTS of Cattle functions:

(11) EXPORTS = f_{11} (P_a, P_s, US prices, tariffs, transport costs).

(12) IMPORTS = f_{12} (P_a, P_s, US prices, tariffs, transport costs).

• Grain production and demand functions:

(13) GRAIN = f_{13} (land, labor, other capital, non-farm inputs, technology).

(14) GRAIN PRICE = f_{14} (GRAIN, BREEDING HERD, international price, institutional factors).

The balance of this section develops the concepts introduced above, while drawing on this simple simultaneous equation model. It should be emphasized that this dissertation basically expands on equations (1), (4), (5), and (6).

Investment and Disinvestment[1]

Neo-classical capital theory makes provision for depreciation of capital stock through a process of physical depletion and functional obsolescence. Capital stock may also be reduced by direct sale or salvage. The investment and disinvestment processes, discussed in a growth context, also make provision for capital of different vintages and different embodied technology.

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[1]The notational convention described in Table 2 is dropped for the balance of Chapter II.

Normally or usually depletion, disinvestment or depreciation take the form of the oldest and/or lowest technological items being displaced first. Investment normally takes place in terms of new items embodying superior technology. In addition, neo-classical theory allows for the possibility of investment and disinvestment taking place concurrently.[1]

Neo-classical theory suggests that investment takes place when the marginal value product (MVP_i) of an asset exceeds its market price.[2]

(15) $$P_i < MVP_i$$

Disinvestment takes place when expected marginal value is less than market price.

(16) $$P_i > MVP_i$$

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[1]A traditional treatment of investment, business cycles and growth is given in R. G. D. Allen, Macro-Economic Theory, A Mathematical Treatment, New York, St. Martin's Press, 1968.

An excellent review of recent literature on the economics of investment in fixed capital is given in Dale W. Jorgenson, "Economic Studies of Investment Behavior: A Survey," Journal of Economic Literature 9:1111-1147, Dec. 1971.

Because the nature of investment and disinvestment in livestock differs in some fundamental ways from investment in industrial capital goods, the method used in this study diverges somewhat from the method and studies cited in Joregenson.

The theoretical argument that is developed in this section is presented in a very lucid fashion by Dan Sumner in a mimeographed paper, "An Empirical Examination Concerning Investment and Disinvestment in Durable Assets: Econometric Analysis of U.S. Milk Cow Herd," Michigan State University, 1973.

[2]Market price or P_i refers to the asset's rental price.

Fluctuations in P_i <u>or</u> in MVP_i lead either to investment or disinvestment.

A revision to neo-classical theory, developed by G. L. Johnson and his associates leads to a third alternative, that of assets (stock) fixed in production.[1] The three investment possibilities depend on the existence of two prices, not one. The two prices are referred to as acquisition price, P_a, and salvage price, P_s. The divergence of these two prices is attributed to cost of obtaining information, transaction and transport costs.

The three investment possibilities now are:

$$\text{Invest if } P_{ai} < MVP_i$$

$$\text{Disinvest if } P_{si} > MVP_i$$

$$\text{Neither invest nor disinvest if } P_{si} < MVP_i < P_{ai}.$$

This latter position is known as the fixed asset position where assets are fixed or locked in production for the firm. A firm never plans on being in this position, a position in which it incurs a capital loss. This situation comes about through mistakes made in past investment decisions or where expectations do not materialize.

This discussion indicates that net investment takes place in two activities, gross investment in new capital usually of high

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[1]For a detailed description and mathematical treatment refer to G. L. Johnson and C. L. Quance, <u>The Overproduction Trap in U.S. Agriculture</u>, Baltimore, John Hopkins Press, 1972.

technological content and gross disinvestment in older capital of lower technological content. Further, this investment and disinvestment considers two prices, not one. In addition, the optimum stock of capital is reached when the adjustment is completed with respect to a change in the two prices, P_a and P_s, and to changes in MVP.

This adjustment process may be represented as[1]

$$(17) \qquad STOCK_{t+1} - STOCK_t = (1 - \lambda)\ (STOCK_t^* - STOCK_t)$$

where

$STOCK^*$ = the desired level

$1 - \lambda$ = the accelerator

and

$$(18) \quad STOCK_{t+1} - STOCK_t = \text{Gross Acquisitions}_t - \text{Gross Dispositions}_t$$

This theory may now be applied to the instance of a specific operator or decision maker, making marginal adjustments to his breeding herd. While prices (P_a, P_s, and input prices) are determined at a macro level, aggregate supply of cull or slaughter animals or demand for replacements is the sum of the decisions made by the micro units.

The micro decision makers in the cattle sub-sector are farmers, ranchers, and cattle feeders. Their large numbers and dispersion at the

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[1]This formulation is that of the flexible accelerator. Much of the recent literature on investment uses this formulation with emphasis on the determination of the level of desired capital, the time structure of the investment process and the treatment of replacement investment.

cow-calf production level suggests that the sub-sector can be approximated by the competitive model. However, at the feedlot level, competition might be something less than perfect, leading to increasing vertical coordination.[1]

The actions of these micro decision makers result in investments disinvestment, and calf slaughter which control the capacity of the sub-sector to subsequently produce more beef and veal. It is their aggregate behavior that is of major interest in these models.

It is assumed that the decision makers are utility maximizers, that is, they attempt to acquire and utilize resources in such a manner as to maximize utility over time. It is further assumed that utility is a function of the goods and services that they can command and leisure. This utility function may be expressed

$$(19) \qquad \text{Utility}_t = f_1 \; (\text{goods and services}_t, \text{ leisure}_t).$$

Assuming that profit, however defined, is a good proxy for command over goods and services and, that given leisure, utility is a function of profit, then equation (19) can be written

$$(20) \qquad \text{Utility}_t = f_2 \; (\pi_t/\text{leisure}_t).$$

[1]There is increasing concern that vertical coordination is resulting in less than desirable price reporting due to the lower volume of cattle through public stockyards. Price quotations are given for sales at this point. The concern is expressed by C. Mills, "WSGA Market Information Services (CANFAX)," Proceedings of the CAES Workshop, Banff, 1970; and by R. G. Marshall and H. B. Huff, A National Research Program for the Marketing of Canadian Cattle and Beef, a restricted distribution publication, School of Agricultural Economics and Extension Education, University of Guelph, 1970.

The profit function for the dairy or beef (cow-calf) farmer could be depicted as follows:

$$(21) \quad \pi_t = P_{milk}\, Q_{milk} + P_{beef}\, Q_{beef} + P_{grain}\, Q^{*}_{grain}{}^{1} - f_3(Q_{milk}, Q_{beef}, Q_{grain}, \text{other expenses}).$$

But each output is subject to the constraint of the production function. Production functions can be written as follows.

$$(22) \quad Q_{milk} = f_4 \text{ (dairy cows, grain, forage, labor, housing, non-farm inputs, technology).}$$

$$(23) \quad Q_{beef} = f_5 \text{ (cows, grain, forage, labor, housing, non-farm inputs, technology).}$$

It will be noted that grain is an input into the production of beef and milk, it also competes for resources with beef and milk production. Thus a production function can be written

$$(24) \quad Q_{grain} = f_6 \text{ (land, labor, machinery, non-farm inputs, weather, technology).}$$

The following argument is developed in terms of these basic production functions. It should be recognized that (1) grain and livestock production are both competitive and complementary in production and (2) that milk and beef are produced as joint products in some proportions.

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[1] Q^{*}_{grain} is grain sold, Q_{grain} is grain produced.

Substituting equations (22) and (23) into (21) and differentiating (21) with respect to cows, the following is obtained.

$$(25)\quad \frac{d}{d\ cow} = P_{milk}\frac{\partial\ Q_{milk}}{\partial\ cow} + P_{beef}\frac{\partial\ Q_{beef}}{\partial\ cow} + P_{grain}\frac{\partial\ Q_{grain}}{\partial\ cow}$$

$$+ Q_{milk}\frac{\partial\ P_{milk}}{\partial\ cow} + Q_{beef}\frac{\partial\ P_{beef}}{\partial\ cow} + Q_{grain}\frac{\partial\ P_{grain}}{\partial\ cow} - \frac{f_3(\ \ )}{cow}\ .$$

Since for each farmer $\frac{\partial\ P}{\partial\ Q} = 0$, the fourth to six terms drop out. If P_{grain} is equated with the value in milk or beef production then the third term is cancelled out as well by the last (cost function) term. The MVP_{cow} then equals

$$(26)\qquad MVP_{cow} = P_{milk}\frac{\partial\ Q_{milk}}{\partial\ cow} + P_{beef}\frac{\partial\ Q_{beef}}{\partial\ cow} - \frac{f_3}{cow}\ .$$

Using an adaptation of equation (26) the E(MVP) of a cow can be approximated by the discounted value of all future net returns.[1]

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[1]This formulation is an adaptation of the familiar capital budgeting discounted present value formula. It is given in many texts including J. C. Van Horne, Financial Management and Policy, 2nd ed., Englewood Cliffs, N.J., Prentice Hall, Inc., 1968, pp. 53-55.

Branson provides a lucid argument demonstrating that utility is maximized by maximizing present value in W. H. Branson, Macroeconomic Theory and Policy, New York, Harper and Row, 1972, pp. 199-203.

Branson goes on to demonstrate that the present value criterion is preferred to the marginal effeciency of capital criterion in that the former explicitly considers the opportunity cost of capital.

Because of uncertainty, MVP is seen as a random variable with first and second moments. For this reason, MVP will be expressed as *E(MVP)* for the balance of this theoretical development. It should be explained that MVP is the marginal value of a cow over cost thus for an individual farmer it is discrete rather than continuous. This usage differs from the usual definition of the marginal addition to gross revenue made by the last unit produced and sold. The latter is usually thought of as a continuous differentiable function of output.

$$(27) \qquad E(MVP) = \sum_{j=n}^{T} \frac{[E(P_1)_j - E(C)_j]}{(1+i)^j} + \frac{E(P_2)_T(1-R(t))^{T-n}}{(1+i)^{T-n}}$$

where

P_1 = price of milk x quantity of milk
price of calf x weight of calf,

P_2 = price of cull cow x weight of cull cow,

C = cost of maintaining cow for 1 year plus cost of maintaining calf until sold (1 year or less),

R(t) = a risk factor associated with death; assume that it increases with age,

$E(P_1)_j$ = contain the risk associated with conception, medical problems, calving problems. They also are assumed to increase with age,

i = the discount factor, a measure of the opportunity cost of resources, a variable that has a P_a and P_s,

T = some terminal length of stay in the herd under existing technology, a function of (MVP, P_s), and

n = current age of cow, N = 0 at first calving.

In making decisions on whether or not to invest in breeding stock, farmers look largely at the recent past and next immediate year.[1] This is the case as retain-cull decisions can be made almost continuously and are revocable at a cost for the herd. The lower limit is to cull all the breeding herd or to completely disinvest; the upper limit is imposed by the capacity of the physical plant. Alteration of

[1]While this model does include expected prices, price expectation models are not explicitly incorporated into subsequent applications. All prices that are subsequently considered are either current or lagged, as noted. The author recognizes, however, that a price expectation model is implicitly suggested.

the physical plant requires that E(MVP) of the physical plant exceeds its acquisition price.[1]

For an individual cow, E(MVP) diminishes with age as $n \dashrightarrow T$, as shown in equation (27) for positive i. This circumstance is shown graphically in Figure 9.

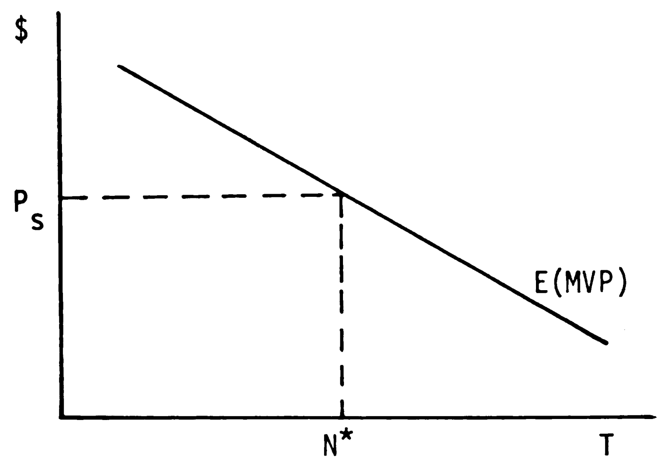

Figure 9. Expected marginal value product, E(MVP), of a cow.

The dotted horizontal line represents salvage price or cull cow price. At some age, P_s = E(MVP); call this age N^*. This can be considered as the average or expected length of stay in the herd for any one cow. At equilibrium, $(N^*)^{-1}$ of the herd is replaced each year. If the herd size is k, then culls = k x $(N^*)^{-1}$ per year.

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[1]Expansion of the herd through utilization of existing capacity as compared with expansion through investment in additional plant capacity suggests an interesting and realistic dimension to the problem. This question is left for future studies.

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At equilibrium (no growth), $X = k \times (N^*)^{-1}$ represents a supply of cull cows and demand for replacements. That is, at equilibrium, no net investment is taking place, gross investment covers only the depreciation on the stable stock of capital (the cow herd).

Heifers available to enter the cow herd, Q, also have a distribution of genetic desirability. For this reason, E(MVP) of heifers can be depicted as a downward sloping curve as with cows, however, age is constant (say 1-2 years) while quantity is variable.

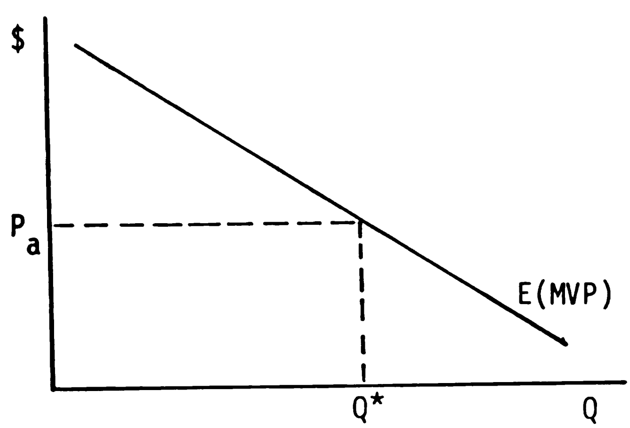

Figure 10. Expected marginal value product, E(MVP), of a heifer.

The E(MVP) here represents E(MVP) of a cow. But heifers have an opportunity cost as slaughter animals. This is represented by the dotted horizontal line P_a or acquisition price. P_a = E(MVP) indicates the supply of replacement heifers. This quantity is denoted as Q^*. By necessity, $Q^* \leq Q$.

The above formulations consider P_a and P_s as constants. This is the situation for a farmer in competitive equilibrium. In the aggregate, however, the price is jointly determined with quantity.

These E(MVP) curves become the demand curve for stock of cows and supply curve for replacement heifers, respectively. These curves are considered further in the next section.

The above discussion develops the E(MVP) formulation and determines that it is a downward sloping function as well. In the case of a stock of (fixed genetic desirability) cows, this downward slope can be attributed to the aging or physical deterioration process. In the case of a stock of heifers (fixed age), a downward slope can be attributed to a distribution of genetic desirability.

Given these downward sloping functions, an optimum stock can be determined, given P_a and P_s as shown in Figures 9 and 10. A shift in P_a of P_s or a shift in the E(MVP) curve would indicate a new optimum stock. The adjustment process is indicated by equation (17). This adjustment is carried out by acquisitions and dispositions as noted in equation (18).

The E(MVP) function is really a distribution function as previously noted. Thus Q^* or N^* are not known with certainty. Rather, Q^* (and N^*) represent a range with an upper bound and lower bound. These might be interpreted in terms of Q_a^* and Q_s^* where the subscripts "a" and "s" have the usual meaning. If this interpretation of Q^* is used, then a small change in P_a (or P_s) or any of the E(MVP) shifters, might not dictate a change in optimum stock. Three situations might be noted:

- add to stock if $Q^* > Q_a^*$
- decrease stock if $Q^* < Q_s^*$
- maintain stock if $Q^* < Q^* < Q$.

Competing Demands and Complementary Inputs

At any one time stocks of cows, heifers, bulls, and calves are fixed. This is certainly the case when the time period under consideration is short. Facing this fixed supply are competing demands--the market price is that price that will simultaneously satisfy all demands given supply.

This situation is demonstrated in Figure 11 for the competing demands of heifers for replacement and the demand for heifers for slaughter. This situation occurs also in the case of the demand for slaughter calves and the demand for calves for further feeding.

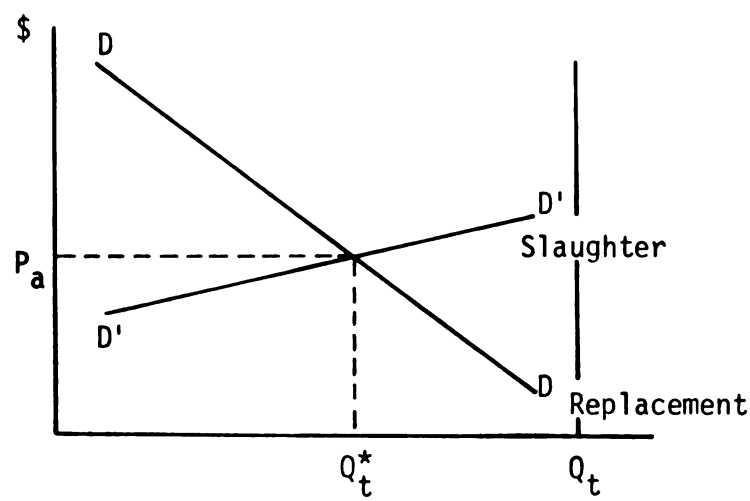

Figure 11. Price determination given competing demands and fixed supply.

Thus, the determination of optimum rate of flow (or stock) must simultaneously consider competing demands given a fixed initial stock.

From a stock of eligible heifers, Q, only Q_t^* will have $E(MVP) > P_a$.

If the sub-sector is in equilibrium then--

$k \times (N^*)^{-1}$ is the demand for replacement heifers

Q^* is the supply of replacement heifers

and

$Q^* = k \times (N^*)^{-1}$ conditional on P_a, P_s such that this identity holds true.

Also, $(N^*)^{-1}$ would be the average replacement rate and herd size would be an excellent indication of cows culled and heifers needed for replacement. But the industry is not in equilibrium as evidenced by the cattle cycle. The E(MVP) curve shifts as does the demand for cattle for slaughter. Thus the P_a, P_s, and elements in E(MVP) are indicators of the elements to include in the relevant supply and demand equations.

A second supply/demand situation might exist where the demand relative to the stock is so small that the supply is essentially completely elastic. This instance might apply to the demand and supply of bulls. For all eligible male calves, an E(MVP) might be drawn that is downward sloping to the right, as is the case with heifers (as depicted in Figure 10).

For all practical purposes, that portion of the E(MVP) curve lying above P_a represents the demand for herd sires with supply being

unlimited at $P = P_a$. Thus, the demand for herd sires does not effectively influence price; however, price is exogenous to the demand for bulls.[1]

A second phenomena germane to the cattle herd model is the concept of grain (wheat and feed grain, oilseeds) as complementary to the breeding herd in the production of slaughter cattle and as a product competitive with slaughter cattle for land, labor, and capital. The relevant equations from the simultaneous model expressing these two relationships are (1), (4), (5), (13), and (14).

Since both grain and slaughter cattle are final products (with respect to the farm firm) and since both may utilize the same land, labor, and capital, an exogenous rise in the price of grain will raise the MVP of resources employed in grain production. Land, labor, and capital would be expected to shift toward the production of grains and away from cattle production.

This same exogenous rise in the price of grain will raise the cost of slaughter cattle since they utilize grain as an input. The MVP of other inputs, especially stock calves, will be reduced. The MVP of the breeding herd is reduced in like manner. In addition, the costs of land, labor, and capital to all phases of cattle production rises

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[1]Commercial beef bulls sell at a small premium over the price of slaughter steers of comparable weight and age. This premium appears to just compensate the vendor for the additional effect required to market this male animal in the fashion. A few beef bulls earn a noted economic rent due to their unique breeding or intense marketing effect on the part of the vendor. On a national average, these beef bulls are the exception.

because of their opportunity cost in grain production. Through the processes described above, the MVP of a brood cow is reduced still further.

The extent and rate at which resources move out of cattle production and into grain production is a function of their MPP, as well as relative prices. In addition, their degree of "fixity" in the production of grain and livestock is a second consideration. A third consideration is the degree of perception and rate of response of the micro units.

A growing specialization would be expected to fix resources in the production of the product utilizing the specialized inputs.[1] On the other hand, it would be expected that the superior management of larger, more specialized firms would be more cognizant of and responsive to changes in relative prices, as well as being more sophisticated in the formation of expectations.

Since both grain and cattle producers have been rather unaffected by technological innovation, and since the ratio of land to labor or capital remains high, it is expected that resources are rather rapidly switched between livestock (including cattle) and grain production. This rapid reallocation might be expected to lead to unstable supplies of both cattle and grain.

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[1]This fixation is due to the higher proportion of fixed costs, more specialized units and the lower opportunity costs of those resources. Specialized units would be expected to continue to produce even though prices had dropped rather markedly, while smaller, less specialized firms had switched to other products.

Feedback and the Cattle Cycle

The cattle cycle, if one exists, is an example of the well documented cobweb model initially demonstrated with the hog cycle.[1] The cobweb phenomena is the result of three basic considerations. The first consideration is that of imperfect knowledge with respect to future demand, supply, and thus prices. Consequently, incorrect (in retrospect) production and investment decisions are made. The second consideration concerns the biological production lag between the decision to increase or decrease production and the realization of that increase or decrease. The third consideration, in the case of beef, is that the decision to increase or decrease production through change in the size of the breeding herd, leads to immediate changes in the supply that accentuate the observed price movement. A fourth consideration, not developed by the classic cobweb model, is that of shifting supply and demand functions. These shifters are often largely exogenous to the economy being modeled.[2]

The price mechanism can be, and is, influenced by factors apparently exogenous to the cattle-beef economy. Two examples are weather and government policy.[3] These influences can disrupt the smoothly functioning cobweb phenomena. In the instance of government

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[1]Talpaz, op. cit.

[2]The model developed in this dissertation does consider shifting supply and demand curves and because of this, cannot be considered as an adaptation of the cobweb model.

[3]Changes in weather conditions or government policy anywhere in the world may influence domestic demand through the international trade sector.

policy, the intent may be to smooth out this traditional cycle. Ill timed or improperly implemented policy may augment the cycle worsening an already unstable resource allocation situation.

Major changes in input prices and opportunity costs for resources employed in cattle (and grain) production are specific exogenous variables that will disrupt the cattle cycle, and must therefore be given consideration when anticipating future supplies. These impacts may be felt in equations (1), (2), (3), (4), (5), (13), and (14), of the simplified simultaneous equation model presented above.[1]

Restatement of the Hypothesized Model

The simplified simultaneous equation model may be used in still another manner to restate what is and what is not to be included in this Cattle Herd simulator.

Equation (1) is simulated. This equation will be expanded to include Slaughter Steers and Heifers, for Beef and Dairy breeds, for both Eastern and Western Canada. In addition, Male and Female Calves will be estimated, once again for both East and West. Future development will include the economic impacts producing short term changes in Slaughter Cattle supply and slaughter weight.

Equations (4) and (5), as well as identity (6), are modeled. They are, once again, subdivided into Male and Female, Beef and Dairy, East and West. The formulation and parameter estimation of these equations make up the bulk of the next chapter.

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[1]Government policy in Canada normally works through the price system. A stabilization (control) mechanism would typically operate through the variables explicitly recognized.

Equations (7), (8), (9), and (10), are not included, nor are equations (11) and (12). These elements of the simultaneous equation model are being developed in a complementary study being conducted at the University of Guelph, for the Economics Branch.

Equations (13) and (14) are not developed. These endogenous variables are treated as enogenous to this simulation model. The economics Branch currently have models of this sub-sector; however, there are no plans to coordinate them with this study.

Equations (2) and (3) are not being developed in the simulation model at this time; however, it is planned that they be developed for one or more of the planned applications. Specific attention must be given to the economic aspects of changes in slaughter weight. Carcass cut out percentage must also be considered.

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CHAPTER III

THE BEHAVIORAL MODELS

In the previous chapter, it was shown that the change in the size of the breeding herd depended on the relative rate of investment and disinvestment. These rates, in turn, are the result of reactions by farm operators adjusting to realized or anticipated conditions in a competitive environment.

In addition, it was shown that realized or anticipated conditions have a distinct bearing on whether or not the progeny of this herd were fed out to maturity or slaughtered at a younger age and lower weight.[1]

The theoretical behavioral relationships developed in Chapter II are used to develop specific predictive equations for application in the cattle herd simulator. These predictive equations are used to simulate cyclical motion and long term trends; they fall into three basic categories:

1. investment in the breeding herd (by replacement cattle)
2. disinvestment in the breeding herd (by culling)
3. calf slaughter.

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[1]A third possibility exists in the form of interregional trade when relative conditions among regions change. These flows are worthy of consideration; however, as previously explained, they are taken as exogenous in this study.

These equations are both predictive and behavioral. Since price and quantity are determined simultaneously, in this instance, and since only quantity (or flow rate) is required, an econometric model (or models) is/are developed to remove "own price" and thus avoid the need for simultaneous equations. This econometric model is described in the next section.

The econometric model requires that both supply and demand equations be hypothesized. The second section of this chapter lays out these supply and demand models, and in addition, specifies the equations that are to be estimated. The theory developed in Chapter II is used to indicate the structure of these supply and demand models and to suggest the types of variables that should logically be included. The outcome of this chapter is a set of predictive equations developed from these behavioral relationships.[1]

These econometric models raise a problem in that the current statistical data series are not complete enough to provide the necessary time series for the endogenous variables. The third and fourth sections, therefore, lay out a set of identities, a method, and a computer program (RECON) that generates the required endogenous data series from and constrained by existing data series.

The fifth and final section displays the estimated behavioral model parameters and relevant statistics. This last section comments on the reasonableness of these estimators and provides ex post

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[1]No attempt is made to retain any structural nature that exists in the supply/demand relationship or to infer back to them from the fitted reduced forms.

explanations. Finally the estimated endogenous data series are listed in tabular form.

The Econometric Model

In static equilibrium[1] for one commodity in a competitive equilibrium, the Walrasian supply-demand model can be given as:

$$\frac{dP}{dt} = \phi\ [D(P) - S(P)] = \phi\ [E(P)] \tag{29}$$

This formulation was expanded to "n" commodities by Hicks. But the Marshallian stability conditions could be used as a starting point in like manner.[2] This Marshallian formulation would be

$$\frac{dQ}{dt} = \phi\ [D(Q) - S(Q)] = \phi\ [E(Q)] \tag{30}$$

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[1]The argument in this section follow closely that of B. T. McCallum, "Competitive Price Adjustments: An Empirical Study," American Economic Review 44:56-65, March 1974.

[2]The following quote is taken from M. Blaug, Economic Theory in Retrospect, Homewood, Ill., Richard D. Irwin, Inc., 1968, p. 414. "But the Walrasian excess demand treatment which is usually implied in modern text book treatments is no more plausible than the Marshallian excess demand-price treatment." The context of the above quotation indicates that this is true if both price and quantity can vary. In the instances under consideration, the flows do in no way deplete the whole stock even though the stock is fixed for a given period. An example: in time period "t," heifers 1-2 years of age is fixed. The flow, or Q^*, being added to the cow herd as replacements, can be varied by altering the flow, Q', being fed for slaughter.

where

D(Q) = demand price;

D(S) = supply price;

ϕ = an excess price function.

This model can also be presented in graphic terms. The traditional excess demand model is shown in Figure 12(b) as taken from the supply-demand model of Figure 12(a).

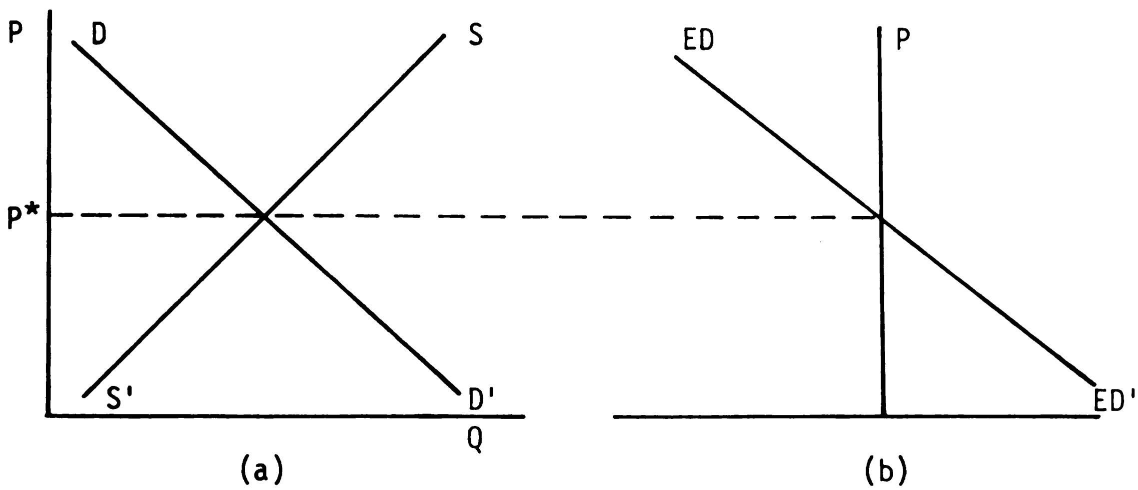

Figure 12. The excess demand model

The axis of these models can be reversed to produce an excess price model. The relationship between P and Q is still negative. These relationships are shown in Figures 13(a) and 13(b).

In Figures 12 and 13, P and Q are in equilibrium at P^* and Q^*; excess price is zero. At a quantity lower than Q^*, say Q^{**}, the demand price is $D(Q^{**})$ and the supply price is $S(Q^{**})$. Since $D(Q^{**}) > S(Q^{**})$, excess price exists equal to $P^{**}-P^*$. To restore equilibrium $\frac{dQ}{dP}$ must be negative as indicated by general equilibrium theory.

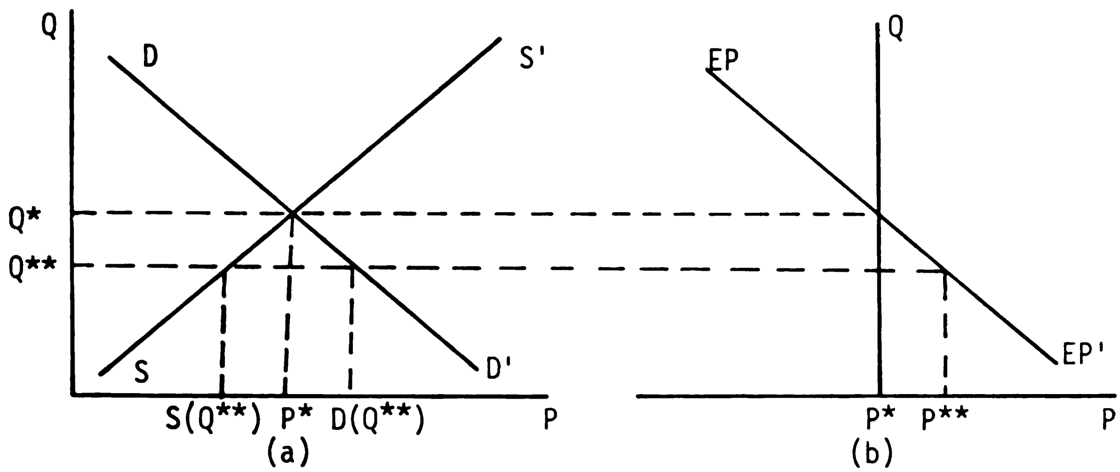

Figure 13. The excess price model

Thus

$$\frac{dQ}{dt} = \phi \text{ [demand price - supply price]}$$

or

$$\frac{dQ}{dt} = \phi \,[D(Q) - S(Q)] = \phi \,[E(Q)]$$

as given in equation (30) above.

Assuming a linear function, ϕ, this differential equation can be specified in discrete difference equation form. Transformation suggests three different models.

(31) $$Q_t - Q_{t-1} = kE_t + e_t$$

or

(32) $$Q_t - Q_{t-1} = kE_{t-1} + e_{t-1}$$

or a linear combination

(33) $$Q_t - Q_{t-1} = \lambda k E_t + (1-\lambda)kE_{t-1} + e'_t \qquad 0 < k \leq 1$$

A fourth modification might be suggested by a distributed lag formulation[1] where the adjustment takes place over several periods rather than within one period.

(34) $$Q_t - Q_{t-1} = k(1-\lambda)E_t + \lambda(Q_t - Q_{t-1}) + \eta_t$$

where[2]

$$\eta_t = e_t - \lambda\, e_{t-1}$$

The excess price function requires both supply and demand functions. These may be specified as:

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[1]This distribution lag uses the familiar geometric lag model. A partial adjustment rationalization is suggested by the theoretical model previously presented. The argument is as follows: given a set of relative prices and other pertinent exogenous variables, call these X_{t-1}, an optimum rate of flow (or stock) is suggested, call this level Y^*_t. A linear relationship could be specified as

$$Y^*_t = \alpha + \beta X_{t-1} + e_{t-1}$$

The relationship between X^*_t, which is not observable, and Y_t could be specified as

$$Y_t - Y_{t-1} = \gamma(Y^*_t - Y_{t-1}) \qquad 0 < \gamma \leq 1$$

That is, the actual adjustment is only part of the desired adjustment in the period between t and t-1. Substitution and the application of a Koyck transformation generates model specification (34) below.

$$D(Q) = \alpha_0 + \alpha_1 Q_t + \alpha D_t + \eta_t$$

$$S(Q) = \beta_0 + \beta_1 Q_t + \beta_2 S_t + \eta_t'.$$

Utilizing these functions the excess price function may now be specified as:

$$(35) \qquad E_t = (\alpha_0 - \beta_0) + (\alpha_1 - \beta_1)Q_t + \alpha_2 D_t - \beta_2 S_t + e_t.^{1}$$

where

S_t = the supply shifters;

D_t = the demand shifters;

$\eta_t \sim N(0, \sigma^2)$;

$\eta_t' \sim N(0, \sigma^2)$;

e_t = a linear combination of η_t and η_t, is $N(0, \sigma^2)$.

The final form of the econometric models is obtained by substituting (35) into equations (31) to (34). Substituting (35) into (31)

$$Q_t - Q_{t-1} = k(\alpha_0 - \beta_0) + k(\alpha_1 - \beta_1)Q_t + k\alpha_3 S - k\beta_3 D + e_t.$$

$$(36) \qquad Q_t = \pi_1 + \pi_2 Q_{t-1} + \pi_3 S_t + \pi_4 D_t + e_t.$$

---

[1]The excess price function, as specified, reverses the sign of the regression coefficients associated with the exogenous and lagged endogenous variables of the supply function.

and (35) into (32)

$$Q_t - Q_{t-1} = k(\alpha_0 - \beta_0) + k(\alpha_1 - \beta_1)Q_{t-1} + k\alpha_3 S_{t-1} - k\beta_3 D_{t-1} + e_t.$$

(37) $$Q_t = \pi_1 + \pi_2 Q_{t-1} + \pi_3 S_{t-1} + \pi_4 D_{t-1} + e_t.$$

and (35) into (33)

$$Q_t - Q_{t-1} = k\theta(\alpha_0 - \beta_0) + K\theta Q_t + K\theta\alpha_3 S_t - k\theta\beta_3 D_t + (1-\theta)k\theta(\alpha_0 - \beta_0)$$

$$+ (1-\theta)kQ_{t-1} + (1-\theta)k\theta S_{t-1} - (1-\theta)k\theta D_{t-1} + e_t.$$

(38) $$Q_t = \pi_1 + \pi_2 Q_{t-1} + \pi_3 S_t + \pi_4 S_{t-1} + \pi_5 D_t + \pi_5 D_{t-1} + e_t.$$

and finally (35) into (34)

$$Q_t - Q_{t-1} = (1-\lambda)k(\alpha_0 - \beta_0) + (1-\lambda)kQ_t + (1-\lambda)k\alpha_3 S_t - (1-\lambda)k\beta_3 D_t - \lambda Q_{t-2} + e_t.$$

(39) $$Q_t = \pi_1 + \pi_2 Q_{t-1} + \pi_3 Q_{t-2} + \pi_4 S_t + \pi_5 D_t + e_t.$$

Behavioral Model Development

The economic theory presented in Chapter II (pages 59-80) is combined with the econometric models suggested in the previous section of this chapter to provide the required prediction behavioral models. These behavioral models are developed in this section and subsequently fitted to the data to provide the parameter estimates presented in the final section of this chapter.[1]

The behavioral models required for the Cattle Herd simulator fall into three general categories:[2]

1. investment in the Breeding Herd (REPLACEMENTS)
2. disinvestment in the Breeding Herd (CULLS), and
3. Calf SLAUGHTER.

These behavioral models are required for both Eastern and Western Canada. The investment/disinvestment models are required for Beef Cattle as well as Dairy Cattle. In addition, SLAUGHTER models are required for Calves on an East/West, Male/Female basis. In total, 16 behavioral models or estimating equations are developed and fitted to the data.

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[1]The author wishes to acknowledge helpful consultation with G. MacAuley, who was concurrently developing somewhat similar models for his Ph.D. dissertation at the University of Guelph. His dissertation is cited elsewhere in this dissertation. Also, specifically consulted were T. C. Kerr, Determinants of Regional Livestock Supply, Agricultural Economics Research Council of Canada, Publication No. 15, Ottawa, 1968; and Kulshreshtha et al., *op. cit*.

[2]The stock and flow notational convention is resumed at this point in the dissertation. This notational convention is given in Table 2, pp. 50-51.

The various econometric models developed in the previous section are not considered as alternate hypotheses, although they lend themselves readily to that purpose. They are considered, rather, as alternate possible forms that will be examined to obtain accurate estimates of, or predictors for, the endogenous variables required in the Cattle Herd simulation.

In order to utilize the econometric models previously developed, both supply and demand functions must be hypothesized for each estimating equation. These in turn are used to develop excess price models. As previously implied, the development of the supply and demand models draws on the economic theory, sub-sector description, and statistical data description presented in Chapter II.

The supply and demand equations fall into two general categories: (a) those that are derived from the E(MVP) or production function formulation, and (b) those derived from the traditional final demand formulation.

Because of the similarity in the basic argument, use of the same or similar data and the similarity in algebraic manipulation, all demand/supply and excess price functions will not be developed in detail. In addition, the excess price model will not be fitted for each of the four variations on the basic excess price model as given in equations (31) to (34).

Cow SLAUGHTER

Four separate Cow SLAUGHTER equations are required for the Cattle Herd simulator. They are:

- Dairy Cow SLAUGHTER, East;
- Dairy Cow SLAUGHTER, West;
- Beef Cow SLAUGHTER, East; and
- Beef Cow SLAUGHTER, West.

Because of the similarity of these equations, only one will be developed in detail; the other three will be taken as variations on this equation.

SLAUGHTER Cows are supplied by farmers and ranchers. These are Cows that are surplus to the Herd because their expected productivity has become very low relative to their salvage price.[1] As previously mentioned, culling takes place during both expansion and contraction of the herd--only the rate changes.

If the Cow Herd is in a steady state, then a fixed proportion would be culled annually due to physical deterioration. In this rather hypothetical instance, Herd size would be an excellent indicator of the CULLING Rate (number CULLED per unit time).

The production function or E(MVP) formulation, equation (27), indicates the basic variables or type of variables that should be included in a supply function for Slaughter Cows. The first variables

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[1]As previously stated no price expectation models are specifically employed to generate expected prices. All prices used in the behavioral models are current or lagged. Specific lags are stated below.

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are those associated with revenue, namely, milk and veal calf prices. One index of milk price is the price of manufacturing milk for all purposes plus the government net subsidy on such milk. It is expected to have a negative sign. Since this subsidy was introduced during the 1958-1972 period, a dummy variable is indicated to express years of subsidy.[1] This variable is intended to reflect the economic impacts of the psychological effects of the subsidy and the expectations associated with federal government involvement in manufactured milk policy and pricing. A positive sign might be expected. In addition, a quota system was subsequently introduced with penalties applied for production in excess of quota. The years of over quota penalty are recognized with a second dummy variable. A negative coefficient is expected. The value of the calf is recognized by the inclusion of the price of veal calves giving a positive coefficient.

A second major element in the calculation of E(MVP) is the cost of inputs. Three major elements are identified: feed, labor, and cost of capital. All are expected to positively affect the CULLING Rate. The feed cost used is the offboard price of barley. This is the local price at grain elevators for non-Canadian Wheat Board sales.[2] The labor proxy used was the monthly salary of farm labor without board.

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[1]The subsidy coincides with the establishment of the Canadian Dairy Commission. This commission is a federal agency which monitors the sub-sector, makes policy recommendations and implements programs aimed at improving the well-being of the manufactured milk industry.

[2]International and interprovincial sales of prairie grains, including barley, are a monopoly of the Canadian Wheat Board. Within each province, grains, including barley, trade on a competitive basis. It is felt that this offboard price reflects the within-province competitive price.

A third element in the E(MVP) formulation is the salvage value of the cull cow. An increase in cull cow price increases E(MVP), thus a negative sign would be expected. However, cull cow price is also P_s. As P_s rises, more cows could be culled, thus a positive sign would be expected. Consequently, the a priori sign associated with this variable is indeterminate. The price of cull cows is represented by the price of canner and cutter cows.

A fourth and final element in the E(MVP) formulation is the opportunity cost of resources. While this variable can be estimated by the interest rate, a more direct proxy is the price of competitive products. For this purpose, the price of barley and the price of hogs provide one index. The coefficient associated with hogs is expected to be negative, while the coefficient associated with barley is expected to be positive. In the West, due to the actions of the Canadian Wheat Board, the back-up of grains in storage on farms is thought to be a good index of the opportunity cost of resources in grain production.

Over the period 1958-1972 there have been considerable technological advances in dairying as well as increased incidence of adoption. These changes fall into the general areas of feeding, breeding, housing, and equipment. It might be expected that husbandry and business management, as well, have improved. These changes have resulted in increased milk yield per cow. One proxy for the net effect of technological changes is milk yield per cow; a second might simply be a time variable.

The demand for Cull Cows is a demand derived from the demand for beef, especially low grade beef. It would be expected that demand will vary inversely with own price and directly with the price of substitutes and income. The own price is again taken as the price for canner and cutter cows. The price of choice slaughter steers and index 100 hogs are taken as substitutes. Aggregate national income deflated by the consumer price index is taken as the income variable.

The supply and demand functions for Cull Dairy Cows are laid out below and manipulated to produce excess price functions as given by equation (35). The excess price function in turn is substituted into the first of the four econometric models represented by equations (31), (32), (33), and (34).

The supply function for Cull Dairy Cows is:[1]

$$(40) \qquad C^{c} = b_0' + b_1 P^{c+c} + b_2' POP^{c} - b_3' P^{m} - b_4' N + b_5' L - b_6' P^{v} + b_7' P^{b} + b_8' I$$

$$+ b_9' W + b_{10}' M + b_{11}' I.$$

This function is manipulated into the form required for the excess price functions as follows:

$$(41) \qquad P^{c+c} = b_0 + b_1 C^{c} + b_2 POP^{c} - b_3 P^{m} - b_4 N + b_5 L - b_6 P^{v} + b_7 P^{b} + b_8 I$$

$$+ b_9 W + b_{10} M + b_{11} T.$$

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[1]For a description of the variables used in these equations, refer to Table 3.

Table 3. **Notation for and description of behavioral model variables**

Variable name	Symbol[a]	Source and description
Cow SLAUGHTER (CULLS) Bull SLAUGHTER (CULLS) REPLACEMENTS, Heifers REPLACEMENTS, Bulls Calf SLAUGHTER Heifer SLAUGHTER Steer SLAUGHTER	C^c C^b R^h R^b S^v S^h S^s	Revised output of program MATRIX, expressed in head.
Cow Population Bull Population Heifer Population Steer Population	POP^c POP^b POP^h POP^s	Source: Report of Livestock Survey's Cattle, Sheep Horses. Expressed in head. January 1 value--published December 1 statistics. July 1 value--published June 1 statistics. April 1 and October 1 value--average of December 1 and June 1 published statistics.
Price of choice slaughter steers Price of good heifers Price of canner and cutter cows Price of good stock steer calves Price of good veal calves	P^s P^h P^{c+c} P^{cv} P^v	Source: Quarterly Bulletin of Agricultural Statistics. Expressed in dollars per pound. Toronto and Calgary prices used except for veal where Edmonton replaced Calgary prices, expressed in dollars per pound.
Price of index 100 hogs	P^{hg}	Source: Quarterly Bulletin of Agricultural Statistics. Expressed in dollars per pound. Toronto and Calgary prices used. Grade A hog prices converted to index 100 by: index 100 = 0.971429 x grade A.
Price of barley (off board)	P^b	Source: Economics Branch, Agriculture Canada. Expressed in dollars per bushel.
On farm grain stocks (March 31)	K	Source: Quarterly Bulletin of Agricultural Statistics. Expressed in millions of tons. The March 31 value is used for the first quarter and the last three quarters of the previous year.
Price of manufactured milk for all purposes plus subsidy	P^m	Source: Dairy Review. Expressed in dollars per hundred weight.
Years of milk subsidy	N	A zero/one variable. Value of 1 for the second quarter of 1962 forward.
Years of over quota penalty	L	A zero/one variable. Value of 1 for the second quarter of 1967 forward.
Interest Rate	I	Source: Bank of Canada, Annual Statistics Review. Expressed in two places of decimal.
Farm wages (without board)	W	Source: Quarterly Bulletin of Agricultural Statistics. Expressed in dollars per month. In all cases the value for the fourth quarter is a repetition of the third quarter value.
Milk yield per cow	M	Source: Dairy Review and Report of Livestock Survey's Cattle, Sheep, Horses. Calculated in hundred weight per annum by the formula: $\frac{\text{total milk production}}{\text{average dairy cow population}}$ The one annual figure was replicated for the four quarters.
Aggregate real income	Y	Source: Prices and Price Indices and National Accounts. Income and expenditures by quarters, expressed in millions of dollars at annual rates.
Time	T	First quarter 1948 = 0.

[a]The following superscripts modify the variable symbols: E = Eastern Canada; W = Western Canada; B = Beef Cattle and D = Dairy Cattle.

The demand function is stated and manipulated in equations (42) and (43).

(42) $$C^c = a_0' - a_1'P^{c+c} + a_2'P^s + a_3'P^{hg} + a_4'Y.$$

(43) $$P_t^{c+c} = a_0 - a_1C^c + a_2P^s + a_3P^{hg} + a_4Y.$$

Equation (44) is obtained by substituting equations (42) and (43) into the excess price function, equation (35).

(44) $$E_t = (a_0-b_0) - (a_1+b_1)C^c + a_2P^s + a_3P^{hg} + a_4Y - b_2POP^c + b_3P^m$$
$$+ b_4N - b_5L + b_6P^v - b_7P^b - b_8I - b_9W - b_{10}M - b_{11}T.$$

This excess price function is then substituted into the first of the econometric models, equation (31), where C_t^c is now substituted for Q_t^c in that equation.

$$C_t^c - C_{t-1}^c = k(a_0-b_0) - k(a_1+b_1)C_t^c + k(a_2P^s \,,\ldots,\, b_{11}T).$$

$$C_t^c + k(a_1+b_1)C_t^c = k(a_0-b_0) + C_{t-1}^c + k(a_2P^s \,,\ldots,\, b_{11}T).$$

(45) $$C_t^c = \frac{k(a_0-b_0)}{(1+ka_1+kb_1)} + \frac{1}{(1+ka_1+kb_1)}C_{t-1}^c + \frac{k}{(1+ka_1+kb_1)}$$
$$(a_2P^s \,,\ldots,\, b_{11}T).$$

The estimating equation for the Eastern Dairy Cow SLAUGHTER becomes, in reduced form:[1]

$$(46) \qquad C_t^{cDE} = \pi_0+\pi_1 C_{t-1}^{cDE} - \pi_2 POP_t^{cDE} + \pi_3 P_t^{sE} + \pi_4 P_t^{hgE} + \pi_5 P_t^{mE} + \pi_6 N_t - \pi_7 L_t^E$$

$$+ \pi_8 P_t^{vE} - \pi_9 P_t^{bE} - \pi_{10} I_t^E - \pi_{11} W_t^E + \pi_{12} Y_t^E - \pi_{13} M_t^E - \pi_{14} T_t.$$

To obtain the Western Dairy Cow SLAUGHTER equation, grain stocks are added as an opportunity cost of dairying.

$$(47) \qquad C_t^{cDW} = \pi_0+\pi_1 C_{t-1}^{cDW} - \pi_2 POP_t^{cDW} + \pi_3 P_t^{sE} + \pi_4 P_t^{hgW} + \pi_5 P_t^{mW} + \pi_6 N_t - \pi_7 L_t$$

$$+ \pi_8 P_t^{v} - \pi_9 P_t^{bW} + \pi_{10} K_t - \pi_{11} I_t^W - \pi_{12} W_t^W + \pi_{13} Y_t^W - \pi_{14} M_t^W - \pi_{15} T.$$

To obtain the Eastern Beef Cow SLAUGHTER equation, the price of veal calves is replaced by the price of good stock steer calves while those variables related to milk are dropped.

$$(48) \qquad C_t^{cBE} = \pi_0 + \pi_1 C_{t-1}^{cBE} - \pi_2 POP_t^{cBE} + \pi_3 P_t^{sE} + \pi_4 P_t^{cE} + \pi_5 P_t^{hgE} - \pi_6 P_t^{bE}$$

$$- \pi_7 I_t^E - \pi_8 W_t^E + \pi_9 Y_t^E - \pi_{10} T.$$

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[1]The additions to the superscripts refer to Dairy (D), Beef (B), East (E), and West (W), as indicated in Table 3.

Finally, to obtain the estimating equation for Western Beef Cow SLAUGHTER, farm stocks of grain are added.

$$(49)\qquad C_t^{cBW} = \pi_0 + \pi_1 C_{t-1}^{cBW} - \pi_2 POP_t^{cBW} + \pi_3 P_t^{sW} + \pi_4 P_t^{cW} + \pi_5 P_t^{hgW} - \pi_6 P_t^{bW}$$

$$+ \pi_7 K_t^W - \pi_8 I_t^W - \pi_9 W_t^W - \pi_{10} Y_t^W - \pi_{11} T.$$

REPLACEMENTS, Heifers

As with Cow SLAUGHTER, four estimating equations are required:

- REPLACEMENTS, Dairy Heifers, East;
- REPLACEMENTS, Dairy Heifers, West;
- REPLACEMENTS, Beef Heifers, East; and
- REPLACEMENTS, Beef Heifers, West.

At any one time, the supply of Heifers available for REPLACEMENT is fixed. Two separate demands face this fixed supply; namely, demand for REPLACEMENT and demand for SLAUGHTER.

The supply/demand model for REPLACEMENT Heifers is then:

$$D^{\text{replacements}} = f(\text{Price, MVP})$$

$$D^{\text{slaughter}} = f(\text{Price, Price}^{\text{compet. prod.}}\text{, Income})$$

$$S = D^{\text{replacements}} + D^{\text{slaughter}}$$

If at a steady state, the Herd would require a fixed REPLACEMENT Rate. Thus, size of Cow Herd is a good indicator of the required flow of Replacement Heifers.

The demand for Dairy REPLACEMENTS is expected to vary directly with milk price, directly with the years of milk price subsidy and inversely with the years of over quota penalty. In the case of Beef Cows, the demand for REPLACEMENTS will vary directly with calf and slaughter cattle prices. The salvage price of cull cows, canner and cutter cow price, is expected to have a positive effect on REPLACEMENT Rate.

Labor cost, feed cost and interest costs are expected to have a negative affect on REPLACEMENT Rate, as would the indicators of technological progress.

The price of replacement heifers is expected to have a negative effect on REPLACEMENT Rate.

The demand for Slaughter Heifers is expected to vary indirectly with own price and directly with the price of good substitutes such as choice slaughter steers, veal calves, canner and cutter cows, and index 100 hogs. The demand for Slaughter Heifers is also expected to vary with real aggregate income.

The REPLACEMENT demand function is:

$$(50) \qquad R^h = b_0' - b_1'P^h + b_2'POP^c + b_3'P^m + b_4'N - b_5'L + b_6'P^v + b_7'P^{cv} + b_8'P^s$$

$$+ b_9'P^{c+c} - b_{10}'P^b - b_{11}'W - b_{12}'I - b_{13}'M - b_{14}'T.$$

It is manipulated so that price appears on the left hand side.

$$(51)\qquad P^h = b_0 - b_1R^h + b_2POP^c + b_3P^m + b_4N - b_5L + b_6P^v + b_7P^{cv} + b_8P^s + b_9P^{c+c} - b_{10}P^b - b_{11}W - b_{12}I - b_{13}M - b_{14}T.$$

The SLAUGHTER demand function is:

$$(52)\qquad S^h = a_0' - a_1'P^h + a_2'P^v + a_3'P^s + a_4'P^{c+c} + a_5'P^{hg} + a_6'Y.$$

In equation (53), price is placed on the left hand side.

$$(53)\qquad P^h = a_0 - a_1P^h + a_2P^v + a_3P^s + a_4P^{c+c} + a_5P^{hg} + a_6Y.$$

The above two demands represented by equations (51) and (53) are constrained by total available Heifers.[1] The excess price function thus becomes the difference between the two demands.[2]

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[1]At any point in time the stock of Heifers available for either slaughter or replacement is fixed at level POP^h_t.

[2]The excess price formulation being used is $E_t = \phi$ (Price Replacements - Price Slaughter). If the values in the brackets are reversed, then the excess price function is $E_t = \phi$ (Price Slaughter - Price Replacement). The use of the latter has the impact of reversing all the signs in the excess price function.

The former was used as it was felt that demand for replacements "dominated" SLAUGHTER demand or SLAUGHTER demand was a residual. The use of the former, therefore, retained the signs associated with the "dominant" REPLACEMENT demand. This decision can be viewed as a hypothesis--the predominancy of "correct" or "incorrect" signs on the parameter estimates will determine whether the decision was correct or incorrect.

$$E_t = (-a_0+b_0) + a_1S^h - b_1R^h - a_2P^v + b_6P^v + b_7P^{cv} - a_3P^s + b_8P^s - a_4P^{c+c}$$

$$+ b_9P^{c+c} - a_5P^{hg} - a_6Y + b_2POP^c + b_3P^m + b_4N - b_5L - b_{10}P^b - b_{11}W$$

$$- b_{12}I - b_{13}M - b_{14}T.$$

(54) $$E_t = (-a_0+b_0) + a_1S^h - b_1R^h - (a_2-b_6)P^v + b_7P^{cv} - (a_3-b_8)P^s$$

$$- (a_4-b_9)P^{c+c} - a_5P^{hg} - a_6Y + b_2POP^c + b_3P^m + b_4N - b_5L - b_{10}P^b$$

$$- b_{11}W - b_{12}I - b_{13}M - b_{14}T.$$

The constraint is imposed by $POP^h = S^h + R^h$ or $S^h = R^h - POP^h$.

$$E_t = (-a_0+b_0) + a_1(R^h-POP^h) - b_1R^h \;,\ldots,\; - b_{14}T.$$

(55) $$E_t = (-a_0+b_0) + (a_1-b_1)R^h - a_1POP^h - (a_2-b_2)P^v + b_7P^{cv} - (a_3-b_8)P^s$$

$$- (a_4-b_9)P^{c+c} - a_5P^{hg} - a_6Y + b_2POP^c + b_3P^m + b_4N - b_5L - b_{10}P^b$$

$$- b_{11}W - b_{12}I - b_{13}M - b_{14}T.$$

This excess price function is then substituted into equation (31), where $R_t^h = Q_t$.

$$(56)\qquad R_t^h - R_{t-1}^h = k(-a_0+b_0) + k(a_1-b_1)R^h + k(-a_1 POP^h \; , \ldots, - b_{14}T.$$

$$R_t^h - ka_1R^h + kb_1R^h = k(-a_0+b_0) + R_{t-1}^h + k(-a_1 POP^h \; , \ldots, - b_{14}T.$$

$$(57)\qquad R_t^h = \frac{k(-a_0+b_0)}{(1-ka_1+kb_1)} + \frac{1}{(1-ka_1+kb_1)} \; k_{t-1}^h + \frac{k}{(1-ka_1+kb_1)}$$

$$(-a_1 POP^h \; , \ldots, - b_{14}T).$$

The estimating equation for Eastern REPLACEMENTS, Dairy Heifers now becomes:

$$(58)\qquad R_t^{hDE} = \pi_0 + \pi_1 R_{t-1}^{hDE} - \pi_2 POP_t^{hDE} \mp \pi_3 P_t^{vE} \mp \pi_4 P_t^{sE} \mp \pi_5 P_t^{c+cE} \mp \pi_6 P_t^{hqE}$$

$$- \pi_7 Y_t^E + \pi_8 POP_t^{cDE} + \pi_9 P_t^{mE} + \pi_{10} N_t^E - \pi_{11} L_t - \pi_{12} P_t^{bE} - \pi_{13} W_t^E$$

$$- \pi_{14} I_t - \pi_{15} M_t^E - \pi_{16} T.$$

The estimating equation for Western REPLACEMENTS, Dairy Heifers is similar except that grain stocks are added as an opportunity cost for resources employed in dairying. In addition, good stock steer calf price replaces veal calf price.

$$(59) \qquad R_t^{hDW} = \pi_0 + \pi_1 R_{t-1}^{hDW} - \pi_2 POP_t^{hDW} + \pi_3 P_t^{cW} \pm \pi_4 P_t^{sW} \pm \pi_5 P_t^{c+cW} - \pi_6 P_t^{hgW}$$

$$- \pi_7 Y_t^W + \pi_8 POP_t^{cDW} + \pi_9 P_t^{mW} + \pi_{10} N_t^W - \pi_{11} L_t - \pi_{12} P_t^{BW} + \pi_{13} K_t$$

$$- \pi_{14} W_t^W - \pi_{15} I_t - \pi_{16} M_t^W - \pi_{17} T.$$

Eastern REPLACEMENTS, Beef Heifers are estimated with a similar equation except that those variables related to milk are dropped.

$$(60) \qquad R_t^{hBE} = \pi_0 + \pi_1 R_{t-1}^{hBE} - \pi_2 POP_t^{hBW} + \pi_3 P_t^{cE} \pm \pi_4 P_t^{sE} \mp \pi_5 P_t^{c+cE} - \pi_6 P_t^{hgE}$$

$$-\pi_7 Y_t^W + \pi_8 POP_t^{cBE} - \pi_9 P_t^{BE} - \pi_{10} W_t^E - \pi_{11} I_t - \pi_{17} T.$$

The Western REPLACEMENTS, Beef Heifer estimator includes the farm stock of grain as an index of on-farm opportunity cost of resources employed in grain production.

$$(61) \qquad R_t^{hBW} = \pi_0 + \pi_1 R_{t-1}^{hBE} - \pi_2 POP_t^{hBW} + \pi_3 P_t^{cW} \pm \pi_4 P_t^{sW} \pm \pi_5 P_t^{c+cW} - \pi_6 P_t^{hgW}$$

$$-\pi_7 Y_t^W + \pi_8 POP_t^{cBW} - \pi_9 P_t^{BW} + \pi_{10} K_t - \pi_{11} W_t^W - \pi_{12} I_t - \pi_{13} T.$$

Bull SLAUGHTER and REPLACEMENT

The demand for Bulls is derived from a technical requirement for the production of Cattle and thus, from the demand for Cows. This latter demand, in turn, is derived from the demand for beef and dairy products. It is expected that if the Cow Herd expands, then more Bulls will be required and vice versa.

If Bulls have a fixed useful life, then the demand for Replacement Bulls, as well as the supply of Cull Bulls, are indicated by the stock of Bulls, everything else being equal. Since the flow for both SLAUGHTER and REPLACEMENT are influenced by changes in the size of the Cow Herd, factors influencing that Herd would be expected to influence the Bull Herd, and in the same direction.

The demand for Replacement Bulls is expected to vary directly with the price of milk, directly with the price of stock calves, and inversely with the cost of barley, labor, and interest. In addition, it is expected that the increased use of artificial insemination and possibly more efficient use of existing bulls, could result in a negative time trend.

The demand for Slaughter Bulls is expected to be a competing demand with Replacement Bulls, both constrained by the supply of existing eligible Male Calves. However, only a small proportion of such Calves are required for Herd sires. In addition, the cost of maintaining a Herd sire is a relatively minor cost in the production of Calves, therefore, these cost factors are not considered.

The market for Slaughter Steers is not felt to be influenced by the demand for Replacement Bulls; however, the price of choice slaughter steers may represent an acquisition price for Bulls. In the context of the following model, the indicated sign would be negative. However, the price of slaughter steers should directly affect the price of the stock calves and positively influence the E(MVP) of cows. This latter positive influence is felt to be the stronger of the two.

The model that is proposed may be represented by Figure 10, of the last chapter, where the E(MVP) curve becomes the demand curve for Replacement Bulls, D-D'. The D-D' curve is derived from the demand for a Cow Herd and thus the E(MVP) of Cows. The supply curve is infinitely elastic at P_a = f(price of choice slaughter steers). Thus, the estimates for Cull and Replacement Bulls are based on derived demand.

The estimator for Eastern Bull REPLACEMENTS then becomes:

$$(62) \qquad R_t^{bE} = a_0 + a_1 R_{t-1}^{bE} + a_2 P_t^{sE} + a_3 POP_t^{cE} + a_4 P_t^{mE} + a_5 P_t^{cE} + a_6 P_t^{c+cE} + a_7 P_t^{hgE} - a_8 P_t^{bE} - a_9 W_t^E - a_{10} I_t^E - a_{11} T.$$

The estimator for Western Bull REPLACEMENTS is similar with the exception that grain stocks are added as an index of opportunity cost.

$$(63) \qquad R_t^{bW} = a_0 + a_1 R_t^{bE} + a_2 P_t^{sW} + a_3 POP_t^{cW} + a_4 P_t^{mW} + a_5 P_t^{cW} + a_6 P_t^{c+cE} + a_7 P_t^{hgW} - a_8 P_t^{bW} + a_9 K_t - a_{10} W_t^W - a_{11} I_t^W - a_{12} T.$$

The supply of Slaughter Bulls is once again thought to be mainly a function of the demand for a Cow Herd and beef in general. Thus, the demand for Bulls as a source of beef will not be considered.

The estimator for Eastern Bull SLAUGHTER then becomes:

$$(64) \qquad C_t^{bE} = a_0 + a_1 C_{t-1}^{bE} - a_2 P_t^{sE} - a_3 POP_t^{cE} - a_4 P_t^{mE} - a_5 P_t^{cE} - a_6 P_t^{c+cE}$$

$$- a_7 P_t^{hgE} + a_8 P_t^{bE} + a_9 W_t^E + a_{10} I_t^E + a_{11} T.$$

and for the Western Bull SLAUGHTER:

$$(65) \qquad C_t^{bW} = a_0 + a_1 C_{t-1}^{bE} - a_2 P_t^{sW} - a_3 POP_t^{cW} - a_4 P_t^{mW} - a_5 P_t^{cW} - a_6 P_t^{c+cW}$$

$$- a_7 P_t^{hgW} + a_8 P_t^{bW} - a_9 K_t + a_{10} W_t^W + a_{11} I_t^W + a_{12} T.$$

<u>Calf SLAUGHTER</u>

The Cattle Herd simulator requires four Calf SLAUGHTER estimating equations:

- Male Calf SLAUGHTER, East;
- Female Calf SLAUGHTER, East;
- Male Calf SLAUGHTER, West; and
- Female Calf SLAUGHTER, West.

At any point in time, the stock of Calves available for SLAUGHTER is fixed. There are two major demands facing the stock of Calves. The first of these is the demand for SLAUGHTER, the second is the demand for further feeding. The next chronological market for Calves, beyond the market for Slaughter Calves, is the market for Stock Calves. The demand for Stock Calves is a function of the cost and availability of feed and the expected price of slaughter cattle.

In Eastern Canada, most Slaughter Calves are a by-product of the dairy industry; thus, the Dairy Cow Herd is a good index of the supply of Dairy Calves; this is more or less true in the West also. Thus, the decision to sell Veal Calves is made in large part by dairymen.

The following factors might affect their decision. A rise in the price of milk would raise the opportunity cost of milk fed to Calves, thus, promoting sales of Calves at the earliest possible age, i.e., as light Vealers. A rise in the price of other inputs, such as barley, wages, and interest, would have the same effect. On the other hand, an increase in the price of stock calves would raise the opportunity cost of calves devoted to veal production, thus, promoting a negative relationship.

Because the two markets for Calves do not operate for the same Calves at the same time (about 3-4 months apart) and historically not for the same Calves (one is largely Dairy, the other Beef), the two demands were <u>not</u> treated as with Replacement Heifers. Another more practical reason also existed; official estimates of Male Dairy Calves are not available. For these two reasons, the traditional supply-demand model is used. The demand function is:

$$S^v = a_0' - a_1'P^v + a_2'P^s + a_3'P^{hg} + a_4'Y. \tag{66}$$

Equation (66) is manipulated to place price on the left hand side.

(67) $$P^v = a_0 - a_1S^v + a_2P^s + a_3P^{hg} + a_4Y.$$

The supply model is:

(68) $$S^v = b'_0 + b'_1P^v - b'_2P^c + b'_3POP^c - b'_4P^m + b'_5P^b + b'_6W + b'_7I - b'_8T.$$

Price is once again placed on the left hand side.

(69) $$P^v = b_0 + b_1S^v - b_2P^c + b_3POP^c - b_4P^m + b_5P^b + b_6W + b_7I - b_8T.$$

Functions (67) and (69) are now put in excess price model form.

(70) $$E_t = (a_0-b_0) - (a_1+b_1)S^v + b_2P^c - b_3POP^c + b_4P^m - b_5P^b - b_6W$$

$$-b_7I + b_8T + a_2P^s + a_3P^{hg} + a_4Y.$$

The excess price function is then substituted into the first statistical model, function (31), where $S^v_t = Q_t$.

$$S_t^v - S_{t-1}^v = k(a_0-b_0) - k(a_1+b_1)S_t^v + k(b_2P^c \;,\ldots,\; a_4Y).$$

$$S_t^v + k(a_1+b_1)S_t^v = k(a_0-b_0) + S_{t-1}^v + k(b_2P^c \;,\ldots,\; a_4Y).$$

$$S_t^v = \frac{k(a_0-b_0)}{(1+kb_1+ka_1)} + \frac{1}{(1+kb_1+ka_1)} S_{t-1}^v + \frac{k}{(1+kb_1+ka_1)}$$

$$(b_2P^c \;,\ldots,\; a_4Y).$$

The estimating function for Eastern Male Calf SLAUGHTER then becomes, in reduced form:

$$(71) \qquad S_t^{vmE} = \pi_0 + \pi_1 S_{t-1}^{vE} + \pi_2 P_t^{cE} - \pi_3 POP_t^{cDE} + \pi_4 P_t^{sE} + \pi_5 P_t^{hgE} + \pi_6 Y_t^E$$

$$+\pi_7 P_t^{mE} - \pi_8 P_t^{bE} - \pi_9 W_t^E - \pi_{10} I_t^E + \pi_{11} T.$$

The estimating equation for Eastern Female Calf SLAUGHTER is

$$(72) \qquad S_t^{vfE} = \pi_0 + \pi_1 S_{t-1}^{vE} + \pi_2 P_t^{cE} - \pi_3 POP_t^{cDE} + \pi_4 P_t^{sE} + \pi_5 P_t^{hgE} + \pi_6 Y_t^E$$

$$+\pi_7 P_t^{mE} - \pi_8 P_t^{bE} - \pi_9 W_t^E - \pi_{10} I_t + \pi_{11} T.$$

The stock of grain on farms is felt, once again, to be a good indicator of opportunity costs and is included in the Western model for both Male and Female.

Table 4. Coefficient signs implied by the theoretical models[a]

	Dairy Cow SLAUGHTER, East	Dairy Cow SLAUGHTER, West	Beef Cow SLAUGHTER, East	Beef Cow SLAUGHTER, West	REPLACEMENTS, Dairy Heifers, East	REPLACEMENTS, Dairy Heifers, West	REPLACEMENTS, Beef Heifers, East	REPLACEMENTS, Beef Heifers, West	Bull SLAUGHTER, East	Bull SLAUGHTER, West	Bull REPLACEMENTS, East	Bull REPLACEMENTS, West	Calf SLAUGHTER, Male, East	Calf SLAUGHTER, Female, East	Calf SLAUGHTER, Male, West	Calf SLAUGHTER, Female, West
Cow SLAUGHTER $_{-1}$	+	+	+	+												
REPLACEMENTS, Heifers $_{-1}$					+	+	+	+								
Bull SLAUGHTER $_{-1}$									+	+						
REPLACEMENTS, Bulls $_{-1}$											+	+				
Calf SLAUGHTER $_{-1}$													+	+	+	+
Population Cows $_{-1}$	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	-
Population Heifers $_{-1}$					-	-	-	-								
Population Bulls $_{-1}$									-	-	+	+				
Price slaughter steers $_{-1}$	+	+	+	+	+/-	+/-	+/-	+/-	-	-	+	+	+	+	+	+
Price can. and cut. cows $_{-1}$					+/-	+/-	+/-	+/-	-	-	+	+				
Price stock steer calves $_{-1}$			+	+		+	+	+	-	-	+	+	+	+	+	+
Price veal calves $_{-1}$	+	+			+/-											
Price index 100 hogs	+	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+
Price manufactured milk	+	+			+	+			-	-	+	+	+	+	+	+
Milk subsidy	+	+			+	+							+	+	+	+
Over quota penalty	-	-			-	-										
Price barley	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Grain stocks		+		+		+		+		-		+			+	+
Interest	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Farm wages	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Real aggregate national income	+	+	+	+	-	-	-	-					+	+	+	+
Milk production per cow	-	-			-	-										
Time	-	-	-	-	-	-	-	-	+	+	-	-	+	+	+	+
Season[b]																

[a]The excess price function, as specified, reverses the sign of the regression coefficient associated with the exogenous and lagged endogenous variables of the supply function.

[b]The theoretical models do not include a seasonal variable; the nature of the data and the process being modeled suggest its inclusion.

$$(73) \qquad S_t^{vmW} = \pi_0 + \pi_1 S_{t-1}^{vmW} + \pi_2 P_t^{cW} - \pi_3 POP_t^{cDW} + \pi_4 P_t^{sW} + \pi_5 P_t^{hgW} + \pi_6 Y_t^W$$

$$+ \pi_7 P_t^{mW} - \pi_8 P_t^{bW} + \pi_9 K_t - \pi_{10} W_t^W - \pi_{11} I_t + \pi_{12} T.$$

$$(74) \qquad S_t^{vfW} = \pi_0 + \pi_1 S_{t-1}^{vfW} + \pi_2 P_t^{cW} - \pi_3 POP_t^{cDW} + \pi_4 P_t^{sW} + \pi_5 P_t^{hgW} + \pi_6 Y_t^W$$

$$+ \pi_7 P_t^{mW} - \pi_8 P_t^{bW} + \pi_9 K_t - \pi_{10} W_t^W - \pi_{11} I_t + \pi_{12} T.$$

Modifications to the Specified Models

The foregoing models are each modified by the four basic statistical models given as equations (31), (32), (33), and (34). Only model (31) was developed above for the sake of brevity.

Equation (32) has the effect of lagging the demand and supply shifters by one period. Equation (33) has the effect of including both lagged and unlagged supply and demand shifters. And finally, equation (36) has the effect of lagging the endogenous variable both once and twice.

The basic period used in establishing the data series is three months or one quarter of a year. The basic production cycle for cattle and grain, and to a lesser extent hogs, is a one-year cycle. Consequently, the lag suggested by the econometric model makes little or no basic sense.

The fundamental purpose of these models is to generate good predictors, not to test hypotheses. Consequently, the question of the appropriate lag is left as an open question. Lags of zero (t) to four (t-4) quarters were considered, and the decision rule used was to select the lag giving the best fit in terms of the "t" statistic.

The final model selected is some combination of statistical models (31) to (34). An ex post rationalization for the selected models is given in the final section of the chapter.

A second major modification to these models is the addition of seasonal dummy variables. The rationale for adding these variables follows the argument presented with respect to lags and the annual production cycle. That is, the basic production cycle for crops and livestock is an annual cycle highly dependent on the seasons. Response to endogenous and exogenous stimuli is not necessarily immediate nor of a fixed lag, but seasonal. The calendar year was divided into four quarters; these quarters were used to represent the seasonal influence.

Accounting Identities for Cattle and Calves

The next major problem to be considered is the availability of time series data for the endogenous variables. In many instances these are not available from any source. The following table indicates the endogenous data series required and those available for both East and West.

Desired	Available
Veal Calf SLAUGHTER	Veal Calf SLAUGHTER
Bull SLAUGHTER	Bull SLAUGHTER
Bull REPLACEMENTS	no data available
Dairy Cow SLAUGHTER Beef Cow SLAUGHTER	Cow SLAUGHTER
Dairy REPLACEMENT, Heifers Beef REPLACEMENT, Heifers	no data available

Thus, an attempt must be made to generate data series from known information and relationships. The following identity is the main relationship which is employed.

$$(75) \qquad POP_{t+1} \equiv POP_t + REPLACEMENTS_t - DEATHS_t - SLAUGHTER_t + IMPORTS_t - EXPORTS_t.$$

POP_{t+1} and POP_t are known from available data series. DEATH Rate is being taken as given from a study of DEATH Rates. $EXPORTS_t$ and $IMPORTS_t$ are known in an aggregate fashion; they must be disaggregated to meet the needs of the model. Three bases will be used for this disaggregation:

1. disaggregate data from 1969-1972, inclusive;
2. informed judgment of professional livestock economists; and
3. evidence given by the simulation model(s).

Thus, we might indicate that the following models are conditional on a set of parameters $(\lambda_3,\ldots,\lambda_k)$[1] which are used to disaggregate EXPORTS and IMPORTS.

Turning to the Cow Herd, there are two unknowns remaining in identity (75), SLAUGHTER and REPLACEMENTS. Since the size of the Dairy Herd is more stable than that of the Beef Herd, the former will be considered first.[2]

Over the period under consideration, 1958-1972, the Dairy Cow Population has been monotonically decreasing, with the exception of the years 1960-1961.

By fixing alternately CULL Rate (λ_1) and REPLACEMENT Rate (λ_2), a data series can be generated for the non-fixed element in the identity. If CULL Rate, λ_1, is set at some Rate known to be historically correct on average, then identity (75) can be solved for REPLACEMENTS_t.

$$\begin{aligned} POP_{t+1} = {} & POP_t + \text{REPLACEMENTS} - DR \cdot POP_t - \lambda_1 \cdot POP_t \\ & + \text{IMPORTS}_t - \text{EXPORTS}_t. \end{aligned}$$

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[1]Parameters λ_3 to λ_k are dummy parameters representing whatever structure and parameter values are necessary to disaggregate the published EXPORT and IMPORT data series.

[2]This same situation applies in reverse to the Eastern Beef Cow Herd, with the exception of 1966, the Herd has been growing at a fairly constant rate since 1958.

Now solve for REPLACEMENTS_t.

$$\text{REPLACEMENTS}_t = \text{POP}_{t+1} - \text{POP}_t + \text{DR} \cdot \text{POP}_t + \lambda_1 \cdot \text{POP}_t$$
$$- \text{IMPORTS } (\lambda_3\text{-}\lambda_j)_j^2 + \text{EXPORTS } (\lambda_{j+1}\text{-}\lambda_k)_t.$$

(76) $$\text{REPLACEMENTS}_t = \text{POP}_{t+1} + (\text{DR.}+\lambda_1-1)\text{POP}_t - \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)$$
$$+ \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k).$$

In a similar fashion if REPLACEMENT Rate, λ_2, is known, then identity (75) can again be used to calculate SLAUGHTER_t(CULLS).

$$\text{POP}_{t+1} = \text{POP}_t + \lambda_2 \cdot \text{POP}_t - \text{DR} \cdot \text{POP}_t - \text{SLAUGHTER}_t$$
$$+ \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t - \text{EXPORTS } (\lambda_{j+1},\ldots.,\lambda_k)_t$$

$$\text{SLAUGHTER}_t = \text{POP}_t + \lambda_2 \cdot \text{POP}_t - \text{DR} \cdot \text{POP}_{t+1} + \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)$$
$$- \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)$$

(77) $$\text{SLAUGHTER}_t = (1+\lambda_2\text{-DR}) \cdot \text{POP}_t - \text{POP}_{t+1} + \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t$$
$$- \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$$

If Dairy Cow REPLACEMENT Rate is taken as known (an historical average figure) then Dairy Cow SLAUGHTER can be calculated by identity (75). Since Total Cow SLAUGHTER_t is also known, Beef Cow SLAUGHTER_t can be calculated.

(78) Beef Cow $\text{SLAUGHTER}_t \equiv$ Total Cow SLAUGHTER_t - Dairy Cow SLAUGHTER_t

Beef Heifer REPLACEMENTS can be calculated by substituting (78) into (75) and solving for REPLACEMENTS_t

(79) Beef Heifer $\text{REPLACEMENTS}_t = \text{POP}_{t+1} - \text{POP}_t + \text{DR} \cdot \text{POP}_t$

$+$ Beef Cow $\text{SLAUGHTER}_t - \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t$

$+ \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$

Since Bull SLAUGHTER (CULL) data is published, this figure can be substituted into (75) to calculate Bull REPLACEMENTS_t.

(80) Bull $\text{REPLACEMENTS}_t = \text{POP}_{t+1} - \text{POP}_t + \text{DR} \cdot \text{POP}_t +$ Bull SLAUGHTER_t

$- \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t + \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$

An identity type computer program (MATRIX) was designed to calculate the required endogenous data series from published data using the above identities where required.

The rates (λ_i's and DR's) previously specified are annual rates while MATRIX requires semi-annual rates, thus, equations (76) and (77) must be slightly modified to fit. POP_t and POP_{t+1} now refer to semi-annual livestock figures as do EXPORTS and IMPORTS.

$$\text{REPLACEMENTS}_t = \text{POP}_{t+1} + \frac{DR}{2} \cdot \text{POP}_t + \frac{\lambda_1}{2} \cdot \text{POP}_t$$

$$- \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t + \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$$

(81) $$\text{REPLACEMENTS}_t = \text{POP}_{t+1} + \left(\frac{DR}{2} \cdot \frac{\lambda_2}{2} - 1\right) \cdot \text{POP}_t$$

$$- \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t + \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$$

$$\text{SLAUGHTER}_t = \text{POP}_t + \frac{\lambda_2}{2} \cdot \text{POP}_t - \frac{DR}{2} \cdot \text{POP}_t - \text{POP}_{t+1}$$

$$- \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t - \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$$

(82) $$\text{SLAUGHTER}_t = \left(1 + \frac{\lambda_2}{2} - \frac{DR}{2}\right) \cdot \text{POP}_t - \text{POP}_{t+1} + \text{IMPORTS}(\lambda_3,\ldots.,\lambda_j)_t$$

$$- \text{EXPORTS}(\lambda_{j+1},\ldots.,\lambda_k)_t.$$

The results obtained from MATRIX are conditional on the parameters $(\lambda_3,\ldots.,\lambda_k)$ used to disaggregate EXPORT and IMPORT data. While the best known estimates will be used initially, subsequent new information may be obtained, some of which may be generated by MATRIX and other computer programs used in this study. This new information will require that a revised set of endogenous variables be estimated.

The results obtained from MATRIX are also conditional on λ_1 or λ_2. These are average or typical values but may not be correct for non-average years; a few, some, or most years, may be non-average. This problem is minimized by selecting that Herd (Dairy or Beef) that demonstrates the most stability in the period under consideration.

For non-average years, when λ_1 or λ_2 do not hold true, the endogenous estimates will be badly biased. Since all endogenous estimates are constrained by published SLAUGHTER and Population figures, manual adjustments can be made to the estimated data series. These adjustments were made in a manner consistent with other known information such as price movements, unusual conditions or unique expectations.

In such a manner, endogenous data series can be generated that are consistent among themselves, consistent within themselves, and consistent with known external influences. The generated endogenous data series will ultimately be verified by knowledgeable livestock economists as reasonable and consistent with their concept of the historical situation. This verification will come at some future date when the models developed in this study are used to solve practical livestock problems.

Generation of Endogenous Variables

Program MATRIX was developed to calculate the time series of endogenous variables required for the behavioral models and ultimately for use in program CATSIM.[1] In addition to generating these endogenous variables, the program provides another check on consistency and in this way aids in verifying the models and in determining likely parameter values.

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[1]A listing of program MATRIX is provided in Appendix C. All programs are written in FORTRAN IV compatible with Michigan State University's CDC 6500 computer.

MATRIX is a quarterly model utilizing identities. The basic identities used are those developed in the previous section, namely, (75) to (82). These basic identities are normally modified slightly to meet the exact application in this model.

To repeat a listing made in the previous section, the following endogenous data series are calculated:

Dairy Cow SLAUGHTER	East and West
Beef Cow SLAUGHTER	East and West
REPLACEMENTS, Dairy Heifer	East and West
REPLACEMENTS, Beef Heifer	East and West
Bull SLAUGHTER	East and West
Bull REPLACEMENTS	East and West
Male Calf SLAUGHTER	East and West
Female Calf SLAUGHTER	East and West

Assumptions

The first assumption made in developing this model is that Dairy Cow SLAUGHTER Rate is basically very stable. An observation leading to a second assumption is that the Dairy Herds, East and West, have been basically declining over the 1958-1972 period, and the Eastern Beef Herd has been climbing steadily over that same period.[1] It is further assumed that the SLAUGHTER Rate on the Eastern Beef Cow Herd has been basically stable over the 1958-1972 period.

The above assumptions plus identities (75) to (82) are used in generating a first estimate of the 16 endogenous data series. These are

[1]As previously noted, a slight upturn in Dairy Cow numbers occurred in 1960-1961.

combined with the various published data series. The most critical of these is the semi-annual Livestock Survey. These data series lead to a fourth and fifth set of assumptions.

The fourth set of assumptions concerns the quarterly distribution of REPLACEMENTS. From STATCAN figures, the number of additions (REPLACEMENTS) can be calculated for each of the two six-month periods (December 1-June 1, June 1-December 1), however, the requirement is for quarterly estimates.

The fifth set of assumptions concerns the disaggregation of the relevant data series to fit the model requirements. Discussion of this third and fourth set of assumptions occupies much of the balance of this section.

Calculation of IMPORTS.--The data series used to calculate IMPORTS is the STATCAN annual series Purebred IMPORTS which is available on an annual basis. This data series was disaggregated into first half/second half, Beef/Dairy, and Male/Female components using available monthly 1969-1972 data as a basis.[1]

The following parameters and their values are used to disaggregate annual Purebred IMPORTS:

Purebred IMPORTS	1st half	V22 = .526
	2nd half	V24 = .474
Purebred IMPORTS	Female	V3 = .90
	Dairy	V10 = .20

[1]Appendix A deals with the discussion of data disaggregation and, in general, information relevant to the building of MATRIX and all other models.

<u>Calculation of EXPORTS</u>.--The STATCAN annual category Purebred EXPORTS is disaggregated in the same fashion as IMPORTS. The parameters employed are:

Purebred EXPORTS	1st half	V72 = .50
	2nd half	V74 = .50
Purebred EXPORTS	Female	V8 = .85
	Dairy	V9 = .826

A second export category is Other Dairy EXPORTS. These EXPORTS are assumed to be Cows and Heifers Over Two Years of Age. Further, it is assumed that the semi-annual distribution is similar to that for Purebred EXPORTS.

The final export category of relevance is EXPORTS, Cattle Over 700 Pounds. It is generally believed that a fairly constant number of these are Cull Dairy Cows, the balance being Steers and Heifers for further finishing and Immediate SLAUGHTER.

Observation of the data suggests that at least 11,000 head are shipped annually in this category. These are taken to be largely Cull Dairy Cows. Larger shipments are assumed to be largely Steers and Heifers. This disaggregation was programmed using the following parameters.

Proportion of Cull Dairy Cows in first 11,000 head (East, 3,000 head) (West, 8,000 head)		V11 = .80
Proportion of Cows in the balance (East, 2,400 head) (West, 6,400 head)	East	V111 = .10
	West	V112 = .05

An examination of the data also reveals that 57 percent of EXPORTS are made in the first half and 43 percent in the last half. The following parameters are used for that purpose.

SLAUGHTER Cow EXPORTS	1st half	V82 = .57
	2nd half	V84 = .43

Calculation of SLAUGHTER.--SLAUGHTER is calculated by summing the UNINSPECTED with the INSPECTED. INSPECTED SLAUGHTER data is available in the form required, however, the UNINSPECTED is only available in highly aggregated form.

UNINSPECTED Calf SLAUGHTER is distributed semi-annually by the following parameters.

UNINSPECTED Calf SLAUGHTER	1st half	East	V13 = .60
		West	V14 = .44
UNINSPECTED Calf SLAUGHTER	2nd half	East	V15 = .40
		West	V16 = .56

The Male/Female, first quarter/second quarter, and third quarter/fourth quarter allocations are assumed to be the same as INSPECTED Calf SLAUGHTER and are recalculated semi-annually from that source by the MATRIX program.

Cows and Bulls in UNINSPECTED Cattle SLAUGHTER are calculated using the following parameters.

Proportion of Cows in UNINSPECTED Cattle SLAUGHTER	East	V23 = .28
	West	V19 = .25
Proportion of Bulls in UNINSPECTED Cattle SLAUGHTER	East	V25 = .06
	West	V26 = .06

Calculation of Rates.--A set of parameter values, generally described as rates and distributions, are used in constructing MATRIX. The first of these are the quarterly birth distributions. The quarterly distribution of BIRTHS is also utilized in the program to allocate REPLACEMENTS among quarters. These quarterly distributions are:

Dairy, East and West

1st quarter	VALD(1) = .262
2nd quarter	VALD(2) = .258
3rd quarter	VALD(3) = .222
4th quarter	VALD(4) = .282

Beef, East and West

1st quarter	VALBE(1) = .20	VALBW(1) = .28
2nd quarter	VALBE(2) = .50	VALBW(2) = .64
3rd quarter	VALBE(3) = .15	VALBW(3) = .05
4th quarter	VALBE(4) = .15	VALBW(4) = .05

Two semi-annual Rates are used for DEATHS, one for the first half and a second for the second half. No differentiation is made between East and West.

DEATH Rate	1st half	DR1 = .008
	2nd half	DR2 = .006

The final set of Rates concerns that rate at which Cows are slaughtered or culled from the Herd. Rates are estimated for Beef Cows East and Dairy Cows West.

Beef Cow CULL Rate	East	1st half	V20 = .045
	East	2nd half	V21 = .055
Dairy Cow CULL Rate	West	1st half	V27 = .08
	West	2nd half	V28 = .10

It should be noted at this point that all parameters including BIRTH Rates, CULL Rates, etc. are used in other programs besides MATRIX. Consistency is attempted among the parameters used in all models thus aiding with their validation.

Description of the Model (MATRIX)

The model MATRIX attempts to generate plausible time series data for the 16 endogenous variables previously listed. It does this because and in spite of the fact that some of the basic statistical data are not available.

The method used in approaching the problem is to make a set of reasonable assumptions. Some of these have been made before; more are made in the balance of this section.

MATRIX is divided into two parts. The first calculates endogenous variable values for the first and second quarters, the second part for the third and fourth quarters. Structurally, both parts are identical.

Calculation of the Cow Slaughter series.--The first two values calculated are Eastern Beef Cow Slaughter and Western Dairy Cow Slaughter.[1] The method used is to apply a rate (semi-annual) to the Cow Population to generate that proportion slaughtered. This in turn is allocated quarterly.

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[1]Originally, Eastern Dairy Cow SLAUGHTER was calculated, however, the small errors generated caused relatively large errors in calculation of the much smaller Eastern Beef Cow SLAUGHTER. Calculation of Eastern Beef Cow SLAUGHTER, in this manner, is assumed plausible due to its stable growth over the 1958-1972 period.

The next two values are calculated using identities (78) and (82). The values generated in this way are Eastern Dairy Cow SLAUGHTER and Western Beef Cow SLAUGHTER. Identity (78) uses the fact that there are only two types of Cows, Dairy and Beef. By the residual method, those that are not the one must be the other.

The allocation of SLAUGHTER between quarters is made by allocating the semi-annual in a manner consistent with Eastern (or Western) Cow SLAUGHTER. The seasonal effect is amplified slightly more in the case of Beef Cow SLAUGHTER as opposed to Dairy Cow SLAUGHTER. Examination of monthly Cow SLAUGHTER data shows that Cow SLAUGHTER is low during spring and summer rising during the September-December period. Exceptions occur during periods of rapid expansion or contraction.

Calculation of the REPLACEMENT Heifer series.--The calculation of REPLACEMENTS uses a modification of identity (81) where SLAUGHTER is taken as generated above. The REPLACEMENT values generated are Eastern Dairy, Western Dairy, Eastern Beef, and Western Beef.

The allocation of REPLACEMENTS between quarters is a problem of some significance. From a priori information it is known that the expected age of a Dairy Heifer at first calving is in excess of 33 months or 2 3/4 years. The data series being calculated is by definition, the rate of flow of 12 month old Heifers, to the Cow Herd via the Bred Heifer stream. It can readily be seen that the two ends of the process differ by 1 3/4 years or 21 months (33 months minus 12 months). If the distribution of dairy cow freshenings is to be maintained over

time, it is reasonable to assume that Dairy Heifers freshen according to the same distribution. It can then be calculated that Heifers entering the Bred Heifer stream in the first quarter (at 12 months of age) will be in the same ratio as Dairy Cow freshenings 21 months later during the fourth quarter. Consequently, Dairy Heifer REPLACEMENTS are allocated between quarters as follows where VALD is the quarterly birth distribution for Dairy Cows.

1st quarter $\quad$ 1st half REPLACEMENTS x $\dfrac{\text{VALD}(4)}{\text{VALD}(4) + \text{VALD}(1)}$

2nd quarter $\quad$ 1st half REPLACEMENTS x $\dfrac{\text{VALD}(1)}{\text{VALD}(4) + \text{VALD}(1)}$

The same reasoning is used to allocate Beef REPLACEMENT Heifers. In this instance, for lack of better information, it is assumed that Beef Heifers calve at two years of age. Thus Beef Heifers entering the Cow Herd in the first quarter, also enter the Bred Heifer stream in the first quarter. Western REPLACEMENTS are distributed quarterly as follows:

1st quarter $\quad$ 1st half REPLACEMENTS x $\dfrac{\text{VALBW}(1)}{\text{VALBW}(1) + \text{VALBW}(2)}$

2nd quarter $\quad$ 1st half REPLACEMENTS x $\dfrac{\text{VALBW}(2)}{\text{VALBW}(1) + \text{VALBW}(2)}$

For Eastern Beef REPLACEMENTS, the distribution used is VALBE rather than VALBW.

Calculation of Bull REPLACEMENTS.--This calculation utilizes a modification of identity (80). As with Heifer REPLACEMENTS, Bull REPLACEMENTS are allocated using the calving distribution. Since Bulls are assumed to enter the Bull Herd at one year of age, no maturation period need be considered. The distribution used to allocate Bull REPLACEMENTS is VALBE and VALBW in the East and West, respectively.

Calculation of Bull and Calf SLAUGHTER.--These calculations involve a manipulation of the INSPECTED and UNINSPECTED SLAUGHTER data as previously discussed.

The Generated Endogenous Data Series

The endogenous data series generated by MATRIX appear in Tables 5 to 7. Since certain anomalies appear in these data, each data series will be discussed below.

The Calf SLAUGHTER series is generated by simply summing monthly published data and in the case of UNINSPECTED SLAUGHTER, disaggregating quarterly and annual data. The only major assumptions of note concerns this disaggregation. These four data series are used directly as endogenous variables in the Calf SLAUGHTER behavioral models.

The Bull REPLACEMENT series indicates that most REPLACEMENTS are added during the first two quarters of the year. This occurs to such an extent that negative Bull REPLACEMENT values appear sporadically for the last two quarters. Barring errors in the published data series, the only source of this error can be UNINSPECTED Cattle SLAUGHTER. The Bull proportion of this aggregate series was incremented to 6 percent

to generate the series presented even though 6 percent is a much higher proportion than that occurring in INSPECTED SLAUGHTER. The only logical explanation that could be found suggested that high demand for Slaughter Bulls came from small UNINSPECTED meat packers producing specialty meats. The remaining negative values can only be inadequately explained by year to year fluctuations.

The final data series generated by MATRIX are Cow SLAUGHTER and REPLACEMENT. The assumption that Dairy Cow SLAUGHTER is fairly stable is believed to be reasonably accurate. Since this assumption is used for the West, all Western Cow SLAUGHTER and REPLACEMENT figures are used as generated by MATRIX.

In the East, the assumption that the Beef Cow SLAUGHTER rate is stable is undoubtedly a gross abstraction. Consequently, Eastern Cow SLAUGHTER and REPLACEMENT values were adjusted in accordance with a priori information and consistency among these series. These alterations appear in Table 8.

Figures 14 to 17 present a visual display of these 16 generated (and adjusted) endogenous data series.

Table 5. Quarterly INSPECTED plus UNINSPECTED Cow SLAUGHTER and REPLACEMENT, 1958-1972, estimated by program MATRIX

		SLAUGHTER		REPLACEMENTS		SLAUGHTER		REPLACEMENTS	
		Dairy Cows		Dairy Heifers		Beef Cows		Beef Heifers	
Year	Quarter	East	West	East	West	East	West	East	West
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1958	1	88063	34853	103946	39911	14731	49935	7202	57915
	2	80907	30907	99794	37081	14966	40360	12506	132377
	3	83220	38634	94809	39197	15368	49111	23350	41070
	4	115156	43566	78743	33728	19450	55574	23079	41070
1959	1	74248	34090	95569	36033	13613	32585	8331	62389
	2	69909	30230	87507	33478	12865	31750	15827	142601
	3	73163	37609	76941	44178	12445	42261	27213	29500
	4	85846	42411	68787	38014	11543	48636	21724	29500
1960	1	76033	33729	117436	42443	16534	40961	5911	59068
	2	66114	29911	104682	39433	18209	35080	9777	135012
	3	81808	37849	89933	43330	9467	43449	29670	46683
	4	93963	42681	77384	37284	11571	49046	27375	46683
1961	1	77280	33873	119102	47022	10331	39235	7276	77926
	2	69357	30039	110655	43687	8452	41284	18189	178116
	3	72398	38390	97058	39673	10385	53490	23988	25664
	4	102045	43290	83515	34137	12693	54698	21470	25664
1962	1	81916	34005	112568	31194	10910	46288	8151	70652
	2	79930	30155	104585	28982	8926	43098	20379	161490
	3	91288	37033	91725	27311	11009	61065	25150	67729
	4	117546	41817	78926	23500	13455	70420	22481	67729
1963	1	89823	31970	1155903	35023	11553	42439	9583	72871
	2	81792	28350	107683	32539	9453	37315	23959	166562
	3	90567	35391	90690	32621	11739	49618	19956	73591
	4	108468	39909	77519	28069	14348	52715	17110	73591
1964	1	86798	31037	134495	31818	11979	39920	11477	94168
	2	83686	27523	124956	29561	9801	51994	28693	215242
	3	89048	34163	94529	27275	17303	55644	20151	80126
	4	111346	38531	78641	23469	22037	76864	19168	80126
1965	1	82059	29638	130794	27786	22269	66493	21300	100942
	2	85447	26282	120809	25815	20038	58747	39251	230724
	3	109865	32336	116453	21296	37548	84019	28658	74987
	4	131064	36456	96715	18324	40000	130291	25616	74987
1966	1	98081	27645	113786	18436	24917	107750	13441	86085
	2	81347	24515	105786	17129	21750	78856	23102	196765
	3	78951	29516	91466	20127	21620	81909	25967	69662
	4	100393	33284	77308	17319	24202	124490	23150	69662
1967	1	78409	25313	92514	16135	11652	86141	10556	74502
	2	74976	22447	95953	14991	9534	60507	26391	170291
	3	81734	26978	91288	21636	11920	92044	26539	48879
	4	100324	30422	78550	18617	14568	113638	23650	48879
1968	1	84088	23405	101497	18783	12476	94870	13424	75903
	2	82981	20755	94299	17451	10208	76778	33560	173493
	3	84770	25239	101451	22771	12944	98819	11231	53853
	4	102484	28461	87295	19593	15821	109501	8093	53853
1969	1	84363	22048	111194	20149	12677	80961	20398	82610
	2	85453	19552	103308	18720	10372	67167	50994	188823
	3	89086	23923	97429	31115	13736	63384	16905	64225
	4	100544	26977	83834	26773	16789	53550	13575	64225
1970	1	92160	21582	114934	24374	13699	50974	17707	89879
	2	90049	19138	106783	22645	11208	52434	44267	205437
	3	86246	23782	80734	20806	14444	51995	31618	62658
	4	93571	26818	69469	17903	17654	49897	28116	62658
1971	1	90515	20606	95698	25073	15065	57336	20855	124728
	2	85780	18274	88910	23295	12326	61883	52138	285094
	3	86571	22917	91283	6423	16036	64059	11089	49151
	4	91571	25843	78546	5527	19599	74657	7202	49151
1972	1	74635	18826	119990	32605	15568	75404	24600	109788
	2	80584	16694	111480	30293	12737	68371	61499	250943
	3	80220	21799	98824	8749	16840	64934	11592	83018
	4	91380	24581	85035	7528	25582	75271	7509	83018

Table 6. Quarterly INSPECTED plus UNINSPECTED Calf SLAUGHTER, 1958-1972, estimated by program MATRIX

Year	Quarter	Male Calf SLAUGHTER East	Male Calf SLAUGHTER West	Female Calf SLAUGHTER East	Female Calf SLAUGHTER West
		(head)	(head)	(head)	(head)
1958	1	120313	38887	48729	27792
	2	251992	48884	104570	29249
	3	130870	53297	58467	35342
	4	107924	40174	47071	32216
1959	1	116830	31376	44796	20441
	2	222390	38791	85906	22330
	3	121915	38145	49838	30290
	4	96522	37019	39380	40867
1960	1	121120	29866	45870	29221
	2	213970	36017	79561	29034
	3	122806	41841	49743	34894
	4	100059	32512	42188	43950
1961	1	121708	26100	47999	25190
	2	210161	33911	82919	27543
	3	115485	37954	47231	36356
	4	107624	33276	44697	46473
1962	1	119415	26871	43093	29131
	2	222525	29068	84375	25397
	3	130655	31036	54253	31783
	4	114648	31008	48966	47107
1963	1	114754	22202	45737	21448
	2	219997	24436	90824	20267
	3	128630	27607	55821	27365
	4	108176	27391	45879	39196
1964	1	107653	19944	46480	20660
	2	216460	32612	98441	31480
	3	128418	31635	56870	32648
	4	118900	35725	53386	52293
1965	1	146252	29970	61855	39292
	2	234858	30265	93795	35526
	3	147950	35036	69673	37525
	4	122524	40191	57228	62670
1966	1	146780	26834	65524	39118
	2	213605	27470	96429	32768
	3	107356	25285	48767	32617
	4	104601	34402	48172	53758
1967	1	127370	21841	56176	29346
	2	217327	23098	93746	29552
	3	109493	26561	45485	41798
	4	98887	28820	44512	55400
1968	1	125431	20374	55621	31325
	2	196746	20021	84872	29856
	3	110320	22955	46943	37779
	4	104547	24464	44411	40152
1969	1	130806	17983	59265	25288
	2	174722	15780	80897	20182
	3	97658	16218	42114	22219
	4	100221	16834	43698	22778
1970	1	115478	11849	48637	13845
	2	150924	11676	74241	12269
	3	93328	11305	37751	15372
	4	85789	12269	34035	16715
1971	1	109068	10207	46304	13518
	2	155940	8570	68484	10966
	3	90890	9950	35409	13039
	4	83773	12381	32265	15091
1972	1	101983	9945	41021	11722
	2	144224	8885	64806	10385
	3	72409	9457	30633	11104
	4	76449	11741	28459	13840

Table 7. Quarterly INSPECTED plus UNINSPECTED Bull SLAUGHTER and REPLACEMENT, 1958-1972, estimated by program MATRIX

Year	Quarter	Bull SLAUGHTER East (head)	Bull SLAUGHTER West (head)	Bull REPLACEMENT East (head)	Bull REPLACEMENT West (head)
1958	1	11469	6491	15095	9156
	2	13070	8043	37737	20928
	3	19511	9379	63	-30
	4	14890	9414	63	-30
1959	1	8734	4327	15302	9727
	2	11285	6623	38256	22233
	3	16125	8732	4	2978
	4	11055	7211	4	2978
1960	1	9106	5383	15126	8469
	2	12314	7915	37815	19359
	3	16358	8865	-823	3296
	4	11098	8328	-823	3296
1961	1	9350	6242	15317	9102
	2	11541	7817	38292	20806
	3	16432	10901	1924	3162
	4	13111	8921	1924	3162
1962	1	9352	5251	13713	9065
	2	11786	6586	34284	20721
	3	16759	9053	102	2097
	4	12438	10095	102	2097
1963	1	8830	5595	14859	10288
	2	10880	6258	37147	23515
	3	15384	8372	-309	4978
	4	11708	8755	-309	4978
1964	1	8956	5330	13485	11494
	2	11154	7515	33712	26273
	3	15889	8532	1967	7610
	4	12696	9603	1967	7610
1965	1	9237	6118	14212	11310
	2	12319	7908	35529	25851
	3	20153	10007	2818	5976
	4	13728	11969	2818	5976
1966	1	9266	7702	12475	8765
	2	10300	7853	31188	20034
	3	13428	7478	1147	-2190
	4	11614	10136	1147	-2190
1967	1	8053	5365	12597	10385
	2	10153	6648	31492	23737
	3	14024	8949	1561	799
	4	10437	8787	1561	799
1968	1	8609	5240	12318	8859
	2	11554	6639	30794	20250
	3	14307	8573	2961	-4218
	4	12005	8868	2961	-4218
1969	1	8747	5495	12372	10259
	2	11485	6928	30930	23449
	3	14337	8697	2847	-612
	4	11621	7885	2847	-612
1970	1	9363	4797	11278	10635
	2	11759	5756	28195	24308
	3	12960	6535	5027	128
	4	11307	6447	5027	128
1971	1	9385	4937	12662	13884
	2	12466	6851	31656	31553
	3	13167	8762	2504	5845
	4	10998	8679	2504	5845
1972	1	8955	7222	12296	13153
	2	12482	8847	30739	30865
	3	12812	9939	1292	1231
	4	13496	8411	1292	1231

Table 8. Adjustments made to Eastern Cow SLAUGHTER and REPLACEMENT data as generated by MATRIX

			SLAUGHTER		REPLACEMENT		SLAUGHTER		REPLACEMENT	
			Beef Cows		Beef Heifers		Dairy Cows		Dairy Heifers	
Year	Quarter	Adj. Factor	Orig.	Rev.	Orig.	Rev.	Orig.	Rev.	Orig.	Rev.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1958	1	5,000	9,737	14,731	2,202	7,202	93,063	88,063	114,946	109,946
	2	7,000	7,966	14,966	5,506	12,506	87,907	80,906	106,794	99,794
	3	6,000	9,368	15,368	17,350	23,350	89,220	83,220	100,809	94,809
	4	8,000	11,450	19,450	15,079	23,029	123,156	115,156	86,743	78,743
1959	1	4,000	9,613	13,613	4,331	8,331	78,248	74,248	99,569	95,569
	2	5,000	7,865	12,865	10,827	15,827	74,909	69,909	92,507	87,507
	3	3,000	9,445	12,445	24,312	27,213	76,163	73,163	79,941	76,941
	4	0	11,543	11,543	21,724	21,724	85,846	85,846	68,787	68,787
1960	1	6,000	10,034	16,034	-89	5,911	82,033	76,033	123,436	117,436
	2	10,000	8,209	18,209	-223	9,777	76,114	66,144	114,682	104,682
1964	3	5,000	12,303	17,303	15,151	20,151	94,048	89,048	99,529	94,529
	4	7,000	15,037	22,037	12,168	19,168	118,346	111,346	85,641	78,641
1965	1	10,000	12,269	22,269	11,300	21,300	92,059	82,059	140,794	130,794
	2	10,000	10,038	20,038	21,251	38,251	95,447	85,447	130,809	120,809
	3	25,000	12,548	37,548	3,658	28,658	134,865	109,865	141,457	116,453
	4	25,000	15,337	40,337	616	25,616	156,064	131,064	121,715	96,715
1966	1	13,000	11,917	24,917	441	13,441	111,081	98,081	126,786	113,786
	2	12,000	9,750	21,750	11,106	23,102	93,342	81,347	117,794	105,786
	3	10,000	11,620	21,620	15,967	25,967	88,951	78,951	101,466	91,466
	4	10,000	14,202	24,202	13,150	23,150	110,393	110,393	87,308	77,308

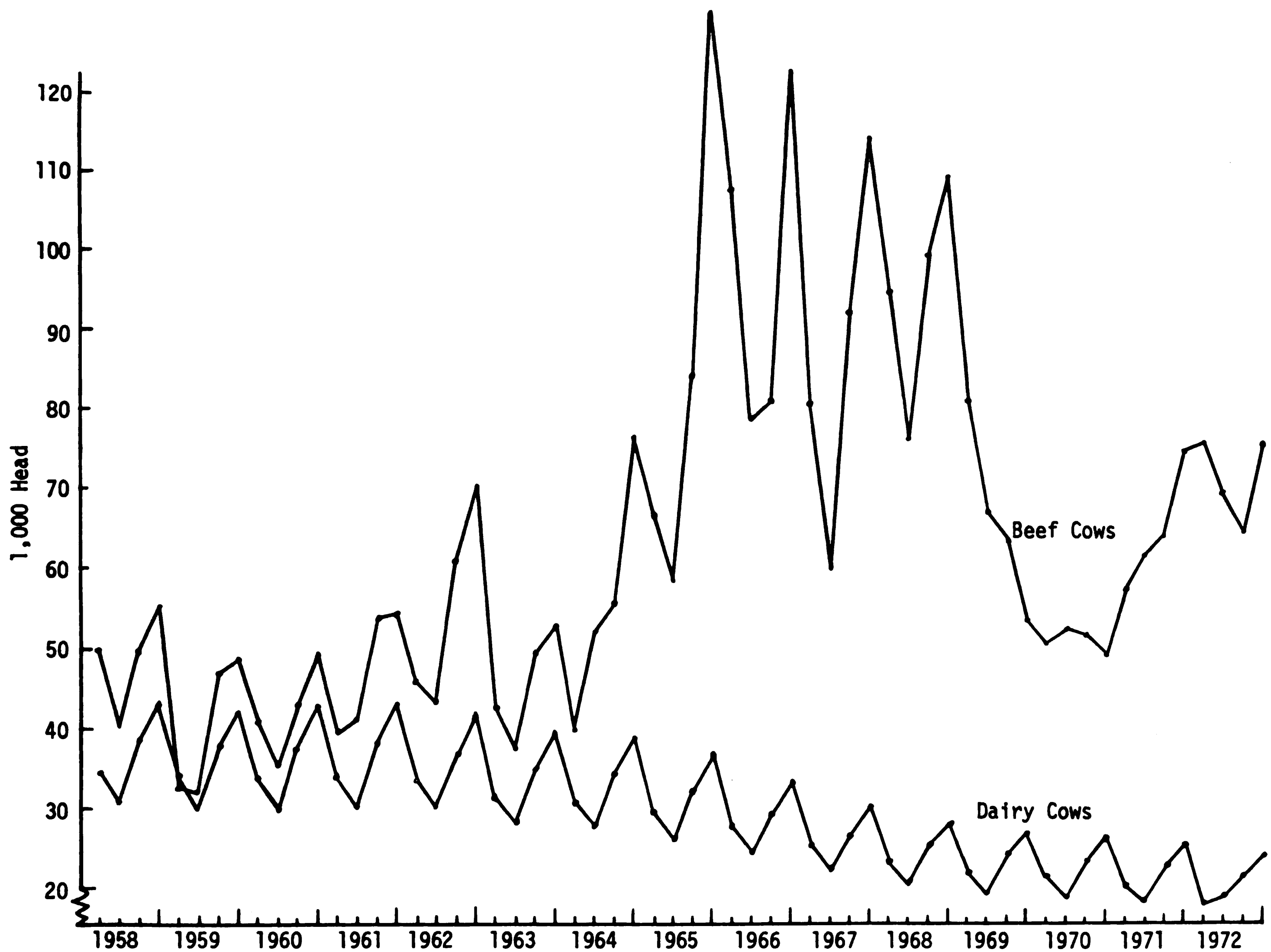

Figure 14. Quarterly INSPECTED plus UNINSPECTED Beef and Dairy Cattle SLAUGHTER, West, 1958-1972, estimated by program MATRIX.

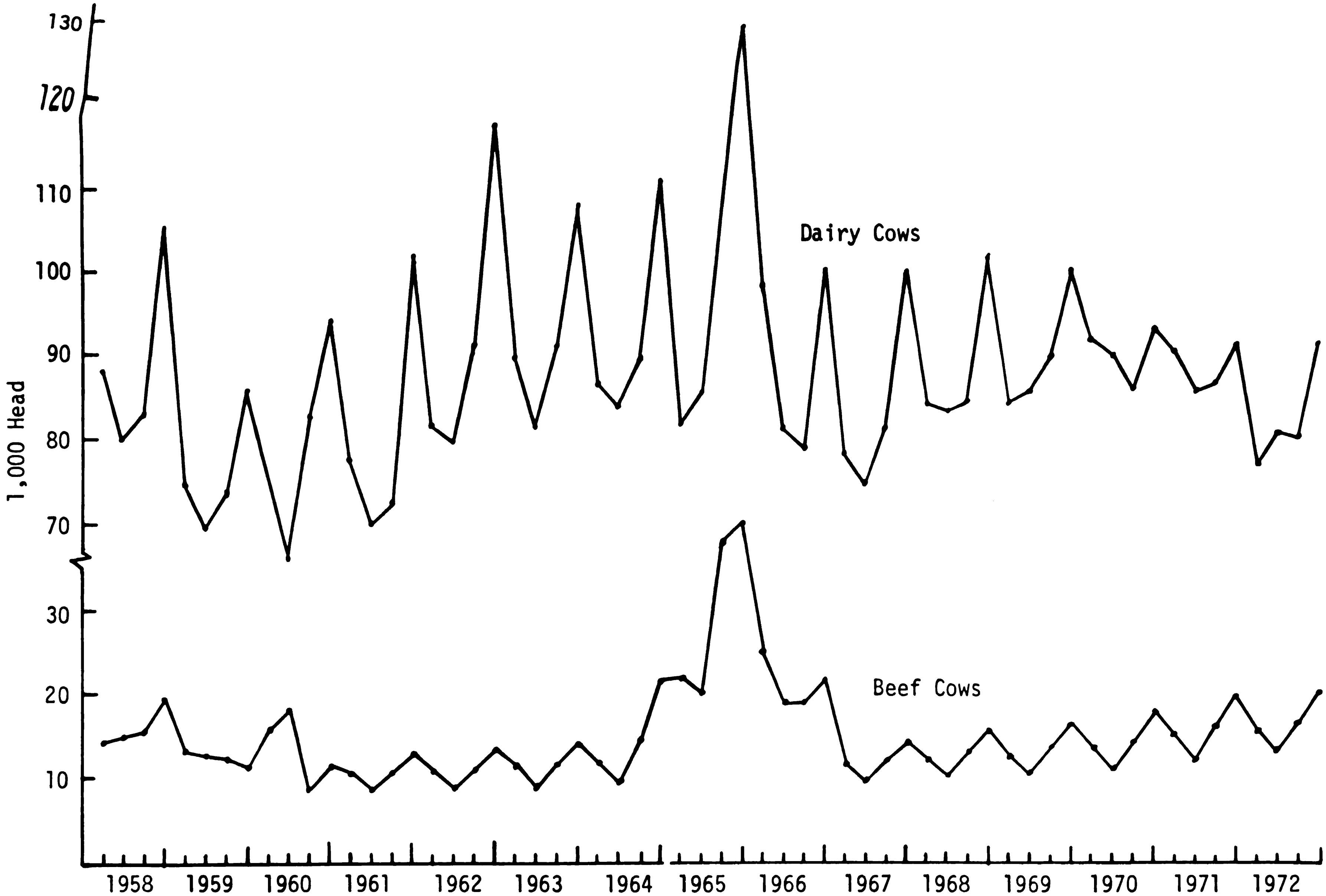

Figure 15. Quarterly INSPECTED plus UNINSPECTED Beef and Dairy Cow SLAUGHTER, East, 1958-1972, estimated by program MATRIX.

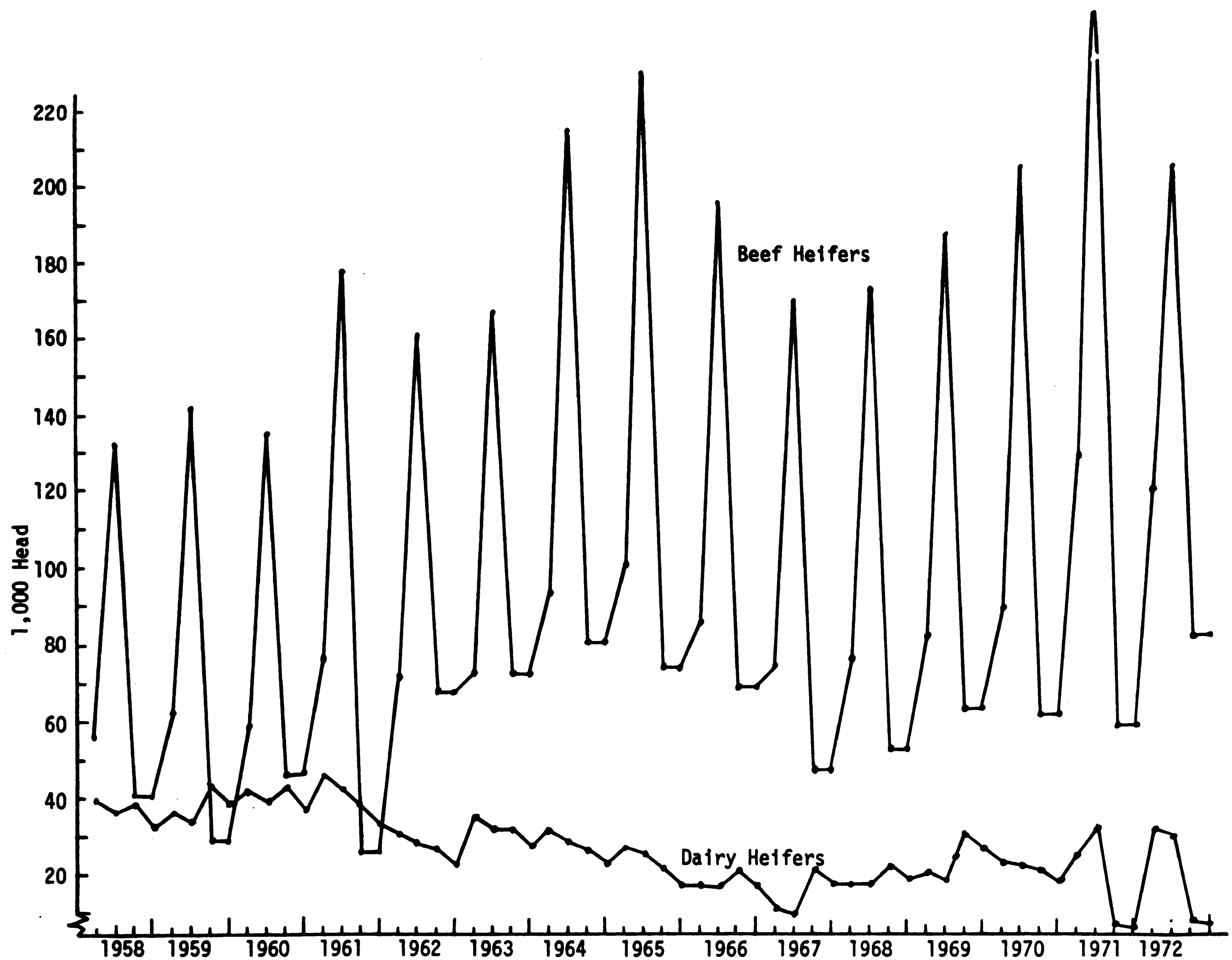

Figure 16. Quarterly Beef and Dairy Cow REPLACEMENTS, West, 1958-1972, estimated by program MATRIX.

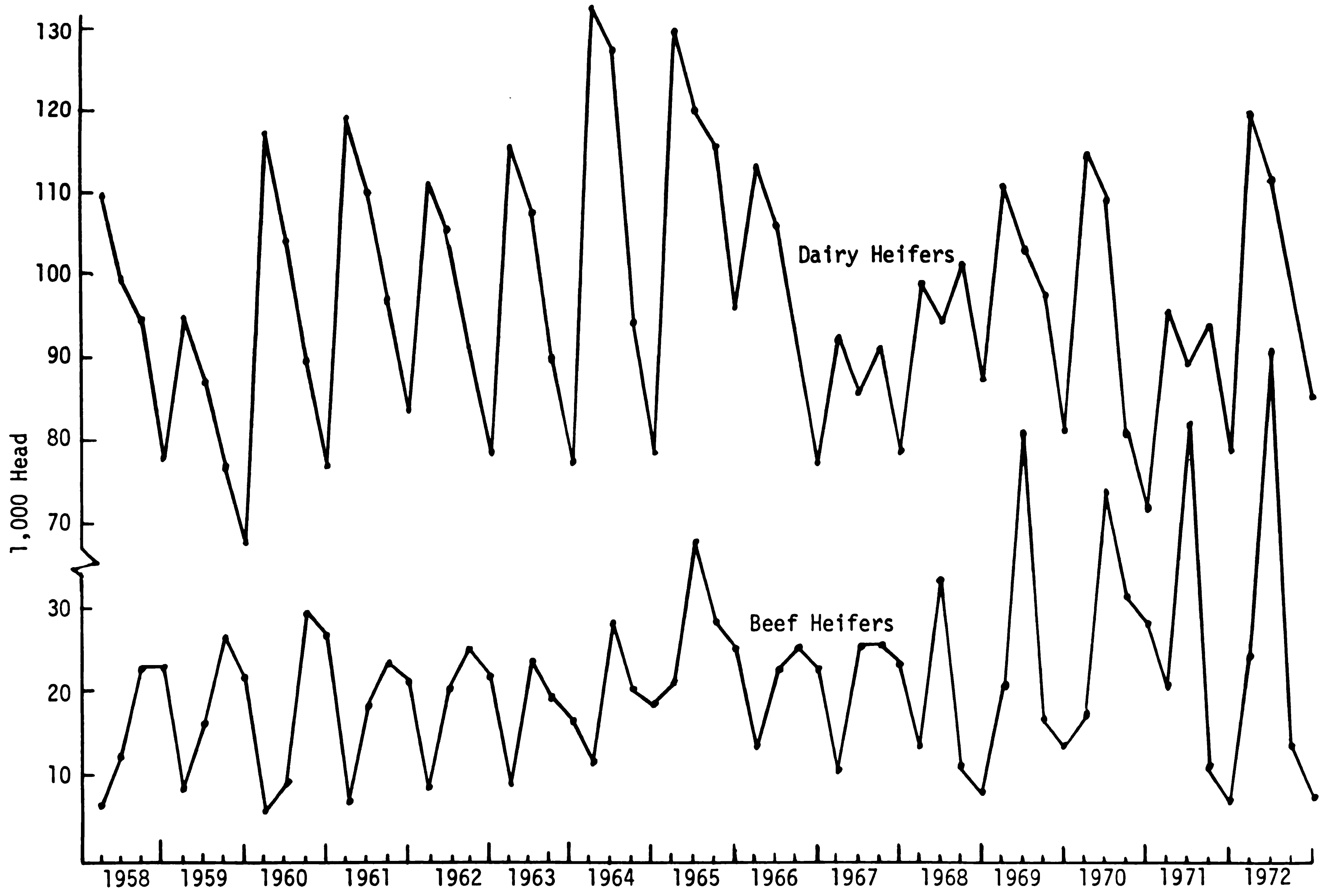

Figure 17. Quarterly Beef and Dairy Cow REPLACEMENTS, East, 1958-1972, estimated by program MATRIX.

Parameter Estimates and Behavioral Model Appraisal

The parameter estimates for the 16 behavioral models are given in Tables 9 to 11. The balance of this section briefly discusses these models, their parameter estimates and properties. Estimated values for the endogenous data series are listed in Tables 12 to 14.

The excess price model formulation developed in the first section of this chapter met with only modest success in terms of predicted sign of the coefficients. That is, many of the explanatory variables had significant coefficients that were opposite in sign to those predicted by the excess price model. This is particularly true in the case of Calf SLAUGHTER. The behavioral models, however, serve as good predictors in most instances when assessed in terms of R^2 and $\bar{R}^2$. The excess price model was a success in that the models retain high explanatory power in spite of the fact that "own price" was excluded from each model in keeping with the theoretical excess price model.

In almost all instances, the lagged endogenous variable proved to be significant when evaluated in terms of the Student's "t" statistics. It is retained in each model in keeping with the theoretical econometric model even though in a few instances this variable was not significant at the 5 percent level.

The form of the models finally selected do not necessarily conform to the four models given by equations (31) to (34). For those exogenous variables representing cattle and calf price, only lagged values are accepted. The reason for this is twofold. First, these behavioral models are part of an unspecified but highly related simultaneous equation system such as the one given earlier in this chapter. Thus, these prices could be construed to be endogenous, not exogenous. Second, these econometric models (as used in CATSIM) may be operated in a recursive mode with other beef models, such as those being developed by the Economics Branch. These other models generate cattle and calf prices.

For all other variables, the lag that has been accepted ranges from zero to four periods--the decision rule used was to retain the lag giving the best fit in terms of the Student's "t" test. For many variables, the lag was either zero or one period, in accordance with the econometric models (31), (32), and (33).

One notable exception occurs very consistently; that exception is the lagged endogenous variable. In all cases, econometric model (34) did not fit as well as the form finally selected. In most models, a single four period lag, for the lagged endogenous variable, provided the best fit. The explanation rests with the data, not the econometric model. All endogenous data series are of a highly seasonal nature, thus a lag of four periods (a one year lag) has more explanatory power than a one period lag.

The seasonal dummy variables were all retained regardless of significance as most, if not all, endogenous variables were considered a priori to have a distinct seasonal component. In addition, a time trend was often noted that was not explained in terms of other included variables. For this reason, a "time" variable appears in many models.

Since all models have a lagged endogenous variable on the right hand side in accordance with econometric models (31) to (34), the statistic that is normally used to indicate the degree of serial correlation, the Durbin-Watson (DW) statistic, is unreliable. Thus, another statistic, the "h" statistic, is used in this dissertation.[1] This "h" statistic is distributed approximately N(0,1) but has only large sample properties.

The condition of serial correlation often occurs when time series data is used, as opposed to those instances when cross sectional data is employed. This condition proved to be significant in one "Cow" model, three "Bull" models and just significant in one "Calf" model.

Serial correlation is usually based on the interpretation of the error term as "a summary of a large number of random and independent factors that enter into the relationship under study, but which are not measured."[2] Thus, an excluded, but systematic

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[1]This alternate statistic is presented in J. Durbin, "Testing for Serial Correlation in Least Squares Regression When Some of the Regressors Are Lagged Dependent Variables," Econometrica 38:410-421, 1970.

The statistic "h" is calculated as follows:

$$h = r\sqrt{\frac{n}{1 - nV(b_i)}}$$

where $r \simeq 1 - \frac{1}{2}d$ d = the DW statistic; and
$V(b_i)$ = the variance of the coefficient of the lagged endogenous value.

The test fails when $1 - nV(b_i) < 0$.

[2]Jan Kmenta, Elements of Econometrics, New York, The MacMillan Company, 1971, p. 269.

relationship may cause serial correlation. Johnson adds a second potential source of this condition, namely, a measurement error in the explained or endogenous variable.[1] Either or both of these causes are likely to be present in these models, especially the latter, as these data are generated by a simulation method that undoubtedly, (1) provides more stability than is present in the real world, and (2) fails to generate at least some of the systematic variation that is present in the real world phenomena being modeled.[2]

Both Johnson and Kmenta indicate that the properties of serially correlated models are:

1. unbiased estimates of the regression coefficients and large sample consistency, and

2. inflated and thus inefficient estimates of the standard errors of the regression coefficients--these standard errors are not asymptotically efficient.

The consequences of these properties are that the tests of significance of the regression coefficients are incorrect, and development of accurate confidence intervals is precluded as well. In addition to the above, the models are inefficient predictors in that the standard error of estimate is needlessly large.

The significance of these properties for the purpose of the five serially correlated behavioral models is that variables might have

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[1]J. Johnson, Econometric Methods, New York, McGraw-Hill Book Company, 1963, p. 178.

[2]While I refer to the generation of the endogenous data series by MATRIX, it should also be recognized that the published data sources undoubtedly are subjected to a "revision or correction" by a simulation type process.

been retained as significant or discarded as insignificant due to the inaccurateness of the Student's "t" test. This was not considered as serious since most variables with "t" > 1 were retained. The second property (prediction inefficiency) was not considered as serious in that the five effected models have either high R^2 (i.e., .9948, .9208, .9913, .8687, and .9586) or have low impact on the overall situation model, as is the case with the "Bull" predictors.

Cow SLAUGHTER and REPLACEMENT

In most of the 16 behavioral models, a lag of more than one period, usually four periods, was found to be most significant, for reasons given above. In the case of Cow SLAUGHTER and REPLACEMENT models, only two of eight have a four period lag, the balance have a one period lag. In the case of Dairy Cow SLAUGHTER and REPLACEMENT, this one period lag can be attributed to a weakness of the seasonal variation. An explanation for Eastern Beef Cow SLAUGHTER and REPLACEMENT lag does not readily come to mind.

The price of slaughter steers entered the four Eastern models with a four period lag in three instances and a three period lag in one instance. In the West, the lag on this variable was two period except in one instance when it was three periods.

It is interesting to note that farm wages enter both the Eastern and Western Dairy Cow SLAUGHTER models and very significantly so in the East, the dairy region. In this same regard, milk production per cow was a significant variable in the Eastern Dairy REPLACEMENT model.

The price of veal calves entered the Eastern Dairy SLAUGHTER model at a very significant level reflecting the significance of this source of income to dairy farmers. As might have been expected, veal calf price was insignificant but stocker calf price was significant in the Western Dairy Cow SLAUGHTER model as well as the Western Dairy REPLACEMENT model.

The price of feed, as represented by the price of barley and western grain stocks, were not found to be significant in any of these eight models. It is believed that this is due to the inappropriateness of the statistical index used or to the structure of the model or both. In any case, the real effect of these variables is obscured.

The price of hogs enters some models usually with no lag. While price of milk would normally be thought of as a very significant variable, it did not prove to be significant in any one of these models--this is undoubtedly a result of institutional involvement in price stabilization and its impact on expectations. The imposition of an over quota penalty was not found to be significant; however, the application of milk subsidy had a significant effect in the Eastern Dairy Cow SLAUGHTER model.

It was thought that farm wages, interest rates, and milk production per cow would influence SLAUGHTER/REPLACEMENT decisions. With the exception of farm wages, these variables proved to be rather insignificant in most instances.

It should be noted that distinct non-linear time trends were observed in the four Eastern models, while the non-time variables proved to be adequate in the Western models.

It was observed that the seasonal pattern of Eastern Beef Heifer REPLACEMENT changed over the 1958-1972 period. The early part of the period was characterized by high fall REPLACEMENT, while the latter part incurred high spring REPLACEMENT--as in Western Canada. For this reason, one set of regional dummies (the "A" set) was used for the years 1958-1967, and another set (the "B" set) for 1968-1972.

Serial correlation proved to be a problem with early Eastern Beef Cow SLAUGHTER models. This condition was removed by using time, $time^2$ and $time^3$ variables. While this removes the serial correlation, the basic underlying relationship still remains unidentified. The "h" statistic indicates that the Western Dairy Cow SLAUGHTER model has significant serial correlation. The model used above was attempted but without success.

Two different statistics were consulted in an attempt to determine which exogenous, and lagged endogenous, variables were the most important in explaining variation in the endogenous variables. These statistics are the beta coefficient[1] and the R^2 delete

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[1]A reference for this statistic is Robert Ferber and P. J. Verdoorn, Research Methods in Economics and Business, New York, The MacMillan Company, 1962, pp. 99-100. The authors state, "an idea of the relative importance of each independent variable in a multiple regression is obtained through the so-called beta coefficient." "This is not the only means of evaluating the relative importance

value.[1] While the ranking of these two indices rarely agreed, both identified the same five most important variables in most instances.

Dairy Cow Population proved to be very important in both Western Dairy models with Dairy Heifer Population being important in the Dairy REPLACEMENT models. In these latter models real income, price of stocker calves, and the seasonal variable prove important. In the SLAUGHTER model, both fall and spring as well as farm wages were isolated as being important.

The seasons fall and summer proved important in the Beef Cow SLAUGHTER model while spring and summer had the same effect in the REPLACEMENT model. Beef Cow Population was important in both with lagged Cow SLAUGHTER important in the SLAUGHTER model. The price of stock steer calves proved to be important in both Beef models, as in both Dairy.

In all Eastern Cow models, the time variable (including squared and cubed terms) proved important as did specific seasonal variables in all models except Beef Cow SLAUGHTER. Cow Population proved important in all models except Beef Cow REPLACEMENTS. In the Dairy SLAUGHTER

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of the different independent variables." Given the model

$$x_1 = \alpha_1 + \alpha_2 X_2 + \sum_{i=3}^{h} \alpha_i X_i + E$$

the beta coefficient is defined as

$$\beta_{1i} = \alpha_{1i} \frac{\sigma_{x_i}}{\sigma_{x_1}}$$

[1]Both the "t" and "F" statistics for the standard error of the regression coefficients provide the same ranking as the R^2 delete statistic.

model, lagged SLAUGHTER and veal calf prices are noted; Dairy Heifer Population is noted in the REPLACEMENT model. In the Beef models, the two indices fail to agree on the most important variables except as previously noted plus real income.

Calf SLAUGHTER

The four Calf SLAUGHTER models have consistently high R^2 values. In all cases, except Female Calf SLAUGHTER, West, the endogenous variable is lagged four periods--in the exception the lag was one period.

There appears to be no consistency among the models with respect to lagged Cow Population. In the case of Female Calf SLAUGHTER, East, this variable was not found to be significant.

In all cases, the price of stocker calves proved to be a very significant variable. This fact may indicate that dairy farmers, and beef feeders, do consider Dairy Calves as an alternative to Beef Calves for feeding purposes.

The price of slaughter cattle was also a significant variable in all four models with a consistent one period lag. This fact may be interpreted to mean that farmers form expectations strongly influenced by recent slaughter cattle prices--these recent prices thus influence whether or not Calves are slaughtered or retained for further feeding.

The price of hogs entered both Eastern models but was found to be insignificant in both Western models. This situation may indicate that Eastern farmers and Eastern dairy farmers in particular view hogs as a significant production alternative while this relationship is not so clear in the case of the West.

Table 9. Parameter estimates for Cow SLAUGHTER and REPLACEMENT behavior models[a]

A. Dairy Cow SLAUGHTER, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		5239.2920** (2317.2045)
$Slaughter_{-1}$	+	-.2517** (.1024)
Dairy cow $population_{-1}$	-	.0608 (.0051)
Price slaughter $steers_{-2}$	+	-78.4407** (36.2866)
Price $hogs_{-4}$	+	-16.4147 (19.3081)
Farm wages	-	20.3559** (2.8485)
Spring		-5239.1323** (830.4257)
Summer		-42.6815 (1137.0268)
Fall		10395.2214* (669.8801)
R^2		.9948
$\bar{R}^2$		.9939
Standard error		540.1972
h		-3.1645

[a]All regression coefficients significant at the 5 percent level are denoted with a single asterisk (*) while those significant at the 1 percent level have a double asterisk (**). All tests are two-tailed tests. This notational convention is continued to Tables 10 and 11.

Table 9--Continued

B. Replacement Dairy Heifers, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		128129.7538** (37202.5045)
$Replacements_{-1}$	+	.2959** (.1204)
Dairy cow $population_{-1}$	+	-.2556** (.0696)
Dairy heifer $population_{-1}$	-	.8051** (.2300)
Price slaughter $steers_{-2}$	+/-	-481.4096 (431.7824)
Price stocker $calves_{-1}$	+	762.6667** (250.1689)
Real $income_{-1}$	-	-7.4142** (2.1360)
Spring		1476.4807 (2407.4369)
Summer		-2396.8143 (1872.3770)
Fall		-10070.2533** (2062.8982)
R^2		.8073
$\bar{R}^2$		.7696
Standard error		4719.1838
h		1.176

Table 9--Continued

C. Beef Cow SLAUGHTER, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		-37656.1259** (14268.3452)
Slaughter_{-1}	+	.5509** (.0942)
$\text{Beef cow population}_{-1}$	-	.0340** (.0082)
$\text{Price slaughter steers}_{-3}$	+	1370.9668 (928.8684)
$\text{Price stocker calves}_{-1}$	+	-1854.1417** (467.3457)
Spring		2528.2616 (4161.3974)
Summer		14816.0353** (4554.5544)
Fall		21352.8221** (4353.5838)
R^2		.8223
$\bar{R}^2$		.7964
Standard error		10484.4407
h		1.0616

Table 9--Continued

D. Replacement Beef Heifers, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		72005.3371** (36146.2612)
Replacements_{-1}	+	.2870** (.1372)
$\text{Beef cow population}_{-1}$	+	.0496** (.0150)
$\text{Price slaughter steers}_{-2}$	+/-	-4702.1262** (1699.0234)
$\text{Price c+c cows}_{-1}$	+/-	-3962.3855* (2844.0655)
$\text{Price stocker calves}_{-1}$	+	2873.9203* (1503.3735)
Price of barley	-	-15507.6432 (13923.5667)
Spring		107848.8030** (9407.3271)
Summer		-57797.7163** (21798.3628)
Fall		-23375.2773** (7932.4784)
R^2		.9243
$\bar{R}^2$		.9095
Standard error		18404.9669
DW		1.9010

Table 9--Continued

E. Dairy Cow SLAUGHTER, East		
Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		-175450.0196* (99812.7032)
Slaughter_{-1}	+	.2109** (.0139)
$\text{Dairy cow population}_{-1}$	-	.1262** (.0483)
$\text{Price slaughter steers}_{-4}$	+	648.6532 (498.7230)
$\text{Price veal calves}_{-1}$	+	-2156.4092** (455.3432)
Price hogs	+	397.4019** (201.3366)
Farm wages	-	82.1449** (27.4525)
Years of milk subsidy	+	8177.3600** (3740.9331)
Spring		7219.3242** (2840.6800)
Summer		8918.4068** (3114.9672)
Fall		33873.0833** (6898.2210)
Time		-1162.1717** (541.5361)
Time squared		26.5366** (10.0332)
R^2		.8784
$\bar{R}^2$		.8445
Standard error		4870.8309
h		1.785

Table 9--Continued

F. Replacement Dairy Heifers, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error	
Constant		779768.2174** (140060.6315)	461939.2288** (112695.9787)
$Replacements_{-1}$	+	.1319 (.0669)	.2027 (.1423)
Dairy cow $population_{-1}$	+	-.3607** (.0669)	-.1789** (.0416)
Dairy heifer $population_{-1}$	-	.3437** (.0917)	.3132** (.0980)
Price slaughter $steers_{-4}$	+/-	-1408.9147** (643.1696)	-1452.9586** (705.6278)
Price c+c $cows_{-1}$	+/-	-457.6674 (1030.8904)	1065.9288 (1056.3383)
Price hogs	-	1474.8048** (363.4522)	1175.1190** (379.3627)
Milk production per cow	-	-14.4532* (8.3878)	-19.5076** (7.6607)
Spring		-9991.5818* (5626.1975)	-9897.8295 (6183.2009)
Summer		-22355.4252** (4977.9252)	-22645.2115** (5349.7168)
Fall		-35404.4679** (4637.2970)	-37845.2569** (4710.4716)
Time		1530.0588** (503.5889)	
Time squared		-39.1851** (11.6297)	
R^2		.8764	.8438
$\bar{R}^2$		.8420	.8091
Standard error		6302.8194	6927.0427
h		.4753	
DW			1.7345

Table 9--Continued

G. Beef Cow SLAUGHTER, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		-36765.0456 (23493.2732)
Slaughter$_{-4}$	+	.5244** (.0773)
Beef cow population$_{-1}$	-	.1885** (.0267)
Price slaughter steers$_{-3}$	+	-696.5868** (320.4876)
Price c+c cows$_{-1}$		-2247.9625** (391.7064)
Price stocker calves$_{-3}$	+	259.3201 (250.6175)
Price hogs	+	525.8325** (126.9048)
Real income	+	2.5390** (1.2264)
Spring		2725.9907** (1212.2651)
Summer		6119.1481** (1466.6370)
Fall		6370.4933** (1365.0145)
Time		-4780.9209** (808.5554)
Time squared		101.2289** (22.0375)
Time cubed		-.8845** (.1971)
R^2		.8396
$\bar{R}^2$		.7900
Standard error		2817.6410
h		1.3984

Table 9--Continued

H. Replacement Beef Heifers, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		112212.2469** (48163.5818)
Replacements$_{-4}$	+	.1176 (.1419)
Beef cow population$_{-1}$	+	-.0603 (.0476)
Price slaughter steers$_{-4}$	+/-	-1393.5692** (593.2013)
Price c+c cows$_{-1}$	+/-	-2171.3383* (1305.7785)
Price stocker calves$_{-1}$	+	924.2043 (638.4321)
Farm wages	-	97.7775 (61.9624)
Real income$_{-1}$	-	-4.0940* (2.4792)
Spring A		15559.7570** (4089.4627)
Summer A		18752.6570** (4810.2201)
Fall A		32013.6511** (12312.1751)
Spring B		27583.4245** (4827.9243)
Summer B		4004.7022 (5070.9654)
Fall B		26041.7988 (16868.2736)
Time		485.1695 (506.3804)
Time squared		15.4424 (9.6243)
R^2		.8270
$\bar{R}^2$		.7622
Standard error		5640.5029
h		test fails
DW		1.6951

In three out of the four models, real aggregate income lagged one period was significant while the application of the milk subsidy was found to be significant only in the East.

Milk price, price of barley, interest rate, farm wages, and grain stocks proved to be non-significant variables. In all cases, except Western Female Calf SLAUGHTER, a significant time trend was noted. While this trend was downward in all cases, the positive sign on $time^2$ for both Eastern models indicated that the rate of change is slowing.

The excess price model proved particularly disappointing in the case of Calf SLAUGHTER in the sense that the realized sign of the regression coefficients were opposite to the predicted signs in most cases. The "incorrect" signs are mostly associated with variables from the underlying "supply" model--Dairy Cow Population, slaughter steer price, and stock calf price are examples. The sign of real aggregate income is also incorrect in all instances; however, it serves as a factor in the demand for <u>both</u> veal and beef. The simplified Calf SLAUGHTER model used in this study did not adequately reflect these two demand functions and their relative income elasticities.

Lagged Calf SLAUGHTER was consistently an important variable in all Calf models by both indices. The price of stocker calves was also consistently important by the R^2 delete index. Continuing to use this index, the seasonal variable, spring, proved important in Eastern models while fall held the same position in the Western.

Table 10. Parameter estimates for Calf SLAUGHTER behavioral models

A. Male Calf SLAUGHTER, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		80336.0628 (157301.7436)
Slaughter_{-4}	+	.4833** (.1032)
Dairy cow population_{-3}	-	.0986 (.0756)
Price slaughter steers_{-1}	+	-2090.6330** (1056.9372)
Price stocker calves_{-1}	+	-2424.8488** (716.7474)
Price hogs	+	762.2596* (397.0427)
Real aggregate income_{-1}	+	-7.8629* (4.1497)
Milk price	+	11446.9538 (8090.3190)
Years of milk subsidy	+	20245.7945** (6666.7433)
Spring		36665.1023** (9346.3692)
Summer		-4188.0444 (3436.3258)
Fall		-8605.1330** (3737.8357)
Time		-2598.8677** (1190.8180)
Time squared		69.2244** (21.9653)
R^2		.9715
$\bar{R}^2$		.9627
Standard error		8448.7312
h		1.622

Table 10--Continued

B. Female Calf SLAUGHTER, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		95538.9696** (26234.8607)
$Slaughter_{-4}$	+	.4582** (.0880)
Price slaughter $steers_{-1}$	+	-643.3298 (424.7172)
Price stocker $calves_{-1}$	+	-824.5499** (270.3680)
Price hogs	+	407.9670** (157.2757)
Real aggregate $income_{-1}$	+	-2.6336* (1.5608)
Years of milk subsidy	+	8684.8348** (1959.8415)
Spring		17267.3015** (3445.1789)
Summer		-2149.2194 (1446.3352)
Fall		-3912.9951** (1506.4636)
Time squared		11.1973* (6.2663)
R^2		.9672
$\bar{R}^2$		.9599
Standard error		3557.2212
h		-.3554

Table 10--Continued

C. Male Calf SLAUGHTER, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		59399.4215** (25761.4252)
$Slaughter_{-4}$	+	.4085** (.0729)
Population diary + beef $cows_{-1}$	-	.0132** (.0032)
Price slaughter $steers_{-1}$	+	-417.1973* (230.8712)
Price stocker $calves_{-1}$	+	-503.6313** (157.3257)
Real aggregate $income_{-1}$	+	-12.7213** (5.9461)
Spring		1914.7789** (973.3416)
Summer		2741.8436** (1041.2650)
Fall		3340.8456** (1077.0228)
Time		-220.5733** (83.7173)
R^2		.9458
$\bar{R}^2$		.9352
Standard error		2433.7700
h		-.5536

Table 10--Continued

D. Female Calf SLAUGHTER, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		8896.0727 (7753.6348)
$Slaughter_{-4}$	+	.2835** (.0734)
Population diary + beef $cows_{-3}$	-	.0150** (.0029)
Price slaughter $steers_{-2}$	+	-600.6975* (358.4579)
Price stocker $calves_{-1}$	+	-889.2789** (212.3119)
Price barley	-	4379.4108 (2954.2386)
Spring		-1887.9025 (1454.4207)
Summer		2671.5658* (1469.5519)
Fall		12084.5311** (1852.4866)
R^2		.9208
$\bar{R}^2$		.9074
Standard error		3780.6137
h		2.057

For the Eastern models, real income was important by the beta index while the importance of milk subsidy was evidenced by the R^2 delete index. In the case of the Western models, the sum of Dairy plus Beef Cow Population was important. In both models, the slaughter steer price was shown to be important by the beta index.

Bull SLAUGHTER and REPLACEMENT

The least consistent feature of the Bull models is the use of lagged Population as a predictor. In the case of Eastern Bull SLAUGHTER, the sum of Dairy + Beef Cows lagged three periods gave a reasonable fit together with predicted sign. In the case of Western Bull REPLACEMENTS, Bull Population lagged three periods gave the best fit. In the other two instances, a lag of one period on Bull Population was highly significant.

The price of canner and cutter cows, price of slaughter steers and price of feeder calves, enter these four models in a rather inconsistent manner as do hog prices. In the two Western models both interest rate and barley price were good predictors even though the sign was "incorrect" in the Bull SLAUGHTER model. Grain Stocks once again proved to be insignificant.

A time trend was noted in both Bull REPLACEMENT models; however, the sign was not consistent between them. A positive sign was expected; this occurred in the Western model but not the Eastern. The negative Eastern sign might result from the establishment of a large number of small Beef Herds, each with its own Herd size; this is a hypothesis only.

A serial correlation problem occurred with Eastern Bull REPLACEMENTS that could not be removed with either the use of the theoretically suggested variables or by the use of a time trend. The same situation applied to Western Bull SLAUGHTER. The "h" statistic failed in the case of Western Bull REPLACEMENTS: however, the low DW statistic value and high standard error on the lagged endogenous variable suggest that it also has significant serial correlation.

In both Bull SLAUGHTER models, the price of canner and cutter cows was consistently important as were the seasons summer, spring, and fall, and the price of hogs. Lagged REPLACEMENTS was consistently important in the Bull SLAUGHTER models as was lagged Bull Population and time. In both REPLACEMENT models, spring or summer proved important with fall also being important in the Western model.

Table 11. Parameter estimates for Bull SLAUGHTER and REPLACEMENT behavioral models

A. Bull SLAUGHTER, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		23229.2923** (11535.8110)
$Slaughter_{-4}$	+	.1631 (.1142)
Population diary + beef $cows_{-3}$	-	-.0052 (.0044)
Price c+c $cows_{-1}$	-	-673.4769** (141.2890)
Price stock $calves_{-1}$	-	132.4531** (57.9927)
Price hogs	-	77.3524** (30.2596)
Spring		3181.1680** (478.0134)
Summer		6716.5654** (907.6478)
Fall		3519.1658** (591.4977)
R^2		.8864
$\bar{R}^2$		.8671
Standard error		908.6374
h		.4945

Table 11--Continued

B. Replacement Bulls, East

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		69370.8097** (13785.8886)
Replacement$_{-4}$	+	.5187** (.0948)
Bull population$_{-1}$		-.4639** (.1003)
Price slaughter steers$_{-1}$	+	249.3419* (140.6795)
Price c+c cows$_{-1}$	+	-813.9760** (233.7458)
Spring		4653.4734** (1965.2978)
Summer		-3571.4346** (1324.9432)
Fall		1807.8445 (1740.4049)
Time		-270.0263** (63.7154)
R^2		.9913
$\bar{R}^2$		.9898
Standard error		1345.0842
h		2.6093

Table 11--Continued

C. Bull SLAUGHTER, West

Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		7248.6288** (2098.4868)
Slaughter_{-2}	+	-.3554** (.1221)
$\text{Bull population}_{-1}$		.0452** (.0127)
$\text{Price slaughter steers}_{-1}$	-	152.0917** (63.2109)
$\text{Price stocker calves}_{-1}$	-	-176.3291** (40.6994)
Price hogs	-	143.2745** (30.6684)
Interest	+	-711.2955** (161.6899)
Price barley	+	-990.3946* (510.6763)
Spring		2115.7041** (284.2183)
Summer		1717.3784** (491.0127)
Fall		2023.8506** (367.0365)
R^2		.8687
$\bar{R}^2$		.8396
Standard error		678.5276
h		2.806

Table 11--Continued

Replacement Bulls, West		
Variable	Expected coefficient sign	Estimated regression coefficient and standard error
Constant		70266.2945** (11677.6818)
$Replacement_{-4}$	+	.5397** (.1430)
Bull $population_{-3}$		-.3475** (.1029)
Price slaughter $steers_{-2}$	+	-527.0168** (150.5670)
Price hogs	+	-102.4590 (84.6617)
Interest	-	-2029.0168** (610.9371)
Price barley	-	-2922.2334* (1641.2919)
Spring		9555.9719** (1843.8523)
Summer		-4062.9831** (1405.8923)
Fall		-6956.0921** (1410.5917)
Time		365.0983** (80.5094)
R^2		.9586
$\bar{R}^2$		.9494
Standard error		2107.3617
DW		1.3924
h		test fails

Table 12. Quarterly INSPECTED plus UNINSPECTED Cow SLAUGHTER and REPLACEMENT, 1959-1972, estimated by the behavioral model

		SLAUGHTER		REPLACEMENT		SLAUGHTER		REPLACEMENT	
		Dairy Cows		Dairy Heifers		Beef Cows		Beef Heifers	
Year	Quarter	East	West	East	West	East	West	East	West
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1959	1	79943	33823	96196	40783	12907	30032	8249	65591
	2	69426	30826	85732	37823	13587	17159	16824	164131
	3	73742	37059	82899	37261	13974	35394	24155	26064
	4	91106	42096	72461	40175	14230	43650	23842	33913
1960	1	67730	33235	105556	39233	12187	39645	4754	50069
	2	63810	30600	106013	35518	13191	39416	18746	158497
	3	77921	37415	95112	38933	9999	50077	20643	27946
	4	98329	42532	82853	37710	10371	58295	21883	44208
1961	1	71491	33708	119090	41703	12334	37958	10188	67959
	2	72279	31116	110004	42357	11774	33023	23010	182423
	3	80006	37752	97778	38783	11733	53654	27067	42147
	4	100973	43073	81582	35662	13001	68788	25212	39919
1962	1	78324	34046	107662	37125	9693	42432	8253	75657
	2	82049	31078	102376	26758	11297	38487	22358	172969
	3	89531	36918	93630	28429	11724	53565	23933	40901
	4	111874	41444	72611	28595	12413	68091	20555	47789
1963	1	89569	31830	112864	33483	8409	51684	5608	64879
	2	82012	28482	107723	35008	9227	43419	21751	168318
	3	91447	34919	97824	34140	11563	55159	20230	50086
	4	111975	39712	82831	30558	15968	63581	17163	64515
1964	1	84691	30749	124771	30732	14230	48668	9905	85032
	2	80732	28059	122873	28373	13281	48476	24526	208824
	3	90355	33969	102188	30110	18077	66073	24967	79931
	4	114300	38521	83475	23817	23648	81801	25383	67740
1965	1	90731	29817	119718	26580	22346	75761	14824	96518
	2	85252	26712	118904	21405	19858	73268	25552	216748
	3	98313	32466	107523	21989	30069	78579	30175	87220
	4	121230	36550	93068	11834	35545	104198	22637	71309
1966	1	97509	27967	126355	18114	29669	106365	15514	102860
	2	88831	2459[illegible]	107652	17580	16367	88604	27268	207179
	3	88947	29704	90933	17350	23013	84835	27221	56901
	4	97944	33320	77119	15945	25964	101164	22324	59431
1967	1	81747	25541	104330	23061	13374	95978	11818	98437
	2	78718	22152	90218	20908	9169	69231	24533	194294
	3	78960	27393	83936	19166	9357	74077	28889	54210
	4	97426	30744	71719	18315	11940	100735	22733	59322
1968	1	82139	23673	104170	25001	9088	86494	18063	78635
	2	78546	20087	98905	20273	10799	83601	43025	178348
	3	88075	25758	92642	20419	15407	84931	13486	54871
	4	102566	28952	84033	17075	18321	100482	10032	55423
1969	1	88301	28802	116280	23465	13873	83576	15530	75015
	2	84331	18991	107596	22987	12257	68921	47775	191169
	3	90700	24393	96501	25270	14396	62181	17257	69609
	4	102713	27041	82942	22598	16866	59196	11722	58154
1970	1	89926	21617	121362	25665	16103	45952	24194	99574
	2	89398	18224	97712	24941	9428	41060	47675	222185
	3	86921	23797	83375	21888	15779	56053	20567	69297
	4	96972	26870	66897	17376	14681	64183	18740	76483
1971	1	87163	20983	98810	22947	13056	47147	23704	109686
	2	82883	17288	93713	21956	14474	51811	50809	227157
	3	83994	23314	91047	17550	17675	73314	19593	94245
	4	91518	26049	87524	10146	20728	82987	15535	74299
1972	1	81144	19976	118316	18981	15972	63665	22406	111597
	2	88038	15652	107974	22133	11169	68786	53173	208357
	3	76799	22115	93756	15425	14669	78738	11532	76299
	4	91618	24545	92406	6251	21186	80514	8463	77220

Table 13. Quarterly INSPECTED plus UNINSPECTED Calf SLAUGHTER, 1959-1972, estimated by the behavioral model

		Male Calf SLAUGHTER		Female Calf SLAUGHTER	
Year	Quarter	East	West	East	West
		(head)	(head)	(head)	(head)
1959	1	122466	31115	43002	22071
	2	220865	36321	86519	21113
	3	111075	39420	43906	26952
	4	97053	35173	37560	36330
1960	1	122334	30346	44926	24275
	2	212327	35595	83134	25296
	3	122205	36371	48690	34426
	4	103767	36555	41572	44917
1961	1	128309	29710	50263	29409
	2	206405	32865	81763	27776
	3	124090	38298	50740	35145
	4	102630	35405	43367	49175
1962	1	115880	26543	47779	30546
	2	219249	30560	89308	29637
	3	127863	32442	53172	34050
	4	113857	29813	47953	44726
1963	1	124766	22750	50132	25588
	2	221736	27211	89543	24125
	3	122495	28799	53120	32581
	4	107731	29272	47987	43511
1964	1	121739	24150	52003	24831
	2	219228	27245	93652	27059
	3	128973	29802	57577	34540
	4	118203	33031	52275	49103
1965	1	133416	26717	57829	34861
	2	220199	33282	97694	38868
	3	138292	32961	61615	40999
	4	127857	36138	57544	55008
1966	1	149062	28470	64436	38709
	2	215515	26981	93338	33881
	3	128887	30253	59217	36211
	4	115120	35355	52884	54218
1967	1	129803	23060	58406	33941
	2	199689	23501	89029	29497
	3	107468	24217	47343	33183
	4	100422	28783	43888	48392
1968	1	118774	17984	51740	28331
	2	208608	21725	89306	28425
	3	110738	22931	47147	34531
	4	99059	23999	43979	45700
1969	1	121674	16523	53496	25771
	2	188878	16796	83147	23080
	3	92169	14439	42334	22233
	4	85961	14822	39128	23190
1970	1	116550	11492	52643	10907
	2	164193	10063	75128	8765
	3	97833	12951	40984	13254
	4	90460	13828	38441	20088
1971	1	106724	9014	43398	11814
	2	158120	9717	69200	10740
	3	88141	12418	34182	14886
	4	84994	14289	30931	20009
1972	1	93952	7486	38325	8291
	2	148838	8730	64534	9293
	3	77284	9682	30504	11881
	4	74406	12164	29768	15922

Table 14. Quarterly INSPECTED plus UNINSPECTED Bull SLAUGHTER and REPLACEMENT, 1959-1972, estimated by the behavioral model

Year	Quarter	Bull SLAUGHTER East	Bull SLAUGHTER West	Bull REPLACEMENT East	Bull REPLACEMENT West
		(head)	(head)	(head)	(head)
1959	1	8382	4971	13587	10226
	2	10697	6163	37300	21491
	3	15818	8478	2069	1131
	4	12523	8213	1054	1202
1960	1	8990	5656	15690	9681
	2	12158	7492	37638	21833
	3	15648	8493	1158	1762
	4	12519	8747	767	2302
1961	1	9779	5964	15057	9256
	2	12086	7218	36842	22487
	3	16277	8902	830	3705
	4	12665	8224	-507	2569
1962	1	9147	4975	13463	11326
	2	11718	7385	35025	22632
	3	15665	9406	1089	2683
	4	11989	9598	1286	3344
1963	1	8613	5800	13757	9164
	2	11522	6383	34488	22572
	3	15879	8646	333	4194
	4	11954	9291	-703	5174
1964	1	8938	6025	12615	12761
	2	11862	7464	35205	27291
	3	15685	9033	570	6194
	4	12743	9147	1242	5174
1965	1	9737	6140	13792	11682
	2	12451	8302	33873	25818
	3	16567	10403	2300	4089
	4	13305	11138	2095	2535
1966	1	10175	7754	14211	7164
	2	11276	7754	34038	21674
	3	15868	8894	1933	-202
	4	11771	9377	3066	1255
1967	1	8810	6464	12854	8762
	2	9741	7204	31064	22499
	3	13656	8866	1169	85
	4	10768	9257	1877	97
1968	1	8679	4806	13665	7195
	2	11262	6358	32076	19837
	3	15003	8541	1966	148
	4	11159	9260	2497	1673
1969	1	8380	5731	12175	9266
	2	12323	7022	31594	22384
	3	14697	8164	2095	-2119
	4	10584	7382	1147	-3694
1970	1	9561	4540	11957	9859
	2	11742	6095	30705	25586
	3	14649	7659	3494	1585
	4	10688	6827	4649	2905
1971	1	8675	4519	12998	14203
	2	11639	6755	30262	28370
	3	13756	8482	3290	4095
	4	10534	8526	3569	4706
1972	1	8877	5660	12193	14770
	2	11002	8547	29925	27600
	3	13767	9729	726	3730
	4	11111	9107	982	1838

CHAPTER IV

EVALUATION OF THE STATISTICAL DATA BASE

Statistics concerning Cattle and Calves are collected, compiled, and published by several different agencies within Canada.[1] Some relevant data are collected but only used internally by the collecting agency. Much data that would appear to be relevant to a wide range of problems is not collected by anyone. One question that must be asked by researchers, policy makers, and outlook economists is, do these published data represent a sufficiently accurate, comprehensive, and compatible base for the statistical analysis relevant to the execution of their respective tasks. The implication for statisticians is clear, as is the challenge.

These Cattle and Calves data differ among collecting agencies. One such difference concerns the time period of collection. While some series are published weekly, others are published monthly or semi-annually. In addition, some data collection periods coincide with calendar years, others do not. SLAUGHTER and EXPORT-IMPORT data, for example, are aggregated on a calendar year basis while Livestock Population data has historically been published on a June 1 to December 1 basis.

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[1]The reader is reminded that the notational convention employed to denote stock and flow variables continues through Chapter IV. This convention is given in Table 2, pages 50-51.

These data differ in definition among agencies. For example, STATCAN's Agriculture Division defines a Heifer in terms of age (1-2 years of age), while the External Trade Division does not report by sex at all. The Production and Marketing Branch of Agriculture Canada, on the other hand, defines a Heifer in terms of certain recognizable physiological characteristics.

These data differ with respect to the level and basis of aggregation. As one example, STATCAN's Agriculture Division uses age to designate Calf Population with no differentiation between Male and Female. STATCAN's External Trade Division uses weight, but again no differentiation between Male and Female Calves. The Marketing and Trade Division, Agriculture Canada, uses weight and sex to identify Calf SLAUGHTER.

Four related aspects of the overall data problem might be identified. The first of these would be data compatibility--this aspect was discussed above. If all data were compatible with respect to time, definition, and basis of aggregation (disaggregation) it would be possible to add and subtract these various data series to generate some desired bit of information. If these data series are not compatible, then this sort of manipulation may result in such error as to make the end result not only useless, but dangerous.

The second aspect concerns data completeness or comprehensiveness; this aspect was also discussed above and is highly related to data compatibility. The current data base has some glaring omissions. Without commenting further, it is sufficient to say that missing data can only be generated from the current data base with high potential error due to lack of data compatibility.

The third major aspect is data accuracy. Accuracy can be checked by comparing one data series with another. A second method involves periodic completion of a comprehensive and highly controlled survey to generate an "accurate" benchmark. In either case, consistency might be observed, or the two series might differ. If the latter case holds, one series is generally held to be correct and the other incorrect. In the same sense, if the two data series are consistent then they are both considered to be correct. Correct and incorrect are inappropriate words for describing these sorts of consequences. While consistency is necessary for accuracy, it is not sufficient; these data must be believed to be accurate and found to be useful in solving meaningful problems. These data are believed to be correct in a probablistic rather than an absolute sense.

The fourth and final aspect of the data problem concerns application to meaningful problems. If the data is accurate, comprehensive, and compatible, then it may be used for analysis and projection work, among other uses. If the data base were to meet the above three conditions, results of analysis and projections would be held in higher regard and found to be more useful.

In attempting to build a demographic model of the Cattle Herd, it is critical that both the builder and the user have some knowledge of the reliability of these basic data series. While it may not be possible to isolate exact errors, it is hoped that the sign and the relative magnitude of biases may be indicated, trends noted, and the deviation in random errors isolated. Information concerning these biases, trends, and inconsistencies could be conveyed to the collecting agencies; this act would constitute an additional payoff to the investigation.

To this end, a project[1] was initiated in the Research Division, Economics Branch, Agriculture Canada in mid-1973. This work was curtailed in part during early 1974, as the economist in charge changed positions. An internal report on this project was produced in mid-1974. The continuation of that project became part of this current study where its basic concepts are retained intact. The model RECON is an attempt to computerize its major features.[2]

The purpose of RECON is twofold. First, the model attempts to reconcile the various available data series, to note discrepancies, and to evaluate the data series for error, bias, trends, and randomness.[3] The second purpose is to obtain one estimate of some of the parameters that will be used in MATRIX and CATSIM. It should be noted that RECON, MATRIX and CATSIM all model the same Cattle Population over the same time period using the same basic statistical data. The difference

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[1]Bruce Lee, "Simulation of Population in Several Sub-Categories of the Canadian Cattle Herd," a mimeographed paper, Economics Branch, Agriculture Canada, Ottawa, 1973.

[2]The method of analysis involves providing a visual array of RECON output that may be compared with published official data.

[3]A listing of program RECON is provided in Appendix D.

among them basically involves level of aggregation, although methods of calculation vary also. All three models complement each other and should be generally consistent with each other. By utilizing all three models, it is planned that a dynamic picture of Cattle demographics will appear, together with plausible estimates of critical system parameters.

RECON is an annual model utilizing annual data only. All equations are identities using the basic livestock identity (75) from Chapter III. It is reproduced here as follows.

$$\text{(83)} \quad \text{Population}_{t+1} \equiv \text{Population}_t + \text{BIRTHS}_t + \text{TRANSFER IN}_t - \text{DEATHS}_t - \text{SLAUGHTER}_t - \text{EXPORTS}_t - \text{TRANSFER OUT}_t.$$

This identity (in a modified form) is used for each and every row of the RECON output matrix which is displayed in Figure 18. This modification is shown in identities (84) and (85).

$$\text{(84)} \quad \text{TOTAL SOURCES} \equiv \text{Population}_t + \text{BORN}_t + \text{TRANSFER IN}_t + \text{IMPORTS}_t$$

$$\text{(85)} \quad \text{TOTAL DISPOSITIONS} \equiv \text{DIED}_t + \text{SLAUGHTER}_t + \text{EXPORTS}_t + \text{TRANSFER OUT}_t + \text{Population}_{t+1}.$$

If identity (83) holds true, then TOTAL SOURCES ≡ TOTAL DISPOSITIONS; if not, then an "ERROR" of given magnitude and sign is produced. The "ERROR" will be discussed in more detail later in this chapter.

RECON's output matrix is produced for each year under consideration, i.e., 1958-1972 inclusive, for both East and West. WEST-EAST Cattle Movement provides one major link between the two Cattle producing regions. This dichotomy allows an evaluation of the completeness of WEST-EAST Cattle-Calf Movement data. In addition, some evidence may be found concerning the sex of Cattle and Calves shipped East.

There initially appears to be a duplication with respect to Calves; this is not the case however. Calves have been split into two groups; Calves Born This Year (XCAV stream), and Calves On Hand (YCAV stream). This split assists in tracing the flow as it ages. For example, Ending Calf Inventory must all be due to this year's BIRTHS, while all Calves in the YCAV stream must be disposed of or allocated to non-Calf categories by year end.

In the discussion that follows, the calculation of the elements of the RECON output matrix are considered. An important part of the discussion concerns the assumptions made and the initial values of the parameters that are used.

As was the case with MATRIX, a critical problem is the disaggregation of statistical data to fit the structure of the model. This disaggregation is discussed in the next sub-section.

Data Base Disaggregation

The discussion of the data base follows closely the same discussion with respect to program MATRIX presented in Chapter III. To avoid undue duplication, this discussion will be abbreviated.

EXPORT and IMPORT data.--Since RECON is an annual model, only annual data are used. The first export category is Cattle Under 200 Pounds. These are assumed to be solely Male Dairy Calves.

A second export category is Cattle 200-700 Pounds. This flow is divided between Male/Female and XCAV/YCAV streams. The first case is self explanatory; however, the second may need further elucidation. The XCAV stream refers to Calves born this year while the YCAV stream refers to Calves born last year. Calves exported in this category may be either this year's or last year's Calves. A further assumption is made that only Beef Calves are exported in this category. The following parameters are employed.

Proportion of EXPORTS 200-700 Pounds from XCAV stream
V1 = .90

Proportion of Male Calves in EXPORTS 200-700 Pounds[1]
V2 = .135

The export category Other Dairy EXPORTS is assumed to be solely Dairy Cows and Heifers over two years of age. As such, it is in a form for direct use in the model.

The import category Other IMPORTS is assumed to be soley Steers and Heifers for Immediate SLAUGHTER. This category is further assumed to contain only Beef Cattle. The Male/Female separation remains. It is disaggregated by parameter V12.

Proportion of Steers in Other IMPORTS
V12 = .65

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[1]This parameter value is the subject of subsequent discussions in this chapter. This value by itself can be very misleading.

The Purebred EXPORTS and IMPORTS remain to be disaggregated into Beef/Dairy, Male/Female components. The following parameter values are used.

Proportion of Females in Purebred EXPORTS[1]
East, V3 = .90
West, V4 = .90

Proportion of Females in Purebred IMPORTS[2]
East, V5 = .80
West, V6 = .80

Proportion of Dairy in Purebred EXPORTS
East, V7 = .826
West, V8 = .826

Proportion of Dairy in Purebred IMPORTS
East, V9 = .20
West, V10 = .20

The final export category is Cattle Over 700 Pounds. As previously discussed, a fairly stable element in this category is Cull Cows; the transient element is Steers and Heifers for further feeding and Immediate SLAUGHTER. This was programmed using the following parameters. The critical limit referred to is 8,800 head of Cull Cows, 2,400 East and 6,400 West. The following parameters are used to model this feature.

Proportion of Steers in the non-Cull Cow portion of EXPORTS, Cattle Over 700 Pounds, V14 = .35

Proportion of Cull Cows in EXPORT Cattle Over 700 Pounds
Under a critical limit, V15 = .80
Over a critical limit, East, V16 = .10
West, V17 = .05

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[1]These parameter values differ slightly from the values used ultimately in CATSIM and MATRIX; however, all models prove to be relatively insensitive to these parameters.

[2]*Ibid.*

SLAUGHTER data.--Calf SLAUGHTER is assumed to be totally Dairy Calves. Cow SLAUGHTER must be divided between Dairy and Beef Cows, however; the following parameters are employed.

Proportion of Beef Cows in Cow SLAUGHTER, East
V20 = .10

Proportion of Dairy Cows in Cow SLAUGHTER, West
V21 = .18

While the above applies to INSPECTED SLAUGHTER, a second and major category is UNINSPECTED SLAUGHTER. The following are used to disaggregate UNINSPECTED SLAUGHTER.

Proportion of Males in UNINSPECTED Calf SLAUGHTER[1]
East, V22 = .65
West, V23 = .50

Proportion of Steers in UNINSPECTED Cattle SLAUGHTER[2]
(non-Cow, non-Bull UNINSPECTED Cattle SLAUGHTER)
East, V24 = .615
West, V25 = .30

Proportion of Cows in UNINSPECTED Cattle SLAUGHTER
East, V26 = .28
West, V27 = .25

Proportion of Bulls in UNINSPECTED Cattle SLAUGHTER
East, V28 = .06
West, V29 = .06

WEST-EAST Cattle-Calf Movement data.--The data available on WEST-EAST Cattle-Calf Movement covers only Cattle and Calves moved by rail; however, this is believed to be the bulk of such shipments. The

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[1]These parameters are discussed in detail later in this chapter. These values are very tentative and should be treated as such.

[2]Ibid.

data is divided into Cattle and Calves. Each in turn is recorded as to destination, SLAUGHTER, FEEDLOT, and STOCKYARD. All are assumed to be Beef Cattle. The disaggregation is in terms of sex; the following a priori parameter values are used initially.

Proportion of Males in WEST-EAST Calf Movements to FEEDLOTS and STOCKYARDS
V32 = .80

Proportion of Males in WEST-EAST Cattle and Calf Movement for SLAUGHTER
Calves, V33 = .95
Cattle, V35 = .95

Proportion of Males in WEST-EAST Cattle Movement to FEEDLOTS and STOCKYARDS
V = .80

DEATH Rates.--DEATH Rates are assumed to be similar for Dairy and Beef, Males and Females. Differentiation, however, is made between Calves in the XCAV and YCAV streams and Cattle over one year.

Calves XCAV stream, East, XDRME[1] = .03
XDRFE = .03

West, XDRMW = .03
XDRFW = .03

Calves YCAV stream, East, YDRME = .03
YDRFE = .03

West, YDRMW = .03
YDRFW = .03

Cattle over one year, East, DRE = .015
West, DRW = .015

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[1]In all variable names E and W refer to East and West, M and F to Male and Female while B and D refer to Beef and Dairy.

A further parameter is used to proportion Calf DEATHS between the XCAV and YCAV streams.

Proportion of first year Calf DEATHS occurring in the XCAV streams
V38 = .60

BIRTH Rates.--Two BIRTH Rates were used, one for Beef Cattle and the second for Dairy Cattle.

Beef Cow BIRTH Rate, East, BRBFE = .85
West, BRBFW = .85

Dairy Cow BIRTH Rate, East, BRDYE = .75
West, BRDYW = .765

Description of the Model (RECON)[1]

RECON generates BIRTHS by applying a BIRTH Rate to the Cow Population plus that portion of the Heifer Population expected to freshen during the ensuing year. Dairy Cow Population is taken as an average of December 1 plus June 1 STATCAN Inventory. Beef Cow Population is taken as the December 1 STATCAN Inventory of Beef Cows. Separate BIRTH Rates are used for Beef and Dairy; in fact, separate Dairy BIRTH Rates are used for East and West. These rates are initially given by a priori knowledge of the sub-sector and then adjusted upward or downward as indicated by the consistency required in the model.[2]

[1]The discussion in this section follows the form of identities (84) and (85). Together these identities form one row in the output format displayed in Table 15.

[2]The structure of RECON with respect to BIRTHS is discussed in more detail in a subsequent sub-section.

Table 15. Report format for program RECON

	Beginning inventory	Born	Transfer in	Import	Total sources	Died	Slaughter	Export	Transfer out	Ending inventory	Total disposition	Error
BULLS	12[illegible].		33895.	747.	156641.	2032.	27825.	814.		126000.	156641.	
DAIRY COWS	5[illegible].		86651.	597.	596259.	7612.	91350.	11296.		486000.	596259.	
DAIRY HEIFERS	1[illegible].		117128.		219128.	1582.	32884.		86661.	98000.	219128.	
BEEF COWS	2423000.		422386.	2389.	2847775.	36345.	205269.	7161.		2599000.	2847775.	
BF HFR REPLACE			428722.		428722.	6336.	.		422386.		428722.	
BF HFR FEEDING	565000.		642055.	5901.	1212967.	10527.	394271.	7842.		620000.	1053196.	159771.
STEERS	535000.		1015476.	10960.	1561436.	11392.	934087.	4223.		528000.	1651803.	-90367.
TOTAL CATTLE	4255[illegible].		2746333.	20594.	7022927.	75778.	1685687.	31336.	509048.	4457000.	6953524.	6[illegible]04.
ML BF CALVES		1209869.			1209869.	21778.	.	564.	209976.	977551.	1209869.	-53080.
FM BF CALVES		1209869.			1209869.	21778.	.	3612.	51401.	1133077.	1209869.	-38945.
ML DY CALVES		194119.			194119.	3494.	36651.	59.		153915.	194119.	
FM DY CALVES		194119.			194119.	3494.	40431.	.		150193.	194119.	-92025.
SUBTOTAL		2807975.			2807975.	56544.	77083.	4235.	261377.	2414736.	2807975.	8736.
ML BF CALVES	934199.				934199.	11210.		63.	922926.		934199.	
FM BF CALVES	1084199.				1084199.	13010.		401.	1070787.		1084199.	
ML DY CALVES	141584.				141584.	1699.	13438.	2.	126445.		141584.	
FM DY CALVES	133509.				133509.	1602.	14779.	.	117128.		133509.	
SUBTOTAL	2293491.				2293491.	27522.	28217.	466.	2237286.		2293491.	
TOTAL CALVES	2293491.	2807975.			5101466.	78065.	105300.	4701.	2237286.	2414736.	5101466.	

Calf DEATHS are calculated for the XCAV stream by applying a DEATH Rate to Calf BIRTHS. Provision is made in the model to have different Male and Female DEATH Rates. In addition, a second parameter is provided to allocate DEATHS between the XCAV and YCAV streams. This parameter, V38, accounts for the proportion of time (Calves x days) between the two streams--it is set by informed judgment. YCAV stream DEATH Rates are set based on a study done by Agriculture Canada. Thus XCAV stream Rates are the Rates that will be varied, if Calf DEATH Rates are varied.

Calf SLAUGHTER in the XCAV stream is assumed to be totally Dairy Calves for veal; thus, Beef Calf SLAUGHTER is zero. Calf SLAUGHTER is made up of INSPECTED plus INSPECTED SLAUGHTER; the latter is divided between Male and Female by parameters V22 and V23.

Calf EXPORTS are considered next. It is assumed that all Cattle EXPORTS Less Than 200 Pounds are Male Dairy Calves. These are divided between the XCAV stream and the YCAV stream by the parameter V1. These EXPORTS are further split between Male and Female by parameter V2. Beef calving distribution and other a priori information give initial clues to likely values for these parameters.

The final columns considered in the XCAV stream are Ending Inventory and "ERROR." Ending Inventory is calculated by subtracting DEATHS, SLAUGHTER, and EXPORTS from BIRTHS. The "ERROR" is calculated by comparing this figure with the official December 1 Calf Population.

Calves on Hand (the YCAV stream).--Beginning Inventory for the YCAV stream in period t is the Ending Inventory of the XCAV stream in period t-1.

DEATHS are calculated by applying DEATH Rates to the Beginning Inventory. As previously mentioned, parameter (1-V38) is used to weight DEATHS in the YCAV stream.

The assumption is made that no Calves are slaughtered from the YCAV stream. This assumption is applied consistently to MATRIX and CATSIM as well.

It is assumed that no Dairy Calves are exported. The EXPORTS from the YCAV stream are based on published Cattle EXPORTS 200-700 Pounds using parameters (1-V1), and V2 as discussed under the XCAV stream.

Ending Inventory is zero. This occurs as all Calves on hand January 1st must pass one year of age on or before December 31st. TRANSFER OUT is calculated by subtracting TOTAL DISPOSITIONS from TOTAL SOURCES. No consistency check can be made on the YCAV stream as was done with the XCAV stream, that is, no "ERROR" term can be calculated.

Bulls.--Beginning Inventory of Bulls is that given by the December 1 official Bull Population. IMPORTS are taken from Purebred IMPORTS by using parameters V5 and V6 to separate Females from total. At this stage there is no reliable information available on the magnitude of these parameters. DEATHS are calculated by multiplying a DEATH Rate by average December 1 and June 1 Bull Population. This same DEATH Rate applies to all Cattle over one year of age. Bull SLAUGHTER is taken directly from published INSPECTED Bull plus UNINSPECTED Cattle SLAUGHTER statistics. In the case of the latter, only a portion is used. The Bull portion is separated by using parameters V28 and V29. EXPORTS are calculated from Purebred EXPORTS using parameters V3 and V4 to separate Females from total.

Ending Inventory is taken from December 1 Bull Population. The only missing column is TRANSFER IN or Bull REPLACEMENTS. This is the value (number of head) that will equate TOTAL SOURCES with TOTAL DISPOSITIONS.

Dairy and Beef Cows.--Dairy and Beef Cow Beginning Inventory is taken from the December 1 official statistics published for year t-1. IMPORTS are calculated from published Purebred IMPORTS using parameters V5 and V6 to separate Cows from total. Parameters V9 and V10 are used to separate IMPORTS into Beef and Dairy. DEATHS are calculated by applying a DEATH Rate to Beginning Inventory. SLAUGHTER is considered by applying parameters V20 and V21 to separate published Cow SLAUGHTER into its Beef and Dairy components. The method used, which is consistent with MATRIX, is to calculate Dairy (Beef) Cow SLAUGHTER as a proportion of Inventory. Beef (Dairy) Cow SLAUGHTER is the difference between total Cow SLAUGHTER and calculated Dairy (Beef) Cow SLAUGHTER. Total Cow SLAUGHTER includes INSPECTED plus a portion of UNINSPECTED Cattle SLAUGHTER. This portion is separated by parameters V26 and V27.

EXPORTS are calculated by using parameters V3 and V4 to separate Purebred Cow EXPORTS from total published Purebred EXPORTS. In addition, Cows are exported in the category Cattle Over 700 Pounds. Parameters V15, V16, and V17 are used to indicate the Cow proportion in this category. In the case of Dairy Cows, there is still another category of EXPORTS, namely, Other Dairy EXPORTS. These data can be used directly.

Ending Inventory of the Dairy and Beef Cows is taken directly from published Cow Population for December 1.

As in the case of Bulls, the column still unaccounted for is TRANSFER IN or REPLACEMENTS. This figure is the number of Cattle that will balance TOTAL SOURCES with TOTAL DISPOSITIONS.

Dairy Heifers.--Beginning Inventory of Dairy Heifers is calculated from published Dairy Heifer Population, December 1, for year t-1. TRANSFER IN is set equal to TRANSFER OUT for Female Dairy Calves in the YCAV stream. Dairy Heifer DEATHS are calculated by applying a DEATH Rate to average December 1 and June 1 published Dairy Heifer Population. TRANSFER OUT is set equal to TRANSFER IN for Dairy Cows. Ending Inventory is calculated from published Dairy Heifer Population, December 1 in year t. In the case of Dairy Heifers, the missing item is SLAUGHTER. It is the number of head required to balance TOTAL SOURCES with TOTAL DISPOSITIONS.

Beef Heifers.--Beef Heifers are divided into two categories: those for REPLACEMENT and those for SLAUGHTER. For REPLACEMENT Heifers, TRANSFER OUT is set equal to Beef Cow TRANSFER IN. TRANSFER IN is set at (1 + DEATH Rate) times TRANSFER OUT. DEATHS = TRANSFER IN minus TRANSFER OUT.

Beginning Inventory for Beef Heifers Feeding is taken from published Beef Heifer Population, December 1 in year t-1. IMPORTS are taken from published Other Cattle IMPORTS by applying parameter V12 to separate Male from total. EXPORTS are taken from published EXPORTS Over 700 Pounds by applying parameter V14 to separate Male from the non-Cow portion of this EXPORT category.

SLAUGHTER is calculated from published INSPECTED and UNINSPECTED SLAUGHTER less calculated Dairy Heifer SLAUGHTER. In the case of UNINSPECTED SLAUGHTER, parameters V24, V25, V26, V27, V28, and V29 are used to separate Heifers from total. TRANSFER IN is calculated by subtracting Replacement Heifers TRANSFER IN from YCAV stream Female Beef Calves TRANSFER OUT. DEATHS, and ENDING INVENTORY are calculated in the usual manner.

In this instance, all relevant columns have been calculated. A check on consistency is given by comparing TOTAL SOURCES with TOTAL DISPOSITIONS. The difference is given under "ERROR."

<u>Steers</u>.--Not enough information is currently available to separate Dairy from Beef Steers; consequently, they are considered together under Steers.

Beginning and Ending Inventory, as well as DEATHS, are calculated in the usual manner. IMPORTS are calculated from published

Other Cattle IMPORTS by applying parameter V12 to separate the Male portion. EXPORTS are calculated from published EXPORTS Over 700 Pounds, again applying a parameter V14 to the non-Cow portion.

TRANSFER IN is calculated by summing TRANSFER OUT from Dairy and Beef Male Calves in the YCAV stream minus TRANSFER IN for Bulls.

SLAUGHTER is calculated by summing published INSPECTED and UNINSPECTED SLAUGHTER. In the case of the latter, the Male portion is calculated by using parameter V24 and V25.

As was the case with Beef Heifers, all columns have been calculated. Thus, comparison of TOTAL SOURCES with TOTAL DISPOSITIONS provides a consistency check. The difference is given under "ERROR."

Analysis and Evaluation

The output of RECON is an annual matrix (for each of 14 years, 1959-1972 inclusive) presenting beginning and ending stock values for 15 livestock cohorts together with the interconnecting flow values for seven major flow variables. The purpose of the model is to assess these stock and flow values which are the published statistical data series. The major method of analysis is a test of consistency; to execute the analysis, the concept of objectivity is employed. The results or output of RECON also substantiates, at an aggregate level, the results or output of MATRIX and CATSIM. In turn, the knowledge and information obtained from utilizing RECON is used to construct or revise these latter two models.

The analysis of the data base involves applying the four tests of objectivity. Internal consistency is obtained through model design; this has been discussed in the previous sections. External consistency is checked through comparison of RECON output with published data series. Another test of external consistency involves comparison of RECON output with commonly held beliefs about the Cattle-Calves sub-sector. The tests of interpersonal transmissibility and usefulness cannot be fully applied until RECON is operated interactively with individuals knowledgeable of the Cattle-Calves sub-sector. This will occur subsequent to this study.

To assist with the analysis, the concept of the data as a hypothesis was compromised. One data series, INSPECTED SLAUGHTER, is commonly believed to be the most reliable of all data series used in these models. Two identities, Steers and Beef Heifer Feeding, include INSPECTED SLAUGHTER as the major component on the right hand or DISPOSITION[1] side. An "ERROR" element is calculated for each of these two identities as well as a third "ERROR" element that is the algebraic sum of the first two. This "ERROR" is calculated by subtracting DISPOSITIONS from SOURCES. A negative "ERROR" indicates that SOURCES is too low relative to DISPOSITIONS (believed to be reasonably correct) and vice versa.

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[1]The element SLAUGHTER includes both INSPECTED <u>and</u> UNINSPECTED. Later in this analysis, the initial assumptions made concerning UNINSPECTED SLAUGHTER will be called into question.

A very simple objective function is used--it is simply the algebraic sum of the "ERROR" element for any one identity for the 14 observations (1959-1972 inclusive). Variation in the annual "ERROR" values constitute a significant part of the analysis.

Calf Births

RECON calculates Calf BIRTHS in the following manner. A BIRTH Rate is applied to Cow Inventory (Cows and Heifers over two years) plus that portion of Heifers (Females 1-2 years) expected to freshen in the ensuing year.

For Dairy Cows, the Cow Inventory estimate is the average of June 1 and December 1 STATCAN estimates. No Heifers (Females 1-2 years) are added to this base as a priori information indicated that Dairy Heifers freshen with a mean age of two years nine months.

The Inventory of Beef Cows is taken as the December 1 STATCAN estimate. To this figure is added a portion of Beef Heifers (Females 1-2 years) as given by STATCAN's December 1 estimates. An examination of observations for 1958-1972 inclusive, indicates that an approximate average of 30 percent of Eastern Heifers and 75 percent of Western Heifers enter the Cow Herd annually.

The initial BIRTH Rates were selected and restricted by a priori knowledge or beliefs about the sub-sector. First, it was believed that the Beef Cow BIRTH Rate was higher than the Dairy Cow BIRTH Rate. The former would be expected in the .80 to .90 range, while the latter would be expected in the .70 to .80 range. Second, it was believed that the Western Dairy Cow Herd was managed more like the Beef Herd than was the case in the East, at least at the margin. Third, it was believed that WEST-EAST Cattle-Calf Movement statistics underestimated the actual eastward movement. Fourth, there was no reason to believe that BIRTH Rates differed markedly between East and West for Beef Cattle, or for Dairy Cattle for that matter. Finally, the Dairy Cattle BIRTH Rate must be high enough to supply the demand for Replacement Dairy Heifers.

Since the West has a very high proportion of Beef Cattle, while the opposite holds true for the East, a "reasonable" Beef BIRTH Rate was selected for the East and the Dairy BIRTH Rate was adjusted until a "small" negative Steer + Beef Heifer Feeding "ERROR" was obtained.

The same procedure was used for the West except, in this instance, a "reasonable" Dairy BIRTH Rate was used. The Beef BIRTH Rate was incremented until a "small" positive Steer + Beef Heifer Feeding "ERROR" was obtained.

Adjustments in all Rates were made until Eastern and Western Beef BIRTH Rates were equal and the Western Dairy BIRTH Rate equalled the Eastern Dairy BIRTH Rate + .015[1] and all rates fell within a priori ranges. In addition, BIRTH Rate adjustments were made until the Eastern and Western "ERRORS" were equal in magnitude but opposite in sign. As was expected, the Western "ERROR" was positive while the Eastern was

[1]The constant .015 was arbitrarily selected to fall between the Eastern Dairy BIRTH Rate and the Beef BIRTH Rate, to reflect the assumption that the Western Dairy Herd is treated, at the margin, as a Beef Herd.

negative indicating that the statistical WEST-EAST Movement underestimated the actual flow.

The final BIRTH Rates selected were:

East, Beef = .85		West, Beef = .85	
	Dairy = .75		Dairy = .765

BIRTHS generated by the above process were compared with STATCAN's semi-annual BIRTHS as a test of consistency and a check on bias and/or trend. The results appear in Table 16.

From Table 16, it is shown that in the West, STATCAN overestimates Calf BIRTHS by an average of 46,241 head per year or by 1.5 percent of BIRTHS. This could be explained entirely in terms of Calf DEATH Rate.[1] The sign of these "differences" is as expected. A priori, it would be expected that RECON would underestimate BIRTHS in periods of expansion (giving a negative sign) and overestimate BIRTHS in periods of contraction (giving a positive sign) due to the cattle cycle, which is not modeled by RECON.

STATCAN overestimates Eastern Calf BIRTHS consistently by an average of 260,000 head. This difference varies from 8-17 percent over the RECON estimate. Part of this difference can be explained in terms of an actual DEATH Rate which might be higher than that used in RECON. I concur with Lee[2] that it is unrealistic to expect DEATH Rate

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[1]The calf DEATH Rate used in RECON are taken from Yang; however, his estimates show some variance. In addition, a priori information would indicate that these DEATH Rates are a lower bound.

[2]Lee, op. cit.

Table 16. A comparison of RECON generated Calf BIRTHS with Statistics Canada's semi-annual BIRTH estimates, 1958-1972

Year	West		East	
	Difference[a]	Difference / RECON Births	Difference[a]	Difference / RECON Births
	(head)	(ratio)	(head)	(ratio)
1958	-136,733	-.0618	-163,245	-.0800
1959	-65,514	-.0294	-161,279	-.0806
1960	-75,687	-.0330	-175,675	-.0876
1961	-128,612	-.0539	-202,407	-.1001
1962	-54,818	-.0223	-181,941	-.0887
1963	-28,935	-.0114	-219,484	-.1074
1964	19,142	.0071	-271,299	-.1328
1965	51,052	.0177	-324,841	-.1584
1966	-16,975	.0058	-302,268	-.1508
1967	3,695	.0013	-313,196	-.1593
1968	19,592	.0071	-343,923	-.1746
1969	25,330	.0093	-351,317	-.1793
1970	-92,025	-.0328	-349,554	-.1784
1971	-191,198	-.0646	-298,657	-.1544
1972	-21,929	-.0069	-241,711	-.1256
Ave.	-46,241		-260,000	

[a]Formula: DIFFERENCE = RECON BIRTHS - STATCAN BIRTHS.

to account for the total discrepancy in this instance, even though Dairy Calf DEATH Rate may be very high. It should also be noted that the discrepancy has tended to widen over the 1958-1972 period.

A second consistency check was made against data from the Dairy Correspondent Survey. The annual sum of the Cows and Heifers to FRESHEN This Month[1] item from that survey was subtracted from the RECON estimate of Dairy BIRTHS. The results are shown in Table 17.

The Dairy Correspondent Survey overestimates BIRTHS by 9 to 27 percent in the West, and by 15 to 29 percent in the East. There is some indication that the difference is narrowing through the survey period.

Ending Calf Inventory

Program RECON was designed to divide Calves into two categories: those in inventory at the beginning of the year, and those during the year. Only those born during the year would be on ending inventory at year end.

Ending Inventory is calculated as follows:

$$\text{Ending Inventory} \equiv \text{BIRTHS} - \text{DEATHS} + \text{TRANSFER IN} - \text{TRANSFER OUT} - \text{SLAUGHTER} + \text{IMPORTS} - \text{EXPORTS}.$$

DEATHS are calculated by applying a DEATH Rate while SLAUGHTER (INSPECTED + UNINSPECTED) is taken as given by STATCAN. IMPORTS

[1]The freshening ratio from that survey is applied to STATCAN's December 1 and June 1 Milk Cow data series to scale up the actual Dairy Correspondent Survey data.

Table 17. A comparison of RECON generated Dairy Calf BIRTHS with Statistics Canada's Dairy Correspondent Survey, "Estimates of Cow and Heifers to FRESHEN This Month," 1958-1972

Year	West		East	
	Difference[a]	Difference / RECON BIRTHS	Difference[a]	Difference / RECON BIRTHS
	(head)	(ratio)	(head)	(ratio)
1958	-141,671	-.2253	-425,308	-.2573
1959	-150,970	-.2460	-411,223	-.2548
1960	-164,713	-.2690	-412,639	-.2576
1961	-162,587	-.2711	-479,403	-.2979
1962	-107,516	-.1767	-360,828	-.2232
1963	-115,310	-.2000	-315,394	-.1993
1964	-93,720	-.1679	-317,449	-.2025
1965	-89,605	-.1689	-439,167	-.2809
1966	-80,331	-.1646	-336,438	-.2193
1967	-75,111	-.1677	-264,550	-.1765
1968	-39,155	-.0940	-271,866	-.1855
1969	-69,670	-.1769	-255,204	-.1764
1970	-53,080	-.1367	-217,147	-.1534
1971	-80,624	-.2165	-267,045	-.1991
1972	-60,051	-.1730	-257,174	-.1983
Ave.	-98,941		-335,389	

[a]Formula: DIFFERENCE = RECON Dairy BIRTHS - DCS Dairy FRESHENINGS.

are zero while EXPORTS are taken as published by STATCAN. These data series have all been discussed previously.

The remaining elements are TRANSFER IN and TRANSFER OUT. These elements are entirely made up of Calves shipped from West to East. These shipments are recorded in the data series WEST-EAST Calf Movement for those Calves shipped by rail. As previously mentioned, additional Calves are believed to be shipped by other means.

Once again, the "ERROR" in Steer + Beef Heifer Feeding was used to augment rail shipments. A factor of 1.07 (parameter V40 in RECON) is used to scale up rail shipments. This factor has the effect of reducing the above "ERROR" to zero for both East and West, since BIRTH Rates were calculated in such a manner as to make this happen (i.e., equal magnitude but opposite sign).

With TRANSFER IN and TRANSFER OUT adjusted by a factor of 1.07, a comparison was made between RECON's Ending Calf Inventory and STATCAN's December 1 Calf Population. These results are shown in Table 18.

An average overestimation of 27,362 head occurred in the Western STATCAN Calf Population. This error is fairly consistent with the average overestimation of BIRTHS by 46,241 head. The sign (or direction) of the year by year discrepancy is consistent between BIRTHS and Ending Inventory for all years except 1964, 1965, 1970, 1971, and 1972. As previously mentioned with Calf BIRTHS, these discrepancies are largely explained by the cattle cycle. In addition, the average discrepancy is rather small and can be accounted for by a slightly higher DEATH Rate.

Table 18. A comparison of RECON generated Ending Calf Inventory with Statistics Canada's December 1 Calf POPULATION estimates 1958-1972

Year	West		East	
	Difference[a]	Difference / RECON Inventory	Difference[a]	Difference / RECON Inventory
	(head)	(ratio)	(head)	(ratio)
1958	-75,301	-.0340	209,307	.1549
1959	-28,382	-.0163	205,789	.1470
1960	-14,975	-.0082	183,436	.1289
1961	-98,886	-.0584	139,835	.0937
1962	-84,989	-.0476	67,324	.0463
1963	-87,357	-.0429	146,292	.0994
1964	-148,205	-.0685	166,459	.1111
1965	-118,627	-.0564	135,705	.0978
1966	-3,812	-.0018	252,681	.1685
1967	55,997	.0255	253,658	.1662
1968	28,122	.0131	267,021	.1752
1969	21,491	.0094	252,728	.1660
1970	8,736	.0036	326,542	.2073
1971	53,847	.0209	389,228	.2436
1972	81,908	.0300	353,237	.2195
Ave.	-27,362		223,283	

[a]Formula: DIFFERENCE = RECON Inventory - STATCAN Population.

For the East, the STATCAN data series seems highly inconsistent with RECON. In addition, STATCAN's December 1 Calf Population is highly inconsistent with STATCAN BIRTHS. While it was previously noted that STATCAN BIRTHS overestimate RECON BIRTHS by 8 to 17 percent, STATCAN December 1 Calf Population underestimates RECON by 5 to 24 percent. The trend in these two data series is to a widening discrepancy.

REPLACEMENT Cattle

In the previous sub-section it was stated that Calves were considered under two categories, the second of these were Calves on Hand at the beginning of the year. By the end of the year, all such Calves, of definitional necessity, must have transferred to non-Calf categories. The following itemizes the possible transfers.

Dairy Bull Calves Beef Bull Calves	to	Bull REPLACEMENTS or Steers
Dairy Heifer Calves	to	Dairy Cow REPLACEMENTS
Beef Heifer Calves	to	Beef Cow REPLACEMENTS or Feeder Heifers

The calculation of REPLACEMENTS (TRANSFERRED IN) is made through the following identity for Dairy Cows, Beef Cows, and Bulls.

$$\text{REPLACEMENTS} = \text{Ending Inventory} - \text{Beginning Inventory}$$
$$+ \text{SLAUGHTER} + \text{EXPORTS} + \text{DEATHS} - \text{IMPORTS} + \text{TRANSFER OUT}$$

Since EXPORTS and IMPORTS are minor, errors will be of little significance. TRANSFER OUT is nil, while Beginning and Ending Inventory is given by the STATCAN December 1 estimates. The major sources of error occurs in dividing Cow SLAUGHTER between Beef and Dairy. Because the method used does not adequately account for the cattle cycle, RECON estimates are inferior to those made by MATRIX in Chapter III. Table 19 compares REPLACEMENTS with INVENTORY.

The REPLACEMENT Rates for both Beef and Dairy Cows are inferior to the same ratios that may be calculated from adjusted MATRIX output. This is the case as MATRIX output is adjusted for the cattle cycle, while RECON output is not so adjusted. Nevertheless, the Western Beef Rates do trace out a pattern that is consistent with that cycle. These rates should be tempered by the fact that some Herds are expanding while others are contracting. In general, the Beef Herd is expanding while the Dairy is contracting.[1]

The Bull REPLACEMENT Rate differs between the West and the East, with the Eastern Rate being almost twice the Western Rate. No explanation readily comes to mind.

The Sex Ratio of EXPORTS and WEST-EAST Cattle-Calf Movement

To this point in the analysis, the "objective" function has been used to minimize the "ERROR" in Steers + Beef Heifers Feeding. Since these two "ERRORS" were summed, the analysis abstracted from the sex ratio.

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[1]Over the 15 year sample period, the Western and Eastern Beef Herds grew at an average continuous rate of 4.5 and 3 percent, while the Western and Eastern Dairy Herds contracted at an average continuous rate of about 4 and 2 percent.

Table 19. A comparison of RECON estimated REPLACEMENTS with Inventory expressed in terms of a REPLACEMENT Rate, WEST and EAST, 1959-1972

A. WEST

Year	Dairy REPLACEMENTS[a] / Dec. 1 Inventory	Beef REPLACEMENTS[a] / Dec. 1 Inventory	Bull REPLACEMENTS[a] Average June 1 and / Dec. 1 Inventory
	(ratio)	(ratio)	(ratio)
1959	.1896	.1660	.3479
1960	.2052	.1724	.3321
1961	.2068	.1749	.3139
1962	.1396	.1993	.3337
1963	.1712	.1975	.3530
1964	.1544	.2205	.3719
1965	.1347	.2060	.3311
1966	.1134	.1735	.2814
1967	.1211	.1416	.2523
1968	.1440	.1504	.2308
1969	.1879	.1728	.2860
1970	.1703	.1943	.2539
1971	.1258	.1960	.3362
1972	.1793	.1884	.2936

[a]Formula: $\text{RATIO} = \dfrac{\text{REPLACEMENTS (Heifers or Bulls)}}{\text{Inventory (Cows or Bulls)}}$.

Table 19--Continued

B. EAST

Year	Dairy REPLACEMENTS[a] / Dec. 1 Inventory	Beef REPLACEMENTS[a] / Dec. 1 Inventory	Bull REPLACEMENTS[a] / Average June 1 and Dec. 1 Inventory
	(ratio)	(ratio)	(ratio)
1959	.1598	.1664	.5150
1960	.1927	.1507	.4918
1961	.1949	.1774	.5484
1962	.1823	.1800	.4804
1963	.1880	.1580	.5233
1964	.2175	.1456	.5350
1965	.2617	.0948	.5934
1966	.2133	.1019	.5259
1967	.1758	.1915	.5554
1968	.1986	.1372	.5819
1969	.2083	.2020	.5879
1970	.1993	.2248	.6217
1971	.1988	.1543	.6242
1972	.2458	.1706	.6186

[a]Formula: $\text{RATIO} = \dfrac{\text{REPLACEMENTS (Heifers or Bulls)}}{\text{Inventory (Cows or Bulls)}}$.

A priori information concerning the sex ratio of WEST-EAST Cattle-Calf Movement for SLAUGHTER were 90-100 percent Male, while the Cattle and Calves for FEEDLOT and STOCKYARD were 80 percent Male. A priori information about EXPORTS of Feeder Cattle to the United States indicated a sex ratio of 35-42 percent Male.

The procedure used to confirm or reject these ranges involved adjusting the sex ratio of WEST-EAST Movements until the Eastern "ERRORS" summed algebraically to zero. The sex ratios that provide this balance are 95 percent Male in SLAUGHTER and 80 percent Male in FEEDLOT and STOCKYARD Movements. The resultant "ERRORS" are given in Table 20A.

An attempt was then made to bring the Western "ERRORS" into balance by adjusting the sex ratio of EXPORTS, Cattle 200-700 Pounds. This was unsuccessful in that there were still excess Western Heifers on the average, when 100 percent of the above EXPORTS were considered as Heifers.[1] These "ERRORS" are listed in Table 20B.[2]

For the East, the average "ERRORS" are close to zero for both Steer and Beef Heifer, with the sign and magnitude of the "ERRORS" producing no distinct trend.

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[1]This aspect of CATSIM was modeled using a step function with some success. For 1958-1965 inclusive, EXPORTS were considered to be 60 percent Male; after 1965, EXPORTS were considered 0 percent Males (i.e., 100 percent Female).

[2]While the sex ratios of WEST-EAST Movements are not constant between Table 20A and Table 20B, this minor discrepancy does not effectively mask the inconsistency that is being revealed.

Table 20. A listing of Eastern and Western Steer and Beef Heifer Feeding "ERRORS" from given parameter settings,[a] 1959-1972, program RECON

A.

Year	WEST		EAST	
	Steers	Heifers	Steers	Heifers
	(head)	(head)	(head)	(head)
1959	79,991	-87,038	38,352	75,044
1960	6,151	-41,786	50,287	33,649
1961	46,475	-36,991	1,684	3,433
1962	48,108	-92,521	-13,408	30,165
1963	32,503	-122,023	-60,898	26,773
1964	-43,981	-32,813	-37,276	-32,251
1965	11,314	-24,258	-60,896	-134,891
1966	-55,931	-17,687	-95,157	-51,857
1967	-30,161	135,979	72,083	23,527
1968	-2,636	21,436	75,289	-4,323
1969	-34,366	13,936	38,231	-23,835
1970	-61,437	130,840	-51,103	385
1971	-1,403	89,496	10,198	58,546
1972	-49,691	129,013	34,879	4,100
Ave.	-3,933	4,685	162	605

[a]WEST-EAST Cattle and Calf Movement set at 95 percent Males, FEEDLOT, and STOCKYARD Cattle and Calf Movement set at 80 percent Males. EXPORTS, Cattle 200-700 Pounds set at 35 percent Males with UNINSPECTED Male SLAUGHTER at 0 percent (100 percent Female).

Table 20--Continued

B.

Year	WEST		EAST	
	Steers	Heifers	Steers	Heifers
	(head)	(head)	(head)	(head)
1959	127,100	-134,147	34,729	78,667
1960	-10,197	-25,438	46,766	37,169
1961	16,641	7,157	-3,159	8,276
1962	82,332	-126,746	-15,927	32,684
1963	54,938	-144,458	-69,376	35,251
1964	-94,105	17,312	-39,501	-30,026
1965	-54,287	41,343	-53,319	-142,468
1966	-42,199	-31,410	-91,846	-55,168
1967	-40,108	145,925	83,522	12,089
1968	-67,061	85,861	86,026	-15,060
1969	-105,366	84,936	48,156	-33,759
1970	-157,119	226,523	-51,736	1,019
1971	-92,613	180,706	8,011	60,732
1972	-145,882	225,204	29,708	9,272
Ave.	-37,709	38,461	861	-94

[a]WEST-EAST SLAUGHTER Cattle and Calf Movement set at 100 percent Males, FEEDLOT and STOCKYARD Movement 85.5 percent Males. EXPORTS, Cattle 200-700 Pounds set at 0 percent Males (i.e., 100 percent Females). UNINSPECTED Male SLAUGHTER at INSPECTED level.

The Western data presents an anomaly. The a priori assumptions used do not work; on the average there are too many Beef Heifers and too few Steers--by about 38,000 head annually. In addition, a distinct time trend is evident, that is, from 1960 through 1972 the Heifer surplus increased. More Heifers could not have been shipped to the United States because these shipments were set at 100 percent Heifers in the model. One logical conclusion is that UNINSPECTED SLAUGHTER is made up of more Beef Heifers and less Steers.[1]

The procedure used to explore this latter alternative was to initially accept a priori assumptions about sex ratios. Thus, for WEST-EAST Movements, SLAUGHTER was set at 95 percent Male and FEEDLOT-STOCKYARD Movements at 80 percent. The sex ratio of EXPORTS Cattle 200-700 Pounds was set at 35 percent Male. The Eastern Female UNINSPECTED SLAUGHTER[2] ratio was incremented until the Eastern "ERROR" came into balance. A separate Western Female UNINSPECTED SLAUGHTER ratio was then incremented until the Western "ERROR" also came into balance.[3] The results of this analysis are displayed in Table 20A. These results indicate that even at 100 percent Female, the "ERROR" (Western) does not come into balance, although it is close.

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[1]The original assumption was that UNINSPECTED SLAUGHTER had the same ratio as INSPECTED SLAUGHTER.

[2]For the balance of this sub-section UNINSPECTED SLAUGHTER refers to the non-Cow, non-Bull portion.

[3]The sex ratio of INSPECTED SLAUGHTER (excluding Cows, Bulls, and Calves) over the 1959-1972 period ranged from 25.3-30.9 percent Heifers in the East and 25.4-34.2 percent Heifers in the West.

The logical conclusion is that the a priori assumptions do not hold. The Steer content in EXPORTS Cattle 200-700 Pounds must be between 0 and 35 percent concurrently with the Heifer content in UNINSPECTED SLAUGHTER being between 30 and 100 percent. An infinite number of linear combinations would work. One such linear combination is 20.5 percent steers in EXPORTS, Cattle 200-700 Pounds and 70 percent Heifers in UNINSPECTED SLAUGHTER. A distinct trend in the "ERROR" still remains and must be resolved.

An assumption was made that the sex ratio in UNINSPECTED SLAUGHTER[1] is constant over the 1958-1972 period. Consequently, the sex ratio of EXPORTS, Cattle 200-700 Pounds must change over this period. A linear time trend was fitted with the sex ratio being about 50 percent Heifers in 1958 rising to 100 percent in 1972. This tact appeared to be successful for the years 1958-1966; however, the flow of EXPORTS dropped off from 1967-1972, severely reducing the impact of this change. Consequently, the discrepancy remained for those latter years. The results of this run are not listed.

The only possible conclusion, given the above assumptions, is that the sex ratio of <u>both</u> EXPORTS, Cattle 200-700 Pounds and UNINSPECTED SLAUGHTER changed over this period with <u>both</u> exhibiting a high Heifer proportion in the period 1967-1972.

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[1]This appears to be the case in the East; some degree of similarity might exist between East and West in this regard.

Yearling Cattle

The ratio of TRANSFER IN/Ending Inventory gives some index of the average length of stay in the Yearling categories. Theoretically, Replacement Heifers (1-2 years) should stay exactly one year in this category. Thus, the above ratio for Replacement Dairy Heifers should be one.

This same ratio for Beef Heifers (the sum of Replacements plus Feeders) and Beef Steers would be less than one, if the average length of stay is less than one year and vice versa. Another alternative involves believing in the reliability of flows (i.e., TRANSFER IN, SLAUGHTER, etc.) and using an a priori notion of average age of Feeder Cattle. Holding these beliefs then, the reliability of stocks (Beginning and Ending Inventory) can be tested for consistency. Since the author does not have any strongly held beliefs concerning the latter alternative, the former will be used. The results of this analysis appear in Table 21.

The Western Dairy Heifer ratio is about as expected for 1959-1965 but then becomes much "too high" and subsequently "too low." The explanation does not likely involve age of Heifer but rather classification of both Heifers and the Female offspring of Dairy Cows, some of which may be more Dual Purpose or crossbred Beef than Dairy. The ratio is substantially above one during the Herd contraction period, 1965-1969, and substantially below one during the subsequent expansion, 1970-1972.

Table 21. A comparison of RECON Estimated TRANSFER IN with Ending Inventory for all Yearling Cattle categories, 1959-1972, program RECON

A. WEST

Year	Dairy Heifers[a]	Beef Heifers[a]	Steers[a]
	(ratio)	(ratio)	(ratio)
1959	.9604	.9697	.4956
1960	1.0284	.7146	.5589
1961	1.0461	.6652	.5048
1962	1.0233	.8816	.5918
1963	.9349	.9413	.6016
1964	.8535	.7180	.6016
1965	1.0697	.6137	.6137
1966	1.3340	.6666	.5826
1967	1.1574	.5791	.5862
1968	1.5539	.5576	.5618
1969	1.3095	.5644	.5631
1970	.8279	.5723	.5264
1971	.6613	.6193	.5360
1972	.6870	.6057	.5418

[a]Formula: $\text{RATIO} = \frac{\text{Ending Inventory}}{\text{TRANSFER IN}}$.

Table 21--Continued

B. EAST

Year	Dairy Heifers[a]	Beef Heifers[a]	Steers[a]
	(ratio)	(ratio)	(ratio)
1959	.9195	1.0809	.8581
1960	.9144	1.0405	.7892
1961	.9423	1.0459	.8642
1962	.9073	1.0692	.9305
1963	.9337	1.0103	1.0227
1964	.9420	.9677	.8925
1965	.9471	.8442	.8274
1966	.9517	.9310	.9309
1967	.9173	.9971	.7881
1968	.9506	1.0278	.7749
1969	.9639	.9348	.7771
1970	.9151	.9853	.8592
1971	.7961	1.1522	.8629
1972	.8597	.9991	.7685

[a]Formula: $\text{RATIO} = \frac{\text{Ending Inventory}}{\text{TRANSFER IN}}$.

The Dairy Heifer ratio for the East is very stable except for 1971-1972. If Inventory and classification are correct, then a ratio of slightly less than one might be expected to account for DEATHS and culling of Heifers.

The Beef Heifer and the Beef Steer ratios for Western Canada will be biased by the sex ratio errors noted in the previous sub-section and listed in Table 20. If this bias were removed the effect would be to make these ratios even more consistent through time. Taking a typical Steer value as .5, this would imply that the average Steer is 1.5 years or 18 months old at slaughter. A typical Heifer value is .7, this value is made up of Replacement Heifers <u>and</u> Feeder Heifers in about equal proportions. This would imply that the average Slaughter Heifer is slaughtered at about 1.4 years of age or 16-17 months.

The Steer and Beef Heifer ratios for Eastern Canada are substantially higher than for Western Canada. A typical Heifer value is 1.0 while a typical Steer value is .85. If TRANSFER IN is accepted as correct, and it seems to be consistent with SLAUGHTER, then either Ending Inventory is high <u>or</u> Eastern Cattle are slaughtered at an older age than Western Cattle.

<u>Dairy Heifer SLAUGHTER</u>

An initial assumption was made that all Calf SLAUGHTER was of Dairy breeding. At another point in the analysis of RECON, it was stated that Dairy Cow BIRTH Rate must be adequate to generate Replacement Dairy Heifers.

Since the residual element in the Dairy Heifer identity is Dairy Heifer SLAUGHTER, this element merits examination in light of the above assumptions.

It is generally believed that few Dairy Heifers are slaughtered. One explanation might be that some progeny of "Dairy Cows" might be from Beef sires. Table 22 lists Dairy Heifer SLAUGHTER and compares SLAUGHTER to Beginning Inventory.

Dairy Heifer SLAUGHTER in the East appears to be more stable than in the West. The one negative Eastern value (1965) can be attributed to a model design that underestimates Beef Cow SLAUGHTER, leading to an overestimation of Dairy Cow SLAUGHTER thus making an unusual demand on Dairy Heifers. This explanation would also apply to 1964 and 1966. In most other years, from 15-30 percent of Beginning Inventory are slaughtered.

The rather eratic nature of Dairy Heifer SLAUGHTER in the West can possibly be traced to two sources. First, some misclassification might occur, so that the offspring of the Dairy Herd might oscillate between Dairy and Beef, depending on economic outlook. In addition, a given Heifer classified as a Dairy Heifer on one occasion might be classified as a Beef Heifer on a second occasion, depending on the farmer's intentions.

Second, some Female Calf SLAUGHTER may come from the Beef Herd. This would increase the number of Dairy Heifers on Inventory. A wide fluctuation in Beef Female Calf SLAUGHTER would thus cause wide fluctuations in the ratio being considered. The effect of these two

Table 22. A comparison of RECON Estimated Dairy Heifer SLAUGHTER with Dairy Heifer Inventory, 1959-1972, program RECON

Year	WEST		EAST	
	SLAUGHTER	SLAUGHTER as proportion[a] of Inventory	SLAUGHTER	SLAUGHTER as proportion[a] of Inventory
	(head)	(ratio)	(head)	(ratio)
1959	25,340	.1445	164,707	.3485
1960	3,229	.0183	123,080	.2505
1961	2,737	.0152	109,286	.2188
1962	53,497	.3075	162,831	.3185
1963	52,223	.3090	128,775	.2597
1964	66,303	.4196	72,583	.1455
1965	42,222	.2833	-34,133	-.0702
1966	23,768	.1801	36,491	.0798
1967	30,807	.2525	117,163	.2690
1968	-7,852	-.0689	75,128	.1680
1969	-14,815	-.1347	63,219	.1391
1970	32,884	.3224	105,861	.2357
1971	80,171	.8181	171,116	.3903
1972	49,502	.5500	24,485	.0633

[a]Formula: $\text{RATIO} = \dfrac{\text{Dairy Heifer SLAUGHTER}}{\text{Dairy Heifer Beginning Inventory}}$.

possible errors could conceivably provide the variation noted in Western Beef Heifer SLAUGHTER.

Model Accuracy

The overall accuracy or variation in RECON is demonstrated by summing algebraically the Steer plus the Beef Heifer Feeding "ERROR." This data is displayed in Table 23.

Two bases of comparison are used. In the first case, the "ERROR" is compared to total Steer plus Dairy Heifer plus Beef Heifer SLAUGHTER. As the major output of the system, SLAUGHTER seemed like a reasonable basis. The second comparison is between "ERROR" and TOTAL DISPOSITION of Cattle. Since "ERROR" is the sum of all the errors in all data series, for the seven Cattle series, this also appears as a reasonable basis for comparison.

Since the first basis has a much smaller denominator, the relative "ERROR" appears larger. In the West, with the exception of 1963 and 1967, the relative "ERROR" is 6 percent or less. The "ERRORS" appear reasonably random. The "ERROR" in the East appears less random and reaches major proportions in 1959-1960 and 1965-1967.

When the second basis of comparison is used, the relative "ERROR" becomes very small (less than 2 percent) in all but two cases.

Generally, this simple model constructed entirely of identities and naive relationships may be considered as quite consistent internally with the data series being acceptably accurate except where noted.

Table 23. A comparison of RECON "ERROR" with selected data bases

	WEST			EAST		
		ERROR as a proportion[a] of			ERROR as a proportion[a] of	
Year	Error	SLAUGHTER	DISPOSITION	Error	SLAUGHTER	DISPOSITION
	(head)	(ratio)	(ratio)	(head)	(ratio)	(ratio)
1959	-7,048	-.0102	-.0013	113,396	.1469	.0198
1960	-35,635	-.0450	-.0063	83,935	.1000	.0147
1961	9,484	.0105	.0016	5,117	.0062	.0009
1962	-44,414	-.0549	-.0075	16,757	.0195	.0028
1963	-89,520	-.0972	-.0143	-34,125	-.0380	-.0057
1964	-76,794	-.0699	-.0112	-69,529	-.0691	-.0109
1965	-12,945	-.0123	-.0018	-195,787	-.1717	-.0307
1966	-73,609	-.0635	-.0104	-147,014	-.1421	-.0244
1967	105,817	.0882	.0155	95,610	.0942	.0161
1968	18,800	.0199	.0028	70,966	.0670	.0118
1969	-20,430	-.0155	-.0030	14,397	.0134	.0024
1970	69,404	.0510	.0100	-50,718	-.0487	-.0084
1971	88,093	.0627	.0120	68,743	.0667	.0117
1972	79,322	.0527	.0102	38,979	.0361	.0065

[a]Formula: $\text{RATIO} = \dfrac{\text{Steer + Heifer Feeding "ERROR"}}{\text{SLAUGHTER } \underline{\text{or}} \text{ TOTAL DISPOSITIONS}}$.

CHAPTER V

THE CATTLE HERD SIMULATOR

The computer program that simulates the dynamics of the Cattle Herd is called CATSIM.[1] It is the main or focal program in this study. Because of the sheer bulk of the program and the initial requirement to build and debug, the program was built in four parts. The parts are Dairy East, Beef East, Dairy West, and Beef West. The two Eastern parts were subsequently merged to form CATSIM East; and similarly, the West to produce CATSIM West.

A comprehensive knowledge of the simulator can only be gained by a line by line study of CATSIM. The purpose of this chapter, however, is to provide an appreciation of the model through a general discussion of its parts, their interrelationships, the assumptions made, and the parameter values used. The first section of this chapter provides an overview of the model; the second section discusses the model in detail.

A Model Overview

The model of the Cattle Herd, that is simulated by CATSIM, is divided into four parts:

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[1]Three versions of this basic model are developed. They are CATSIM 1, CATSIM 2, and CATSIM 3. Unless otherwise indicated, this chapter will use the name CATSIM when referring to all three versions. A listing of CATSIM 2 West in provided in Appendix E.

1. Beef Cattle West,
2. Dairy Cattle West,
3. Beef Cattle East, and
4. Dairy Cattle East.

The structure of each is deliberately designed to be virtually identical. Thus, the following discussion applies to any or all the four parts. It also follows Figures 18 to 26, which are the exact block diagrams of the above four parts of the model.[1]

The basic element in the model is the Cow Herd.[2] The size of the Cow Herd changes with SLAUGHTER (CULL), IMPORTS, EXPORTS, DEATHS, and addition of Replacement Heifers. The size of the Cow Herd increases due to favorable expectations; there is a reduction of Slaughter Heifers as additional Heifers are retained as REPLACEMENTS. After a two or three year lag, allowing for gestation and progeny maturation, the SLAUGHTER flow is increased. Since ceteris paribus, prices move in the opposite direction to quantities, adverse prices might now reverse the process after appropriate lags. These changes in the size of the Cow Herd lead to further changes in prices and price expectations, which lead to still further changes in the Cow Herd. Thus the Cow Herd is basic to the phenomenon known as the cattle cycle. Consequently, investment (REPLACEMENT) and disinvestment (CULLS) form a major part of this model, providing it with its cyclical motion.

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[1]Appendix B discusses exact block diagrams and explains the symbols used.

[2]A notational convention is followed to denote stock and flow variables. This convention is given in Table 2, pages 50-51.

The Cow Herd is defined as female stock two years and older (Beef and Dairy). This allows comparison of the simulated Cow Herd with Statistics Canada's semi-annual Livestock Survey.

Generation of a Calf crop is produced by breeding the Cow Herd and allowing for a nine month gestation delay. Three aspects are considered at this point:

1. the nine month gestation delay,
2. the birth distribution over the year, and
3. the live BIRTH Rate.

Observation of the exact box diagrams will reveal that First Calf Heifers are treated differently than Mature Cows. This is so with respect to: (1) that portion of gestation occurring after two years of age, and (2) live BIRTH Rate. The former is due to the structure of the model and the age at which Heifers are bred. This structure is discussed in detail in the next section. The latter is a hypothesis that may or may not be true.

The BIRTHS from First Calf Heifers and Mature Cows are combined to produce the Calf crop. This in turn is split between Male and Female Calves. Initially, it is assumed that the sex ratio is .5; this also is a hypothesis and thus subject to subsequent change.

The Calves are subsequently aged through a series of discrete (fixed length) and continuous (variable length) delays,[1] simulating the

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[1]Delays and simulation of delays are discussed in detail in Appendix B.

growing and feeding-finishing processes until they are either slaughtered or added to the Breeding Herd. Through time, addition and attrition occurs due to EXPORTS, IMPORTS, SLAUGHTER, and DEATHS. The following discussion follows these processes looking at each of the several identified stages (delays).

Shortly after birth a certain number of Calves are exported. These Calves are mainly Dairy Males ("bob" Calves) from the East to the United States, although increasing numbers are being shipped to Europe. In addition, the model allows for attrition due to DEATH at the beginning of each period.

At the end of the first period (three months of age) a number of Calves are slaughtered for veal. While Veal SLAUGHTER is currently Male Dairy Calves, it has not necessarily been the case historically. In addition, all Veal is not necessarily slaughtered at three months of age; however, this is a reasonable approximation.

At the end of the second period (six months of age), Calf numbers are adjusted for the flow of Stock Calves. This includes EXPORTS mainly to the United States, as well as Movements from Western to Eastern Canada. This point in time approximates weaning age as well as the first point in time at which Calves are normally placed on feed.

At this point also, the Calves are directed along one of two streams which correspond to ration and method of feeding. The first stream is called Stream A and the ration fed, Ration A. This ration is high roughage, low energy, and is received by all Cattle not placed in a feedlot. It is assumed that all future Breeding Stock will be derived from Stream A.

Ration B (fed in Stream B) corresponds to a high energy, high feed intake ration such as would be fed to Cattle on full feed in a feedlot. It is assumed that none of these Cattle are used for breeding purposes.

Stream B Cattle are matured to Finished Cattle through a variable length delay process. This "continuous" delay provides for: (1) an expected time on feed, and (2) a distribution about this expected value.

This continuous delay attempts to approximate the effect of the different feeds and feeding practice used, as well as variation in genetic growth rates.

As the Finished Cattle leave the feeding-finishing process (continuous delay), they are added to Cattle matured on Ration A to produce total Steers and Heifers Available for SLAUGHTER.

Steers and Heifers Available for SLAUGHTER are adjusted by EXPORTS AND IMPORTS of Slaughter Cattle to produce Steer and Heifer SLAUGHTER for each region (Local SLAUGHTER).

Six month old Calves not going directly into a feedlot proceed to mature along Stream A, on Ration A. The next stage of the growth process is six months in length. This period is simulated by a fixed length or discrete delay. At the end of this period, when Calves are one year of age, adjustments to their numbers are made for EXPORTS and WEST-EAST Movements. It should be pointed out that EXPORTS, IMPORTS, and WEST-EAST Movements do not occur at discrete points in time (age) but occur more or less continuously. Thus the model abstracts from reality to simplify the study.

The numbers of Calves generated by the model may be summed at this point to compare with Statistics Canada's semi-annual Livestock Survey category, Calves Under One Year Old. This summation includes:

calves one to three months

calves four to six months

calves seven to twelve months   Ration A

calves seven to twelve months   Ration B (a portion of total Ration B Cattle)

At this stage (one year of age) a decision is assumed to be made as to whether or not Calves will be added to the Breeding Herd or finished for slaughter. Those <u>not</u> added to the Breeding Herd are matured through a continuous delay process and subsequently added to the flow of Steers and Heifers Available for SLAUGHTER. This was discussed above in connection with Cattle fed on Ration B.

The number of Yearlings entering the Breeding Herd are calculated in the following manner. Their numbers are large enough to provide for DEATH losses and just provide the necessary additions to the Breeding Herd. In actual practice <u>more</u> than this number would be allocated to allow for non-breeders, poor type and to provide flexibility. Thus, this model deals only with actual REPLACEMENTS, <u>not</u> intended or potential REPLACEMENTS.

One year old Bulls are added immediately to the Bull Herd. The size of the Bull Herd generated by the model may then be compared with Statistics Canada's semi-annual Livestock Survey category Bulls, One Year or Older.

One year old Heifers are matured for one more year before being added to the Cow Herd. During this period they are bred. As was discussed in connection with MATRIX, the assumption is made, at least initially, that Beef Heifers are bred at 15 months to calve at 24 months. Thus, all Beef Heifers are assumed to calve immediately upon leaving the one year maturation period. This assumption and subsequent modeling will be followed until new information is found to the contrary.

In the instance of Dairy Heifers a more sophisticated and realistic approach is used. From a priori knowledge, an expected calving age and distribution about this expected age have been determined. Thus, as Dairy Heifers leave the one year delay they enter another continuous or variable length delay with an expected value and dispersion as indicated above. This second delay models the period of time between two years of age and parturition.

For various purposes, all First Calf Heifers are added to (or deleted from) the Cow Herd at three points. In the first instance, Heifers are added to the Cow Herd to provide a total which can be compared with Statistic Canada's semi-annual Livestock Survey category Female Stock Two Years Old and Older. In the second instance, they are deducted from the above total so that different BIRTH Rates and gestation lags can be applied to First Calf Heifers and Mature Cows. In the third instance, the Calves from both groups of Cows are summed to provide the total Calf Crop.

Simulation of the Elements in Cattle Production

The elements in the Cattle Herd simulator are described in detail in this section.[1] The structure of each element, the assumptions made, and the system's key parameters are given together with plausible estimates of their value.[2] This structure is also displayed in the form of exact block diagrams which indicate the relationships of stocks, flows, and system parameters. A rationale for this structure is provided in many instances.

Simulation of BIRTHS

BIRTHS are simulated by applying a BIRTH Rate to the available stock of Cows and Heifers. The first assumption is that BIRTH Rate is a function of the age of the Brood Cow. This model identifies two ages of Brood Cow; namely, First Calf Heifers, and Mature Cows. Different BIRTH Rates could be used for these two ages.

It is initially assumed that the Dairy Cow breeding cycle was approximately 13 months; this figure is based on a priori information. It was then assumed that, everything else being equal, the First Calf Heifer BIRTH Rate would be the Mature Cow BIRTH Rate x 13/12. This was roughly translated to provide a BIRTH Rate differential of .08 for Dairy. The same assumptions were not made for Beef.

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[1]One version of CATSIM, namely CATSIM2 West, is listed in Appendix E together with an explanation of key stock and flow variables not described in this chapter.

[2]These parameters also include those that are required to disaggregate published statistical data in order to generate certain stock and flow variables.

It was further assumed that Eastern and Western Beef BIRTH Rates do not differ. This assumption was made for lack of information to the contrary. Subsequent testing resulted in a slight differential being introduced.

Finally, it was assumed that the Western Dairy Herd was managed somewhat like a Beef Herd, at least at the margin. For this reason, a Western Dairy BIRTH Rate was selected that fell between the Beef and the Eastern Dairy BIRTH Rates.

The Rates used in this model and their variable names are listed below.[1]

Dairy Birth Rate	Cows, East	BREDC = .72
	West	BRWDC = .76
	Heifers, East	BREDH = .80
	West	BRWDH = .84
Beef Birth Rate	Cows, East	BREBC = .85
	West	BRWBC = .84
	Heifers, East	BREBH = .85
		BRWBH = .84

The second assumption is that BIRTH Rate is constant over time. This may well be unrealistic in two respects. First, there may be a long run trend and, second, BIRTH Rate could well be expected to have

[1]Appendix A contains a detailed discussion of the derivation of BIRTH Rates and of many other parameter values used in CATSIM as well as RECON and MATRIX. The parameter values listed in this chapter, in many instances, were derived or at least verified, through the operation of programs RECON and MATRIX. The sensitivity analysis described in the next chapter also influenced the selection of the values listed.

both a predictable and a stochastic element. These two aspects were not considered in constructing CATSIM.

A third assumption concerns sex ratio. It is initially assumed that this ratio is 1:1 or Calves are Male and Female in equal numbers.

A major element in simulating Calf BIRTHS is the quarterly distribution. Various estimates are discussed in Appendix A. CATSIM uses a monthly distribution that is subsequently aggregated to produce the required quarterly distribution.[1] Dairy birth distributions, East and West, are initially assumed to be equal, however, the Eastern Beef birth distribution is assumed to be more uniform than the Western Beef birth distribution.[2] The array "VAL" indicates the monthly BIRTH Rate at the beginning of each month (note that VAL(1) = VAL(13)).

```
VALDE(1), VALDW(1) = .088        VALDE(7),  VALDW(7)  = .054
VALDE(2), VALDW(2) = .093        VALDE(8),  VALDW(8)  = .069
VALDE(3), VALDW(3) = .069        VALDE(9),  VALDW(9)  = .077
VALDE(4), VALDW(4) = .112        VALDE(10), VALDW(10) = .097
VALDE(5), VALDW(5) = .089        VALDE(11), VALDW(11) = .096
VALDE(6), VALDW(6) = .065        VALDE(12), VALDW(12) = .094
                                 VALDE(13), VALDW(13) = .088
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[1]An integration subroutine, INGRAT, is used to calculate the proportion of BIRTHS for any stated period of time. This subroutine is described in Appendix B and listed in Appendix E.

[2]The characters D and B refer to Dairy and Beef while E and W refer to East and West. This convention is followed in all variable names used in all programs. In addition, M and F are used to denote Male and Female.

VALBE(1) = .05	VALBW(1) = .01
VALBE(2) = .06	VALBW(2) = .04
VALBE(3) = .06	VALBW(3) = .11
VALBE(4) = .10	VALBW(4) = .25
VALBE(5) = .20	VALBW(5) = .39
VALBE(6) = .20	VALBW(6) = .11
VALBE(7) = .10	VALBW(7) = .04
VALBE(8) = .04	VALBW(8) = .01
VALBE(9) = .04	VALBW(9) = .01
VALBE(10) = .05	VALBW(10) = .01
VALBE(11) = .05	VALBW(11) = .01
VALBE(12) = .05	VALBW(12) = .01
VALBE(13) = .05	VALBW(13) = .01

Figure 18 is an exact block diagram of the birth generation process. After a stock of Cows are bred, a gestation period is realized. This period is approximately nine months in length or three DT's.[1] The gestation period is simulated by a discrete delay process[2] that essentially retains the generated BIRTHS for nine months before emitting them. First Calf Dairy Heifer BIRTHS are delayed through a continuous or distributed delay. This process which was used as the age at which First Calf Heifers calve, describes a distribution. Since this distribution is known, it is modeled with a continuous delay.[3]

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[1]The model CATSIM simulates the Cattle Herd in time increments of three months or .25 of a year. Each time increment is termed a DT; a DT is the same as the Δt used in other contexts.

[2]A BOXC subroutine is used. This subroutine is described in Robert W. Llewellyn, FORDYN, <u>An Industrial Dynamics Simulator</u>, Raleigh, University of North Carolina, 1965, pp. 52-56. The BOXC program is listed in Appendix E.

[3]The subroutine used was VDELDT. A similar subroutine DELDT is described in Llewellyn, <u>op. cit</u>., pp. 40-51. A complete discussion of VDELDT is contained in Appendix B; the program is listed in Appendix E.

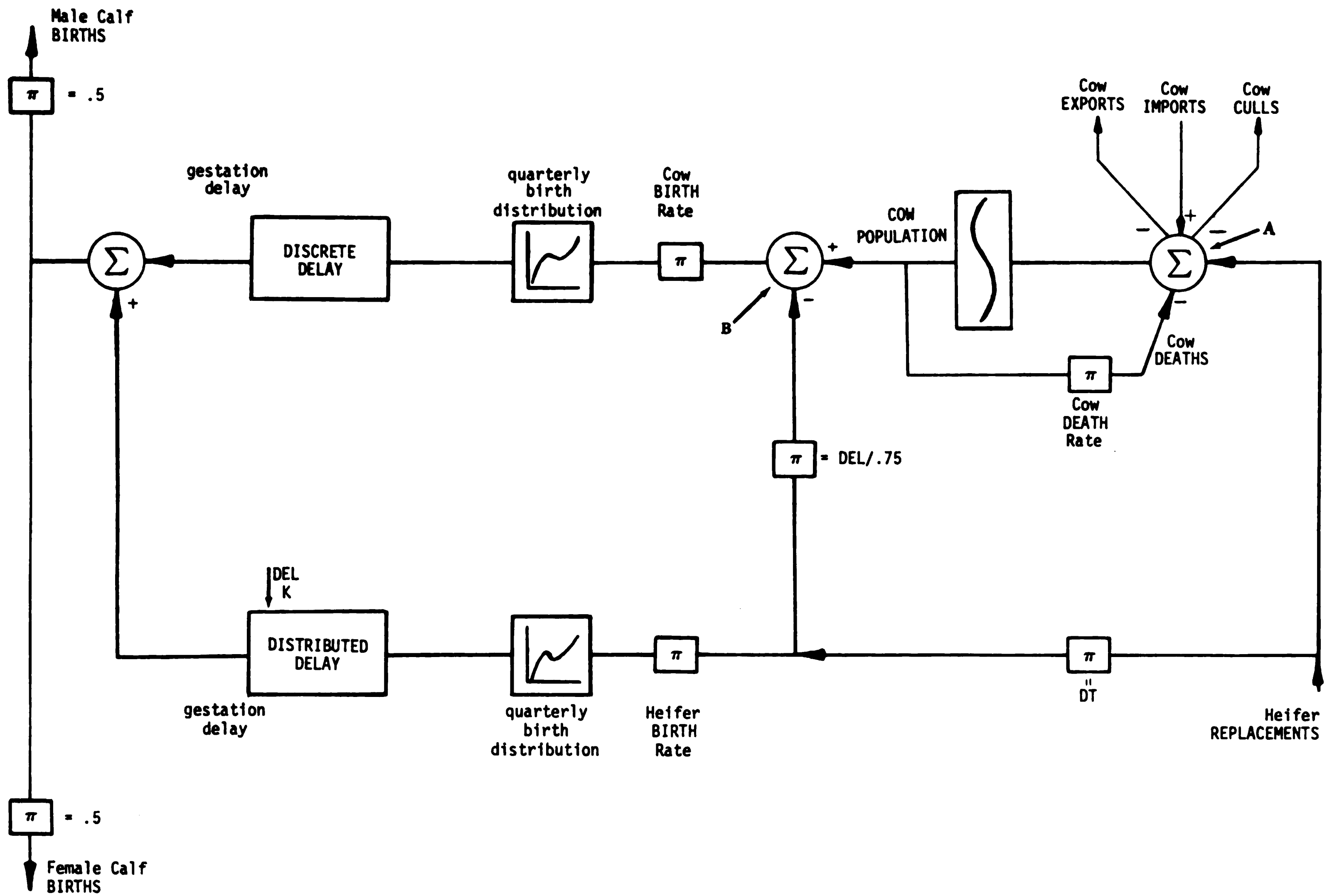

Figure 18. Simulation of Calf BIRTHS.

The expected value of this Dairy Heifer gestation delay is approximately .85 years beyond two years of age. This is modeled by the use of the following parameters.

DELEDH, DELWDH = .85

The distribution is very flat, with some BIRTHS occurring before two years of age and as late as four years. The parameter that provides the shape to the distribution is:

KEDH, KWDH = 3

For lack of proper information, no delay is experienced with First Calf Beef Heifers. It is assumed that they immediately calve upon turning two years of age. Information received in the future may allow this element of the model to be developed more accurately, possibly along the lines of the simulation of First Calf Dairy Heifer BIRTHS.

Figure 18 shows that First Calf Dairy Heifers are added to the Cow Herd at point A and subtracted again at point B. The purpose of this structure is to allow the model to both conform to STATCAN statistics and provide the differential birth process. In the first instance, Heifers are added to the Cow Herd at two years of age. This allows comparison of simulated "Cows and Heifers, Two Years and Over," with the published figures. In the second instance, First Calf Heifers are subtracted after being multiplied by a constant in order to generate BIRTHS in an accurate manner consistent with actual practice. The rationale for this structure is described below.

By definition, Cows are considered to be females over two years of age, kept primarily for milk and for producing Calves. At first glance, BIRTHS would appear to be a product of Cow times BIRTH Rate. That is:

BIRTHS = Cow Population x BIRTH Rate.

This formula assumes, however, that only Cows over two years of age produce calves; in fact, only Cows two years or older are bred.

If Heifers are bred at 15 months, they drop their first Calf at two years. Thus, two groups of Females calve: Replacement Heifers under two years, plus Cows over two years. If Cows only are considered, BIRTHS are understated by the Calves produced by Heifers bred prior to two years of age.

On the other hand, if Cows do not produce their first Calf until they are 3 3/4, then BIRTHS will be overstated if the above formula is used. This occurs as Females two to three years of age do not produce Calves at all.

Sine the possibility of different BIRTH Rates exist for First Calf Heifers, as opposed to Mature Cows, the following formula may be used.

Cow BIRTHS = (Cow Population - Heifer Population[1]) x Cow BIRTH Rate

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[1]Refers to the stock of Replacement Heifers, not total Heifers.

Heifer BIRTHS = Heifer Population x Heifer BIRTH Rate

Total BIRTHS = Cow BIRTHS + Heifer BIRTHS.

This formula applies only to the situation where a Cow has its first calf at approximately 2 3/4 years. It does not apply to the above "early" and "late" calving instances. To do so it must be altered--the critical point is the breeding age of 15 months. At this breeding age, Heifer Population is <u>not</u> subtracted from Cow Population in order to calculate Cow BIRTHS. If bred at two years, then Heifer Population <u>is</u> subtracted; if bred at three years, then Heifer Population is subtracted approximately <u>twice</u>.

The generation of BIRTHS can be reformulated as follows to handle all the above instances mentioned.

Cow BIRTHS = (Cow Population - Heifer Population x A) x Cow BIRTH Rate

Heifer BIRTHS = Heifer Population x Heifer BIRTH Rate

Total BIRTHS = Cow BIRTHS + Heifer BIRTHS

where

A = 0 if Heifers bred at 15 months,

A = 1 if Heifers bred at 24 months,

A = 2 if Heifers bred at 33 months.

The continuous delay parameter DEL is used to indicate the expected age of First Calf Heifers at calving, by measuring time from two years onward; thus, DEL is used to calculate A.

$$A = DEL/.75$$

where

.75 represents gestation period in years, the same unit as DEL.

Thus, if Heifers calve at two years of age, as it is assumed Beef Heifers do, DEL = 0, and A = 0. If Heifers calve at 2 3/4 years, then DEL = .75 and A = 1; this is roughly the case with Dairy Heifers.

If DEL is unknown, but all other elements in the birth generation process are known, it may be possible to optimize on A. DEL would then be estimated by the formula:

$$DEL = A \times .75.$$

Simulation of DEATHS

DEATHS constitute a continuous, but not necessarily constant, depletion of the Cattle Herd. The major parameter of concern is the DEATH Rate, usually expressed in annual terms as a proportion of the Herd. The DEATH Rate is most likely a function of the age of the animal, possibly its sex, possibly its function, and quite likely its environment.

Due to the lack of information concerning DEATH Rate, several assumptions are made to accommodate the simulated process and the available data. The first assumption is that Male and Female DEATH Rates are equal. A second assumption is that for East and West, all Cattle under one year of age have the same DEATH Rate. All non-Fed Cattle over one year of age have a second and different DEATH Rate.

A third assumption is that all Cattle on Feed, East and West, have a third DEATH Rate. A final assumption is that the DEATH Rate for the first six months of the year is at a high level, a lower level is used for the last six months.

The best initial estimates of annual DEATH Rate of Calves are as follows, together with their variable names.

DRMBCE[1]	1st quarter = .048
DRMDCE	2nd quarter = .048
DRFBCE	3rd quarter = .022
DRFDCE	4th quarter = .022
DRMBCW	1st quarter = .040
DRMDCW	2nd quarter = .040
DRFBCW	3rd quarter = .020
DRFDCW	4th quarter = .020

Lower annual DEATH Rates are used for Cattle over one year and all Cattle on Feed. The DEATH Rate variables and their annual rates are listed below.

DRCATE(1) = .015	DRCATW(1) = .016
DRCATE(2) = .015	DRCATW(2) = .016
DRCATE(3) = .012	DRCATW(3) = .012
DRCATE(4) = .012	DRCATW(4) = .012

DRCATF(1) = .014
DRCATF(2) = .014
DRCATF(3) = .012
DRCATF(4) = .012

---

[1]The annual Rates are stored in a set of subscripted variables whose names commence with CY, i.e., CYMBC(1). The DEATH Rate parameters take on different values each quarter. The value of the parameters are changed quarterly by a CBOX subroutine which cycles the subscripted CY variables. This CBOX subroutine is explained in Appendix B as well as in Llewellyn, op. cit., pp. 52-55. The CBOX program is listed in Appendix E.

DEATHS are simulated by generating the flow at the beginning of each period, for each age, and/or function cohort. This is done by multiplying the net inflow rate by the annual DEATH Rate then by the length of time in that cohort. If the cohort is represented by a stock value (i.e., Cows and Bulls) then the stock value is multiplied by an annual DEATH Rate.

These two types of simulation models are shown in the following exact block diagrams (Figures 19 and 20).

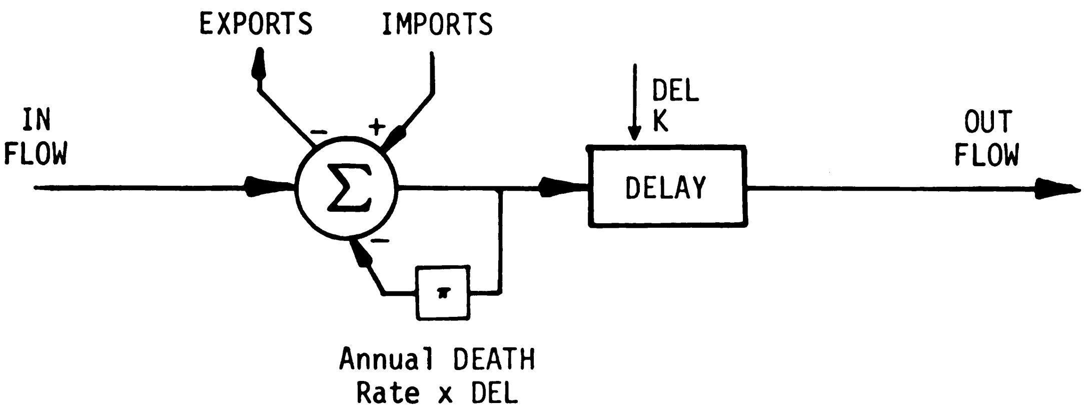

Figure 19. Simulation of DEATHS in a Flow Situation.

Some inaccuracy is introduced as the whole DEATH flow is deducted at the beginning of the period as a continuous process is being simulated by a discrete process. This inaccuracy, however, is not felt to be significant in light of the possible error in the estimated DEATH Rate.

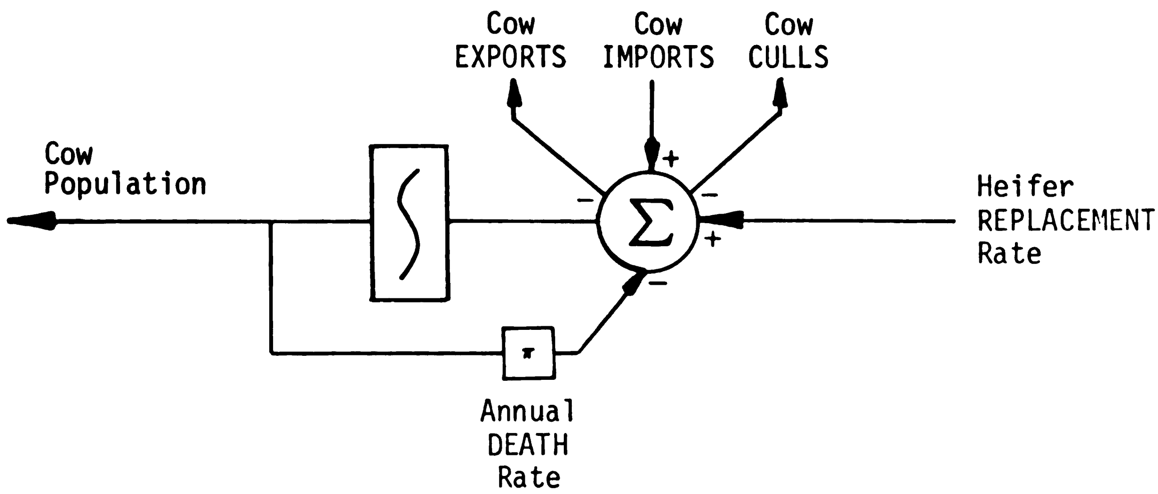

Figure 20. Simulation of DEATHS in a Stock Situation.

Simulation of Calf, Cow and Bull SLAUGHTER

Simulation of SLAUGHTER is not so much a problem of method or model structure as one of data or of obtaining estimates of the magnitude of the flow variables. The technique used to estimate the flow variable, Calf SLAUGHTER, is to employ published statistical data or at least available statistical data.

The data basically fall into two categories: INSPECTED and UNINSPECTED. Both categories have previously been discussed in Chapter II. INSPECTED data are available on a monthly basis, East and West, Male and Female. The only remaining problem is to allocate it between Beef and Dairy. Good estimates are unavailable; consequently, the following parameters are used in CATSIM1 to generate the necessary flows.[1]

Proportion of Male Calf SLAUGHTER that is Beef
East, V41 = .10
West, V1 = .10

Proportion of Female Calf SLAUGHTER that is Beef
East, V42 = .10
West, V2 = .25

The second category of data is UNINSPECTED SLAUGHTER. These data are estimated by STATCAN under the classification, Farm Killed and Eaten, and Farm Killed and Sold. The latter two data series are available only on an annual basis, while the former is available on a quarterly basis. All are available on an East/West separation but not on a Male/Female basis. The problem then is to estimate a quarterly distribution and a Male/Female separation. While this matter is discussed in detail in Appendix B, the first estimates were made by simply applying the comparable rates from INSPECTED SLAUGHTER. The parameter values used are as follows:

Proporion Females in UNINSPECTED Calf SLAUGHTER
East, V43 = .55
West, V3 = .50, before 1966
V3 = 1.00, after 1965.

Quarterly Distribution of UNINSPECTED Calf SLAUGHTER = .25
(included as a structural element, not as a parameter).

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[1]This sub-section is largely devoted to describing the method of estimating SLAUGHTER (Calf, Cow, Bull) flows for CATSIM1. SLAUGHTER flows for CATSIM2 and CATSIM3 have previously been estimated by program MATRIX and the behavioral models, respectively.

The allocation into Dairy and Beef follows the same distribution as INSPECTED Calf SLAUGHTER. CATSIM1 re-calculates this latter distribution quarterly.

Calf SLAUGHTER flow values for CATSIM2 and CATSIM3 are taken as generated by MATRIX and the relevant behavioral models, respectively. These flows are given in Tables 6 and 13.

The allocation of Cow SLAUGHTER into its Dairy and Beef components represents a further data problem. In CATSIM2, Cow SLAUGHTER flows are calculated by MATRIX; these data are given in Table 5. Cow SLAUGHTER flow data for CATSIM3 are generated by the behavioral models; these data are listed in Table 12. Finally, CATSIM1 calculates Dairy Cow SLAUGHTER in the West and Beef Cow SLAUGHTER in the East by selecting fixed values (constants) that maintain the respective Cow Herds at published levels given REPLACEMENT Rates. The replacement process and Rates are discussed below in sub-section Simulation of the Growth Process.

SLAUGHTER Rates are determined by REPLACEMENT Rate plus or minus a constant. The former Rate is then applied to the appropriate Cow Population to determine SLAUGHTER flow. The constants are minus .06 for Eastern Beef Cow and plus .022 for Western Dairy Cows. Calculation of Western Beef Cow SLAUGHTER and Eastern Dairy Cow SLAUGHTER is the residual given the published Total Eastern and Western Cow SLAUGHTER. Program MATRIX corroborates the estimates for these flow values.

As with Calves, UNINSPECTED Cattle SLAUGHTER also contains Farm Killed and Eaten and Farm Killed and Sold estimates. This flow must be disaggregated into its Cows, Bulls, Steers, and Heifers elements.

The calculation of Bull SLAUGHTER follows the pattern of the calculations for Calves and Cows. That is, SLAUGHTER flows for CATSIM2 and CATSIM3 are taken as estimated by MATRIX and the behavioral models. These flows are listed in Tables 7 and 14. For CATSIM1, the UNINSPECTED Bull SLAUGHTER is added to the published INSPECTED Bull SLAUGHTER.

It was initially assumed that Bulls occurred in UNINSPECTED SLAUGHTER in the same proportion as in INSPECTED SLAUGHTER. This assumption was modified as the result of new information obtained through the use of program MATRIX leading to the following parameter values.

Proportion of Bulls in UNINSPECTED Cattle SLAUGHTER
East, V75 = .06
West, V35 = .06

Flow values for UNINSPECTED Heifer SLAUGHTER is required, as well as for Steers. The Heifer value is the residual after UNINSPECTED Steers, Cows, and Bulls have been accounted for. The following parameters are used for this purpose.

Proportion of Steers in UNINSPECTED Cattle SLAUGHTER
East, V76 = .40
West, V36 = .207, before 1966
V36 = .00, after 1965

It was assumed initially that 25 percent of UNINSPECTED Cattle SLAUGHTER was Cows, the balance was Heifers. Program MATRIX indicated an upward revision in the case of the Eastern Cow value.

Proportion of Cows in UNINSPECTED Cattle SLAUGHTER
East, V45 = .28
West, V11 = .25

The allocation of UNINSPECTED Cow SLAUGHTER between Beef and Dairy is the same as that for INSPECTED SLAUGHTER.

When the SLAUGHTER flow has been estimated in the disaggregate form required of CATSIM, it is deducted from the IN FLOW by the simple operation of subtraction. This is demonstrated in Figure 21.

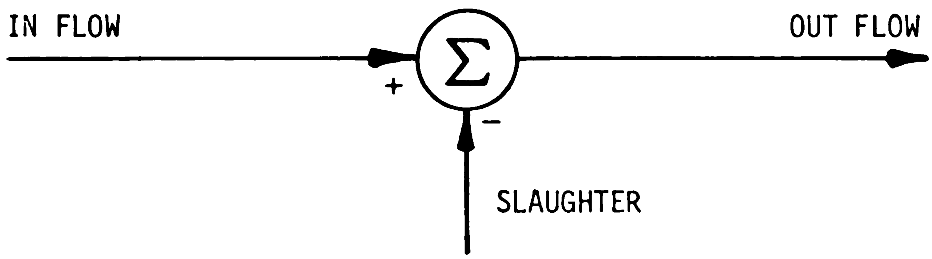

Figure 21. Simulation of SLAUGHTER.

Simulation of EXPORTS and IMPORTS

As with SLAUGHTER, the major problem encountered in attempting the simulation of EXPORTS is the determination of magnitude of the flow. SLAUGHTER statistics are available in a fairly disaggregate form for the years 1969-1972 inclusive and in a highly aggregate form for the years 1958-1968 inclusive.

The 1958-1968 data is available on an annual basis only. The first set of parameters provide initial quarterly estimates.

Quarterly distribution of Purebred IMPORTS

East and West, Q1(1) = .21
Q1(2) = .32
Q1(3) = .18
Q1(4) = .29

Quarterly distribution of Purebred EXPORTS

East and West, Q2(1) = .18
Q2(2) = .28
Q2(3) = .24
Q2(4) = .30

Quarterly distribution of Other Dairy EXPORTS

East and West, Q3(1) = .16
Q3(2) = .32
Q3(3) = .30
Q3(4) = .22

Quarterly distribution of Other IMPORTS

East and West, Q4(1) = .31
Q4(2) = .26
Q4(3) = .03
Q4(4) = .40

Quarterly distribution of EXPORTS, Cattle Under 200 Pounds

East and West, Q5(1) = .20
Q5(2) = .52
Q5(3) = .18
Q5(4) = .10

Quarterly distribution of EXPORTS, Cattle 200-700 Pounds

East	West
Q6(1) = .14	Q6(1) = .04
Q6(2) = .16	Q6(2) = .04
Q6(3) = .29	Q6(3) = .08
Q6(4) = .41	Q6(4) = .84

Quarterly distribution of EXPORTS, Cattle Over 700 Pounds

East	West
Q7(1) = .14	Q7(1) = .31
Q7(2) = .34	Q7(2) = .22
Q7(3) = .26	Q7(3) = .18
Q7(4) = .26	Q7(4) = .29

The next problem is the division of EXPORTS into Male/Female and Beef/Dairy.

Proportion Females in Purebred IMPORTS
East, V59 = .90
West, V19 = .90

Proportion Females in Purebred EXPORTS
East, V58 = .85
West, V18 = .85

Proportion of Dairy in Purebred IMPORTS
East, V55 = .20
West, V25 = .20

Proportion of Dairy in Purebred EXPORTS
East, V56 = .826
West, V26 = .826

The EXPORT category, Cattle 200-700 Pounds, contains Cattle that range from Weaned Calves to Yearlings. A parameter is needed to make the basic division Between six month old Calves and one year old Calves.

Proportion of six month old Calves in EXPORTS,
Cattle 200-700 Pounds
East, V46 = .90
West, V6 = .90

A parameter of major interest, as it has historically hampered Herd expansion possibilities, is the proportion of Male Calves in EXPORTS, Cattle 200-700 Pounds.

Proportion of Males in EXPORTS, Cattle 200-700 Pounds
East, V44 = .145
West, V4 = .50, before 1966
V4 = .00, after 1965

The EXPORT category, Cattle Over 700 Pounds, contains a variety of Cattle. To make this division, the following assumptions are made.

East:

1. Of the first 3,000 head shipped annually, 80 percent are Cull Dairy Cows.

2. Of all Cattle over 2,400 head (80 percent of 3,000) only 10 percent are Cull Dairy Cows.

West:

1. Of the first 8,000 head shipped annually, 80 percent are Cull Dairy Cows.

2. Of all Cattle over 6,400 head (80 percent of 8,000) only 5 percent are Cull Dairy Cows.

ALL EXPORTS, Cattle Over 700 Pounds that are not Cull Dairy Cows are assumed to be Steers and Heifers for Immediate SLAUGHTER.

Proportion of Cull Dairy Cows in EXPORTS,
Cattle Over 700 Pounds <u>below</u> a fixed critical figure
East, V53 = .80
West, V13 = .80

Proportion of Cull Dairy Cows in EXPORTS,
Cattle Over 700 Pounds <u>above</u> a fixed critical figure
East, V531 = .10
West, V131 = .05

Proportion of Steers in the non-Cow portion of EXPORTS,
Cattle Over 700 Pounds
East, V54 = .35
West, V14 = .35

In addition, the Dairy/Beef proportion of EXPORTS of Cull Cows is assumed to be in the same ratio as Cows in the general population. Other assumptions include: (1) all EXPORTS of Cattle Under 200 Pounds are very young Male Dairy Calves, and (2) all EXPORTS of non-Purebred Dairy Cattle are Dairy Cows.

Finally, consideration must be given to the proportion of Males in IMPORTS, Cattle Over 700 Pounds. It is assumed that this category only contains Cattle for Immediate SLAUGHTER.

Proportion of Males in IMPORTS, Cattle Over 700 Pounds
East, West, V16 = .70

Simulation of EXPORTS and IMPORTS is done by the same subtraction operation as was the case with SLAUGHTER.

Simulation of WEST-EAST Cattle-Calf Movement

Closely related to foreign trade are the internal trade flow variables. The following assumptions are made concerning the published data.

1. Eastern Movements by rail are something less than total Cattle Movements. The scale of coefficient for WEST-EAST Cattle-Calf Movement is:
   East, V9 = 1.07
   West, V7 = 1.07

2. Calves shipped for SLAUGHTER are assumed to be slaughtered immediately. Calves shipped to FEEDLOTS or STOCKYARDS are assumed to be placed in a feedlot or on grass.

3. Cattle shipped for SLAUGHTER are assumed to be slaughtered immediately. Cattle shipped to FEEDLOT or STOCKYARDS are assumed to be placed in a feedlot or on grass.

The remaining problem is the Male/Female division. The following parameters are used.

Proportion of Males in Calf Movements for FEEDLOT and STOCKYARDS
V5 = .80

Proportion of Males in Cattle Movements for FEEDLOT and STOCKYARDS
V12 = .80

Proportion of Males in Cattle and Calf Movements for SLAUGHTER
V15 = .95

As with SLAUGHTER, EXPORTS, and IMPORTS, WEST-EAST Movements are simulated by a simple arithematic operator: in the case of the East, the recipient, an addition operator; in the case of the West, the shipper, a subtraction.

Simulation of Feeder Cattle ALLOCATION to Feeding Programs

As previously discussed, CATSIM models the feeding and finishing of Cattle using two processes. The first or Ration A is a low energy ration. The second, Ration B, is a high energy ration. While a whole spectrum of processes are used in practice, these two processes in some proportion are felt to reasonably represent cattle feeding and finishing in Canada. The decision point comes at approximately six months of age when the Calves are weaned and are brought in off the range.

An assumption made in constructing the model is that all REPLACEMENT Cattle are taken from the low energy or A Stream. Thus, at least enough Cattle must remain in this stream to comfortably provide for REPLACEMENT flow. An extension of this assumption is that no Dairy Heifers are diverted to the high energy B Stream.

Appendix A provides a discussion of the initial values used in allocating six month old Calves to the two feeding-finishing processes. These parameters and their values are:

Proportion of Beef Males to Ration B
East, V47 = .70
West, V7 = .60

Proportion of Dairy Males to Ration B
East, V67 = .40
West, V27 = .70

Proportion of Beef Females to Ration B
East, V48 = .30
West, V8 = .20

Proportion of Dairy Females to Ration B
East, V68 = 0.0
West, V28 = 0.0

The simulation of Feeder Cattle ALLOCATION to Feeding Programs is demonstrated in Figure 22.

Simulation of the Growth Process

One of the most important processes in cattle production is that of growth (and feeding-finishing). This process can be of varying length depending on genetic stock, feed intake, disease and environmental factors and the cultural or husbandry practices followed.

Three observations might be made. One, for any group of Cattle, the growth (and feeding-finishing) rate varies from animal to animal. This is true for one feedlot as well as for the total Herd. A second observation is that given constant cultural practices, the average length of the growing period might shorten over time, due to technological improvement in feeding and breeding and wider adaptation of superior techniques. A third observation might be that the shape of the distribution of cattle coming out of the growth process might change for the same reasons as were used to support the hypothesis that the growing rate was increasing.

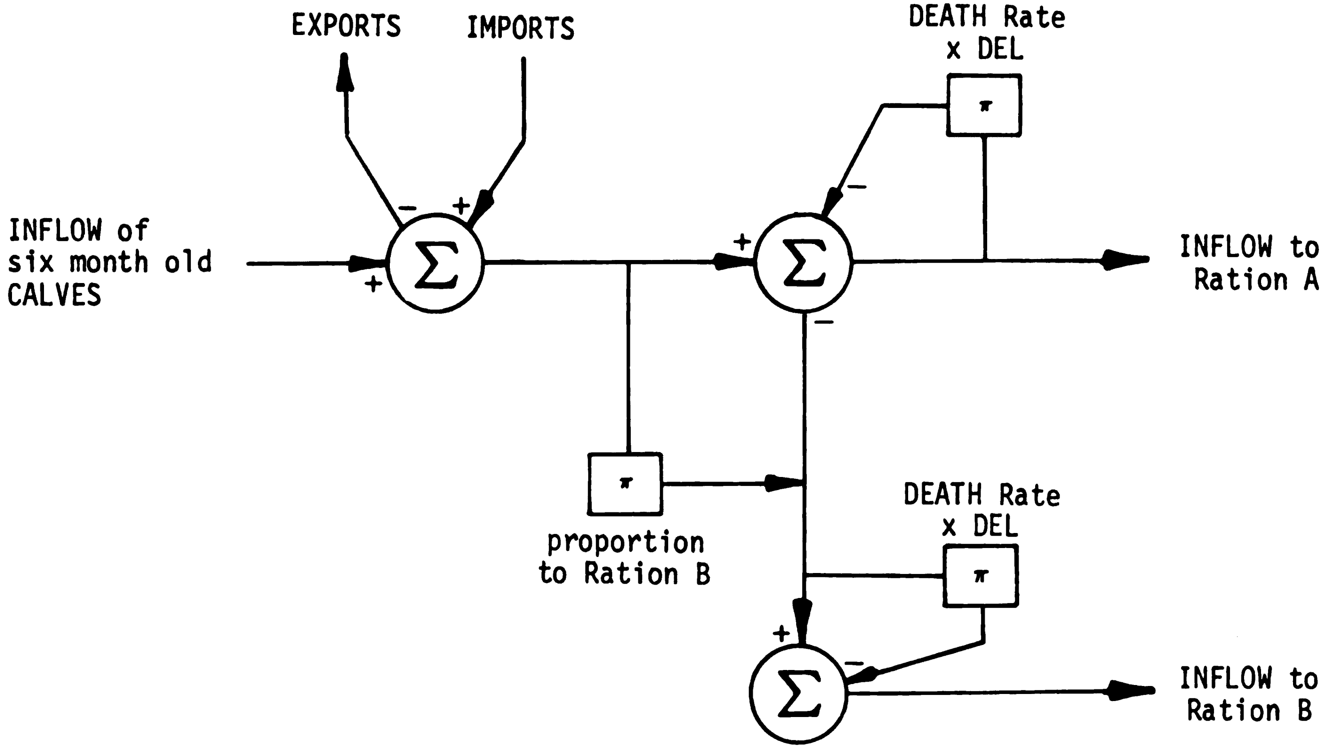

Figure 22. Simulation of Feeder Cattle ALLOCATION to Feeding Processes.

On the other hand, due to economic influences,[1] farmers, ranchers, and feedlot operators might switch from one feeding practice to another, from one breeding practice to another, and, in fact, may be changing several aspects of production concurrently.

CATSIM is designed to accommodate the varying length or distributional aspect of the growth process, the trend in the growth process over time and variation in the proportion of Cattle on one of two feeding processes. Changes in Breeding Stock and cultural practices can be accommodated by a replication of existing "streams" in the model, plus a new vector of parameters describing that new "stream."

CATSIM models the growth process by using a combination of discrete or fixed time period delays, plus continuous or distributed delays. These have been used in modeling the gestation delay and are discussed in detail in Appendix B.

Discrete delays are used to model the first portion of a Calf's life. Variation will occur in the weight and degree of maturity of Calves leaving this fixed period of time. Thus discrete delays are used to model the first six months of all Calves' lives, the next six months of Cattle on Ration A and the subsequent year for Heifers entering the herd.[2]

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[1]Historically, farmers have been switching from a low energy ration to a high feed intake, high energy ration through increased feedlot finishing--with recent high grain prices, there is some evidence that they are switching back to low energy rations.

[2]This simulation element is practical provided that Stream A and B Cattle are not ready for slaughter before twelve and six months, respectively, and Heifers to not calve before two years. In this latter

After this first portion of the Calf's life has been simulated with discrete delays, continuous delays are used to model the remainder. A continuous distribution is characterized by the fact that a flow entering at point A, leaves with an expected value at point B and a distribution about point B. The subroutines used to model continuous delays has two parameters, the first of these, DEL, provides the expected value, the second, K, dictates the shape. The subroutines used, model an erlang distribution. This distribution is described and displayed graphically in Appendix B. By varying parameters DEL and K, the distribution can range from a declining exponential ($K = 1$) through Chi-square ($K = 2,6$) to an approximate normal ($K = 10,25$).

The problem then becomes one of determining the expected value of that aspect of the growth and feeding-finishing process as well as determining the shape or distribution about this expected value.

To bring the modeling of the growth and feeding-finishing process into perspective, the following is laid out:

Growth Process	Simulation Element
Calves one to three months	Discrete delay
Calves four to six months	Discrete delay
Ration B, 7 months onward	Continuous delay
Ration A, 7-12 months	Discrete delay
Ration A, 13 months onward	Continuous delay
Heifers one to two years	Discrete delay
Gestation period First Calf Heifers	Continuous delay

---

regard, CATSIM may be used to model an early calving process where Heifers calve before two years, but a discrete delay could not be used reasonably beyond one year of age.

The discrete delays are modeled with a BOXC subroutine; the distributed delays employ a subroutine called VDELDT. This latter subroutine, VDELDT, has provision for changing DEL during the time period being modeled; this allows a shortening or lengthening trend to be modeled.[1] This trend need not be linear.

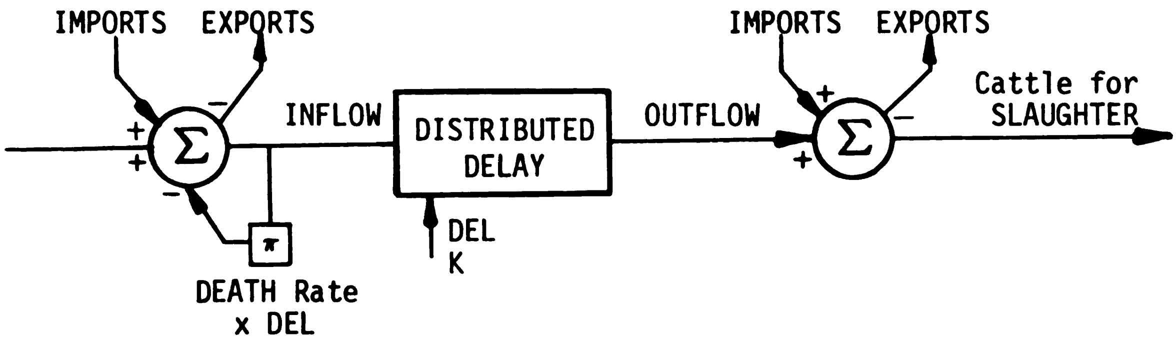

Figure 23. Simulation of Feeding-Finishing Process using a Distributed Delay.

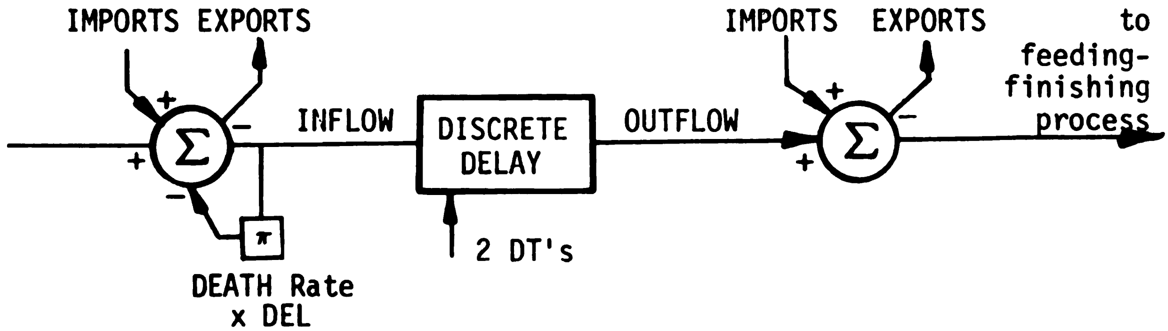

Figure 24. Simulation of a Growing Process using a Discrete Delay.

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[1]CATSIM does not utilize the feature; however, it was built into CATSIM so that it might be exploited in the future.

The following initial parameter values are used in modeling the cattle production and growth processes where distributed delays are employed.

All Dairy Heifer gestation periods
East and West
DEL = .85
K = 3

Ration A feeding-finishing processes

East, Male and Female	West, Male and Female
DEL = .83	DEL = .75
K = 3	K = 3

Ration B feeding-finishing processes

East, Male	West, Male
DEL = .91	DEL = .99
K = 5	K = 4
East, Female	West, Female
DEL = .83	DEL = .83
K = 5	K = 4

Simulation of REPLACEMENTS[1]

The process of adding REPLACEMENTS to the Breeding Herd can be extremely complicated in that this investment function is a function of the market mechanism. To this end, the behavioral models developed in Chapter III are utilized to provide the price feedback of the market mechanism in CATSIM3.

In CATSIM1, a much simpler mechanism is used; this mechanism replaces a fixed proportion of the Herd annually.[2] Since no price or

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[1]The three versions of CATSIM (CATSIM1, CATSIM2, CATSIM3) are basically differentiated on the basis of the simulation of REPLACEMENTS.

[2]As with SLAUGHTER flows, REPLACEMENT flows are calculated by one method in CATSIM1 while estimates are provided by MATRIX and the behavioral models for CATSIM2 and CATSIM3. The following discussion refers to the method used in CATSIM1.

market feedback mechanism is involved, the cattle cycle is not simulated. What is simulated is one of three phenomena, steady state, exponential growth or exponential decline.

The modeling involves two basic parameters. The first dictates the annual proportion of the Herd to be replaced. The following values are used.

Proportion of the Dairy Cow Herd to be replaced
East, V65 = .191
West, V21 = .160

Proportion of the Beef Cow Herd to be replaced
East, V61 = .16
West, V31 = .19

Proportion of the Bull Herd to be replaced
East, V62 = .476
West, V22 = .307

The second basic parameter allocates REPLACEMENTS in a quarterly fashion. The basic assumption is that Heifers are added proportional to the quarterly birth distribution. Bulls are added mainly in the first and second quarters in a manner somewhat consistent with Beef Cow calving distribution. This is verified semi-annually by program MATRIX.

Quarterly Dairy Cow replacement distribution

East,	ADDDCE(1) = .27	West,	ADDDCW(1) = .27
	ADDDCE(2) = .30		ADDDCW(2) = .30
	ADDDCE(3) = .22		ADDDCW(3) = .22
	ADDDCE(4) = .21		ADDDCW(4) = .21

Quarterly Beef Cow replacement distribution

East,	ADDBCE(1) = .20	West,	ADDBCW(1) = .19
	ADDBCE(2) = .50		ADDBCW(2) = .73
	ADDBCE(3) = .15		ADDBCW(3) = .05
	ADDBCE(4) = .15		ADDBCW(4) = .03

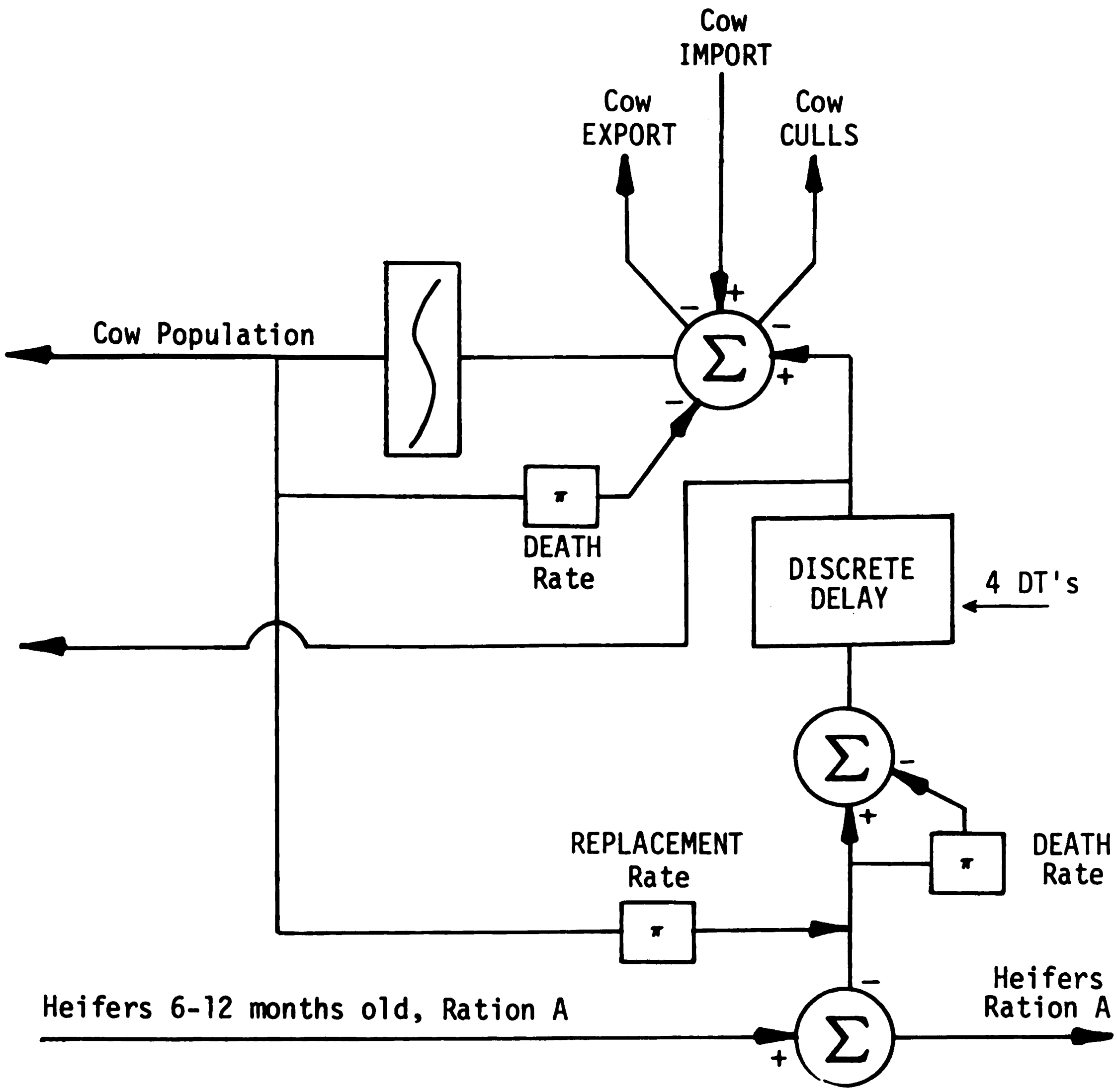

Figure 25. Simulation of the REPLACEMENT Process (CATSIM1).

Quarterly Bull replacement distribution

East,	ADDBLE(1) = .50	West,	ADDBLW(1) = .50
	ADDBLE(2) = .40		ADDBLW(2) = .40
	ADDBLE(3) = .05		ADDBLW(3) = .05
	ADDBLE(4) = .05		ADDBLW(4) = .05

CATSIM2 uses the REPLACEMENT values calculated by program MATRIX. These are listed in Tables 5 and 7. CATSIM3 uses the REPLACEMENT values estimated by the behavioral models developed in Chapter III; these are listed in Tables 11 and 13.

Simulation of Steer and Heifer SLAUGHTER

The purpose of a Cattle Herd in Canada, besides milk production, is for the production of beef and veal. The input into beef and veal production is, of course, Cattle and Calves. CATSIM generates the following vector of SLAUGHTER flows for both East and West.[1]

SLAUGHTER, Stream A (low finish)
- Beef Steers
- Dairy Steers
- Beef Heifers
- Dairy Heifers

SLAUGHTER, Stream B (high finish)
- Beef Steers
- Dairy Steers
- Beef Heifers
- Dairy Heifers

While the generation of each element in this vector is done with something less than absolute accuracy, the potential exists for

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[1]SLAUGHTER estimates for Cull Cows and Bulls, as well as Calves, is provided by program MATRIX and the relevant behavioral models previously discussed.

incorporation of new information to improve accuracy for testing hypothesis, making projections and simulating different grades and quantities of beef and veal.

CATSIM aggregates the output of Stream A and B and adjusts these for appropriate EXPORTS, IMPORTS, and WEST-EAST Cattle Movements. Two basic assumptions are made. The first is that trade in SLAUGHTER Cattle is in terms of Beef Cattle only. The second is that the SLAUGHTER element in WEST-EAST Cattle Movements are Cattle for Immediate SLAUGHTER and all IMPORTS of non-Purebred Cattle and all non-Cull Cow EXPORTS Over 700 Pounds are also for Immediate SLAUGHTER. The problem that remains is one of making the Male/Female separation.[1]

Proportion of Males in WEST-EAST Cattle Movements
East, West, V15 = .95

Proportion of Males in EXPORTS, Cattle Over 700 Pounds
(that portion that is not Cull Cows)
East, V54 = .35
West, V14 = .35

Proportion of Males in IMPORTS, non-Purebred
East, West, V16 = .70

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[1]The SLAUGHTER estimates of CATSIM2 are listed in Appendix G.

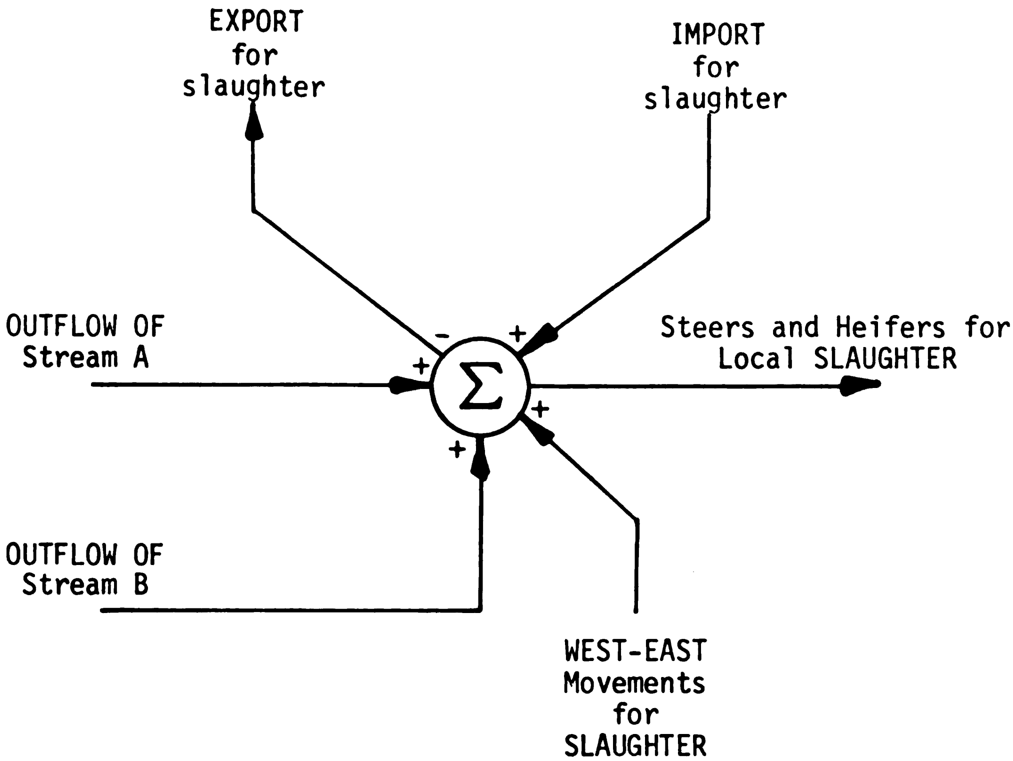

Figure 26. Simulation of Local Steer and Heifer SLAUGHTER.

CHAPTER VI

MODEL TESTING AND OPERATION

Model CATSIM1 is a highly deterministic model incorporating, simplifying and limiting assumptions. These assumptions were discussed in Chapter V and concern investment and disinvestment in the Breeding Herd.[1] While these assumptions might initially appear to be limiting, this model proved to be very useful in developing the more realistic versions that are to be discussed subsequently. It also proved useful for conducting preliminary tests and for estimating the magnitude and sign of preliminary stock and flow variables. It is felt that CATSIM1 will prove useful in certain types of future practical applications.

The output of program MATRIX is incorporated into the basic CATSIM1 to produce CATSIM2. That is, the simplifying investment/disinvestment assumptions of CATSIM1 are dropped and MATRIX output (as amended) is incorporated directly. A comparison of the output of CATSIM1 and CATSIM2 demonstrates the superiority of the second model. CATSIM2 is used for all sensitivity tests on the Cattle Herd simulator.

CATSIM2 is operated in a stochastic mode to generate CATSIM3. In the latter instance, the output of MATRIX is replaced by the

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[1]The stock and flow notational convention continues to be used in Chapter VI.

estimated values produced by the behavioral equations. The operation and output of CATSIM1, CATSIM2, and CATSIM3 are discussed in the last sections of this chapter.

The first section discusses the model validation process. The second section tests the sensitivity of key parameters and serves as a "quasi optimization" procedure for obtaining parameter estimates. The third section discusses model stability while the fourth and fifth sections make the comparisons among CATSIM1, CATSIM2, and CATSIM3.[1]

Validation of the Model

At this stage of model development, the questions "is the model valid" and "how do you know that it is valid" could be asked. As mentioned in Chapter II, the process is largely one of demonstrating that the model fails to be invalid. Two tests of validation were set out in the study objectives. They are repeated here.

1. To successfully "track" past Population and SLAUGHTER data consistent with the simplifying assumptions used (the correspondence test).

2. To generate disaggregation Population and SLAUGHTER data series and to generate REPLACEMENT and CULL data series that are held to be highly plausible (the coherence test).

Starting with the second objective first, REPLACEMENT and Cull data series were generated by program MATRIX. These data series are

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[1]For the balance of this dissertation the program name CATSIM will be used when the discussion refers generally to all three variations of the model.

given in Tables 5 and 7 and displayed in Figures 14 to 17. One test of their validity involves a comparison of the output of CATSIM1 with CATSIM2. Since the output of MATRIX is expected to be superior to the simplifying assumptions concerning investment/disinvestment used in CATSIM1, a comparison of the output of CATSIM1 and CATSIM2 with the official published statistics should reveal the superiority of CATSIM2. These comparisons are demonstrated in Figures 27 to 32.

Appendices F and G contain a list of historic Population and SLAUGHTER data estimates. These data are in the disaggregate form that was initially specified in the hypothesis. A comparison of these data with the published statistics cannot be made for the obvious reason. These disaggregate data must wait to be tested by tests that fall beyond this particular study.

A demonstration of objective one is given in Figures 27 to 40. These figures, for example, compare Cow Population estimates under the assumptions made in CATSIM1, CATSIM2, and CATSIM3. These three sets of estimates and their comparisons occupy the body of the balance of this chapter.

At this point the first two tests of objectivity, as given in Chapter II, are applied to the models. The first is a test of consistency with observed and possibly recorded experience. This first test concerns the relationship of the structure of the model with the structure of the real world--does the model fairly represent the real world? The answer to this question is a qualified "yes." The impetus to develop CATSIM stemmed from lack of detail inherent in compatible models. By including more detail, CATSIM comes closer to the real world than these latter models.[1] A second level of comparison involves the modeling of individual components. At this level, a comparison of assumptions specific to that component may be made with the reviewer's knowledge of the real world. Many oversimplifying assumptions were made--the effect of these is discussed throughout the balance of this chapter, while additional model developments are explored in Chapter VII. A third level of comparison is that of comparing generated data series (or some aggregate) with published data series; these comparisons are scattered throughout the dissertation in the form of figures and tables.

The second test of objectivity is the logical internal consistency of the concepts used. While this test is of necessity related to the one above, the model must prove itself in terms of stability; that is, do the components fit together to present a stable model that accurately reproduces the system being modeled. The model proved to be stable within the confines of the assumptions. The stability aspect of CATSIM is covered in the next section.

The third test of objectivity is one of interpersonal transmissibility of the concepts used and the results produced. This test, together with the fourth, workability of the model, has not been fully applied. These tests are ongoing and will be given a more rigorous

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[1]As has been mentioned, CATSIM does <u>not</u> have complete price feedback loops as do many models to which CATSIM might be compared. This assertion concerns that <u>portion</u> of a model to which CATSIM might be compared.

application when CATSIM is adapted to the set of planned or proposed applications.

The first two objectivity tests were applied during model construction and during model testing. They will continue to be applied during model application--the process never ends. In addition, as the model is given wider exposure during application, the potential for failure increases--in this sense the test of objectivity become more severe through time. Failure will result in a return to some earlier step in the system simulation process to make revisions and to implement additional tests.

Model Sensitivity

The model of the Cattle Herd (CATSIM) is composed of: (1) stocks and flows of Cattle and Calves, (2) a structure describing the relationship of these stocks and flows to each other, and (3) a structure that describes the relationship of the Cattle Herd to the balance of the economy.

The structural relationships are built or designed in terms of parameters. In the behavioral models the relationships are expressed in terms of regression coefficients which are estimates of the true parameters. These regression coefficients are estimated by ordinary least squares regression analysis, which attempts to minimize a squared error objective function. In the balance of this section, a squared error value is also used to provide some insight into the impact on the model's outcome of varying the value of selected parameters. In other words, this "squared error value" will be used as the index of model sensitivity to parameter changes.

In Chapter IV, a simple error value was used as the index to "correctness" in the case of model RECON. This index was used to indicate the direction of change for parameter values in order to achieve some gross indication of optimality. The basis for the error value in that instance was Steer and Heifer SLAUGHTER. It is believed that published Steer and Heifer SLAUGHTER statistics are reasonably accurate; therefore, this basis will be used once again.

Three squared error values are calculated for each parameter setting. These three squared error values are calculated as follows:

$$\text{Steer Squared Error} = \sum_i \sum_j (\text{Published Steer SLAUGHTER}_{ij} - \text{Estimated Steer SLAUGHTER}_{ij})^2$$

$$\text{Heifer Squared Error} = \sum_i \sum_j (\text{Published Heifer SLAUGHTER}_{ij} - \text{Estimated Heifer SLAUGHTER}_{ij})^2$$

$$\text{Total Squared Error} = \sum_i \sum_j (\text{Published Steer SLAUGHTER} + \text{Published Heifer SLAUGHTER} - \text{Estimated Steer SLAUGHTER} - \text{Estimated Heifer SLAUGHTER})^2$$

where

i = years 1958-1975 inclusive

j = four quarters of each year.

These squared error values are given in Tables 24 and 25 for several key parameters. Each of these parameters is varied over a reasonable range. In many instances a minimum squared error value is found within the context of the balance of the model. A true optimization algorithm would allow all parameters (or a relevant sub-set) to vary concurrently. Since this latter instance does not apply, the technique does not necessarily indicate the optimum parameter value. Other evidence of optimum parameter value is incorporated into the analysis such as visual inspection of the output, a knowledge of the model's idiosyncracies[1] as well as some a priori knowledge of likely values for certain parameters.

In order to minimize the potential for error in utilizing this method (sensitivity test results) to provide some sense of optimality, the subject parameters were ranked in order of significance.[2] The results of the sensitivity run on parameter one are used to adjust parameter one prior to conducting the sensitivity test on parameter two, and so on. Regardless of the inaccuracy of parameter estimates, the technique provides a good index of parameter sensitivity.

Many parameters could have been tested. However, it is felt that the key ones have been selected; testing additional parameters would not add a great deal to our knowledge of the system given the

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[1]Problems with initialization of the delay subroutines cause 1958 and 1959 SLAUGHTER estimates to be less than accurate. These obviously inaccurate values are included in the squared error term, tending to bias it in an upward direction.

[2]In developing and building the model, the sensitivity and impact of certain parameters become apparent.

current level of sophistication of the model and the technique. The following parameters were selected for sensitivity tests.

- BIRTH Rate--Beef Cows and Heifers, West
  --Dairy Cows and Heifers, East
- The "DEL" parameter[1] in all Steer and Heifer delays
- The "K" parameter[2] in all Steer and Heifer delays
- The scale up of WEST-EAST Cattle-Calf Movement

For the East only:

- The proportion of Female Calves in UNINSPECTED Calf SLAUGHTER
- The proportion of Female Cattle in UNINSPECTED Cattle SLAUGHTER.

Model Stability

Stability refers to a system's ability to return to the region of a steady state (or growth path) when that system receives an exogenous shock. In this discussion of CATSIM, a slightly wider interpretation of stability is used--that is, stability refers to the system's ability to respond to natural control features inherent in the real world.

Most systems have feedback loops that give direction to the system. In the Cattle-Calves economy these include price feedback loops. These loops provide interaction with the balance of the economy. CATSIM by itself does not have price feedback loops;

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[1]This parameter indicates the expected value of the length of the delay.

[2]The parameter dictates the shape of the delay distribution and is a key parameter in the standard deviation of the delay distribution.

Table 24. Sensitivity test results on selected model parameters--CATSIM2, West

A. Beef BIRTH Rates (BRWBC, BRWBH)

BRWBC BRWBH	Squared error values		
	Steer error	Heifer error	Total error
.82	.25770 E + 11[a]	.20755 E + 11	.43092 E + 11
.83	.22202 E + 11	.20657 E + 11	.36717 E + 11
.84	.20158 E + 11	.21587 E + 11	.34438 E + 11
.85	.19138 E + 11	.33544 E + 11	.36356 E + 11
.86	.19142 E + 11	.30539 E + 11	.42121 E + 11

B. WEST-EAST Cattle Movement, scale-up factor (V9)

V9[b]			
1.00	.19981 E + 11	.20056 E + 11	.34006 E + 11
1.02	.20909 E + 11	.20098 E + 11	.35409 E + 11
1.04	.22185 E + 11	.20154 E + 11	.37311 E + 11
1.06	.23810 E + 11	.20223 E + 11	.39709 E + 11
1.08	.25784 E + 11	.20305 E + 11	.42606 E + 11

C. DEL paramater, the High Energy Ration Streams (B Stream)

DEL			
.67	.54760 E + 11	.25315 E + 11	.84313 E + 11
.75	.37900 E + 11	.26152 E + 11	.65794 E + 11
.83	.27982 E + 11	.26613 E + 11	.55229 E + 11
.91	.22397 E + 11	.26676 E + 11	.48925 E + 11
.99	.19467 E + 11	.36446 E + 11	.44971 E + 11

[a]The value .25770 E + 11 is read .25770 times 10 raised to the power 11.

[b]BRWBC and BRWBH are set at .82; the "DEL" and "K" values are set at their final values.

Table 24--Continued

D. K parameter, the High Energy Ration Streams (B Stream)			
	Squared error values		
K	Steer error	Heifer error	Total error
3	.22584 E + 11	.22513 E + 11	.28277 E + 11
4	.21614 E + 11	.24034 E + 11	.42594 E + 11
5	.22397 E + 11	.26152 E + 11	.50978 E + 11
6	.24687 E + 11	.28652 E + 11	.62281 E + 11
7	.28422 E + 11	.31391 E + 11	.75941 E + 11
E. DEL parameter, the Low Energy Ration Streams (A Stream)			
DEL			
.59	.21757 E + 11	.40285 E + 11	.70318 E + 11
.67	.19556 E + 11	.30074 E + 11	.48699 E + 11
.75	.19702 E + 11	.24582 E + 11	.39456 E + 11
.83	.19605 E + 11	.21582 E + 11	.36494 E + 11
.91	.20389 E + 11	.20089 E + 11	.36570 E + 11
F. K parameter, the Low Energy Ration Stream (A Stream)			
K			
2	.22873 E + 11	.29857 E + 11	.58371 E + 11
3	.19202 E + 11	.24250 E + 11	.39456 E + 11
4	.19136 E + 11	.23588 E + 11	.36369 E + 11
5	.21124 E + 11	.25859 E + 11	.43647 E + 11
6	.24445 E + 11	.30574 E + 11	.58343 E + 11

Table 25. Sensitivity test results on selected model parameters--CATSIM2, East

BREDC BREDH	Squared error values		
	Steer Error	Heifer error	Total Error
A. Dairy BIRTH Rates (BREDC, BREDH)			
.70	.20633 E + 11	.13342 E + 11	.55921 E + 11
.71	.19653 E + 11	.12444 E + 11	.52182 E + 11
.72	.19348 E + 11	.12222 E + 11	.51138 E + 11
.73	.19716 E + 11	.12667 E + 11	.52788 E + 11
.74	.20759 E + 11	.13792 E + 11	.57134 E + 11
B. WEST-EAST Cattle Movement, scale-up Factor (V9)			
V9[a]			
1.00	.20931 E + 11	.14546 E + 11	.58473 E + 11
1.02	.20446 E + 11	.14559 E + 11	.58047 E + 11
1.04	.20314 E + 11	.14558 E + 11	.58120 E + 11
1.06	.20532 E + 11	.14625 E + 11	.58693 E + 11
1.08	.21102 E + 11	.14678 E + 11	.59766 E + 11
C. DEL parameter, the High Energy Streams (B Stream)			
DEL			
.67	.29423 E + 11	.14803 E + 11	.71598 E + 11
.75	.25249 E + 11	.14531 E + 11	.65047 E + 11
.83	.22879 E + 11	.14370 E + 11	.61338 E + 11
.91	.21609 E + 11	.14282 E + 11	.59398 E + 11
.99	.20975 E + 11	.14241 E + 11	.58489 E + 11
D. K parameter, the High Energy Streams (B Stream)			
K			
3	.22578 E + 11	.14492 E + 11	.62113 E + 11
4	.21852 E + 11	.14420 E + 11	.60543 E + 11
5	.21609 E + 11	.14385 E + 11	.59758 E + 11
6	.21713 E + 11	.14387 E + 11	.59573 E + 11
7	.22117 E + 11	.14422 E + 11	.59890 E + 11

[a]BREDC and BREBC are set at .73.

Table 25--Continued

E. Del parameter, the Low Energy Streams (A Stream)

DEL	Squared error values		
	Steer error	Heifer error	Total error
.67	.23162 E + 11	.14797 E + 11	.62987 E + 11
.75	.21609 E + 11	.14385 E + 11	.59758 E + 11
.83	.20386 E + 11	.14084 E + 11	.57265 E + 11
.91	.19396 E + 11	.13848 E + 11	.55254 E + 11
.99	.18580 E + 11	.13653 E + 11	.53581 E + 11

F. K parameter, the Low Energy Ration Streams (A Stream)

K			
2	.21001 E + 11	.13429 E + 11	.57270 E + 11
3	.21609 E + 11	.14385 E + 11	.59758 E + 11
4	.22401 E + 11	.15205 E + 11	.62592 E + 11
5	.23333 E + 11	.16020 E + 11	.65757 E + 11
6	.24376 E + 11	.16834 E + 11	.69145 E + 11

G. Steer proportion of UNINSPECTED Cattle SLAUGHTER

V76			
.20	.39701 E + 11	.33808 E + 11	.57223 E + 11
.30	.25182 E + 11	.19078 E + 11	.57223 E + 11
.40	.20306 E + 11	.14072 E + 11	.57223 E + 11
.50	.25313 E + 11	.18788 E + 11	.57223 E + 11
.60	.39964 E + 11	.33228 E + 11	.57223 E + 11

H. Heifer proportion of UNINSPECTED Calf SLAUGHTER

V34			
.15	.19914 E + 11	.14592 E + 11	.57463 E + 11
.25	.20143 E + 11	.14325 E + 11	.57343 E + 11
.35	.20386 E + 11	.14072 E + 11	.57223 E + 11
.45	.20642 E + 11	.13833 E + 11	.57105 E + 11
.55	.20913 E + 11	.13609 E + 11	.56988 E + 11

however, version CATSIM3 does incorporate price and other stimuli through the behavioral elements. To the extent that these price feedback loops are not closed by incorporation of a second model (a model determining price), CATSIM is unstable.

The CATSIM1 version is highly sensitive and unstable due to the method of Replacement Heifer generation.[1] In CATSIM1, REPLACEMENTS are generated as a proportion of the existing Cow Herd. If the proportion is slightly high (low), the Cow Herd grows (or declines) exponentially, finally exploding (or collapsing). This feature was found to be very useful in arriving at initial values for certain parameters as a slight change in the value of a parameter became very apparent over a 15 year run of the simulator.

To demonstrate, CATSIM1 is analogous to the following very simple system with respect to its dynamic properties.

The model of the simple system is expressed by the differential equation:

$$d\frac{P_t}{dt} = BR \cdot P_t - DR \cdot P_t - S$$

where P_t = population in time period t;

BR = BIRTH Rate;

DR = CULL + natural DEATH Rate; and

S = other factors such as EXPORT and IMPORT Rates.

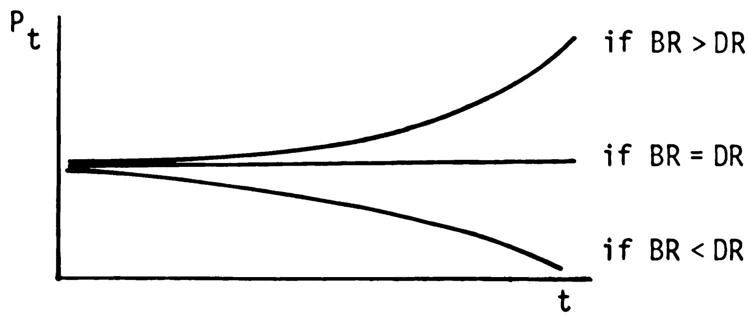
---

[1]This model can be controlled through incorporation of a price feedback loop where price directed the "rate" of REPLACEMENT.

If it is assumed that S = 0, then the solution to the differential equation is:

$$P_t = P_0 e^{(BR - DR)^t}$$

This model's dynamic properties are shown in the following graph. These properties are also shared by CATSIM1.



Version CATSIM2 does not explode in an exponential sense due to the method of calculation of REPLACEMENTS. However, due to the lack of price feedback, the output can become highly biased without a correction mechanism coming into effect.

Since a simulator is a second level of abstraction from reality, instability can occur in the simulator even though it does not appear in the real world or the mathematical model. This stability or lack of stability is a function of the models' parameters and especially those associated with the distributed lag subroutines. This aspect of stability is discussed in Appendix B.

Version CATSIM3 is by design a model reflecting the impact of relevant prices and other external influences. While the model itself does not complete the price feedback loop, to be operated as a partially closed system this loop must be closed. Thus, in operation CATSIM3 is stable within the bounds of the cattle cycle.[1]

CATSIM1 and CATSIM2 are unstable in the sense of the above discussions. Lack of stability, however, does not preclude their application to a range of problems and research questions.

Operation in a Deterministic Mode

CATSIM1 and CATSIM2 operate in a deterministic mode, that is, they contain no stochastic elements. The main difference between CATSIM1 and CATSIM2 involves the method of generation of Cow SLAUGHTER and REPLACEMENTS. This difference has been stated before on several occasions and is discussed in detail in Chapter IV.

The best method of conveying an understanding of the performance of these two models is to visually display the output. To that end, Figures 27 to 32 plot the historical Cow and Bull Population as estimated by these two models. These estimates in turn are compared with the published Population statistics. The estimated flow of Slaughter Steers and Heifers is given in Figures 37 to 40 in the next section. These latter estimates are also compared with published SLAUGHTER statistics.

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[1]This was the case over the 1958-1972 test period. The model could be tested using extreme prices and price variations.

CATSIM2 tracks Cow Population official statistics with extremely low error in the West and with tolerable error in the East. The tracking of official Bull Population statistics is less precise with error mostly below 5 percent although in the 1971-1972 case, the errors are larger.

In operating CATSIM2, it was found to be necessary to alter MATRIX output[1] in three instances. This was found to be necessary to force CATSIM2 output to track the official statistics. This alteration was applied in terms of a factor multiple of the MATRIX REPLACEMENT series. These factors are as follows:

Bull, REPLACEMENTS, West	x .97
East	x 1.03
Beef Cow, REPLACEMENTS, East	x 1.03
All others	x 1.00

In all instances, an attempt was made to keep all parameter settings constant between MATRIX and CATSIM2. This was not always possible as the structure of the two models is inherently different. In the case of Western bulls, CATSIM2's ability to exactly duplicate the conditions of MATRIX is obviously open to some error, as evidenced by the divergence of the estimated from the published Bull Population data series. The fact that a correction factor of .97 is needed indicates that the differences between CATSIM2 and MATRIX are not only random but also biased.

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[1]The reader is reminded that CATSIM2 used REPLACEMENT and Cow SLAUGHTER data as generated by program MATRIX and as amended.

The explanation for Eastern Beef Cows is different. The data series (Cow SLAUGHTER and REPLACEMENT) used in CATSIM2 is not the original MATRIX output but the altered output. This alteration accounts for most of the adjustment factor of 1.03. The Eastern Dairy Herd did not require any adjustment factor since the alterations are relatively much smaller with respect to the larger Dairy Herd. These alterations, however, show up in the form of poorer tracking in the East than in the West.

CATSIM1[1] overestimates Western Beef Cow Population during the 1958-1963 expansion period and underestimates it during the 1964-1969 contraction period, contrary to expectations. In the East, the Beef Cow Population is once again overestimated during the 1958-1963 period but gives predictable (overestimated) results during the 1965-1969 downswing in the cattle cycle.

In the West, the Dairy Cow Herd was assumed a priori to be immune to the cattle cycle, consequently MATRIX was constructed on such a premise.[2] In addition, MATRIX output was used in an unaltered form with respect to Western SLAUGHTER and REPLACEMENT data sources.

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[1]CATSIM1 calculates REPLACEMENTS as a constant proportion of the existing Cow Population. This model then does not respond to the cattle cycle except through the Cow SLAUGHTER element; thus, the response is weak. A priori, it would be assumed that CATSIM1 would overestimate Heifer REPLACEMENTS (thus Cow Population) in the downswing of the cattle cycle and vice versa in the upswing.

[2]The fact that this premise did not hold true resulted in significant serial correlation occurring with the behavioral model for Western Dairy Cow models.

Figure 28 shows the results--a steady decline in Dairy Cow numbers. The published statistics, however, show a rather definite cycle tending to dispute this stability premise.

The alterations made to the Eastern output of MATRIX may have been unnecessary as the output of CATSIM2 clearly exaggerates the cycle indicated by the published Dairy Cow Population series, especially over the 1959-1965 period.

Operation in a Stochastic Mode

CATSIM3 is developed by adding the behavioral models developed in Chapter III to CATSIM2. In effect, the elements of CATSIM2 concerning REPLACEMENT and SLAUGHTER are replaced by the behavioral estimators. To reiterate, these behavior models estimate (1) Cow SLAUGHTER and REPLACEMENT, (2) Bull SLAUGHTER and REPLACEMENT, and (3) Calf SLAUGHTER.

CATSIM3 represents the most sophisticated version of CATSIM developed in this study. The inclusion of the behavioral models allow the incorporation of price feedback loops and provide other points of interaction between the Cattle-Calves sub-sector and the balance of the economy.

Figures 33 to 36 compare the output of CATSIM3 with CATSIM2 as well as with the official published statistics with respect to Cow Population. Figures 37 to 40 make these same comparisons with respect to Steer and Heifer SLAUGHTER. The first comparison reflects the accuracy of the behavioral models with respect to Cow SLAUGHTER and REPLACEMENT. The second comparison reflects the accuracy of the

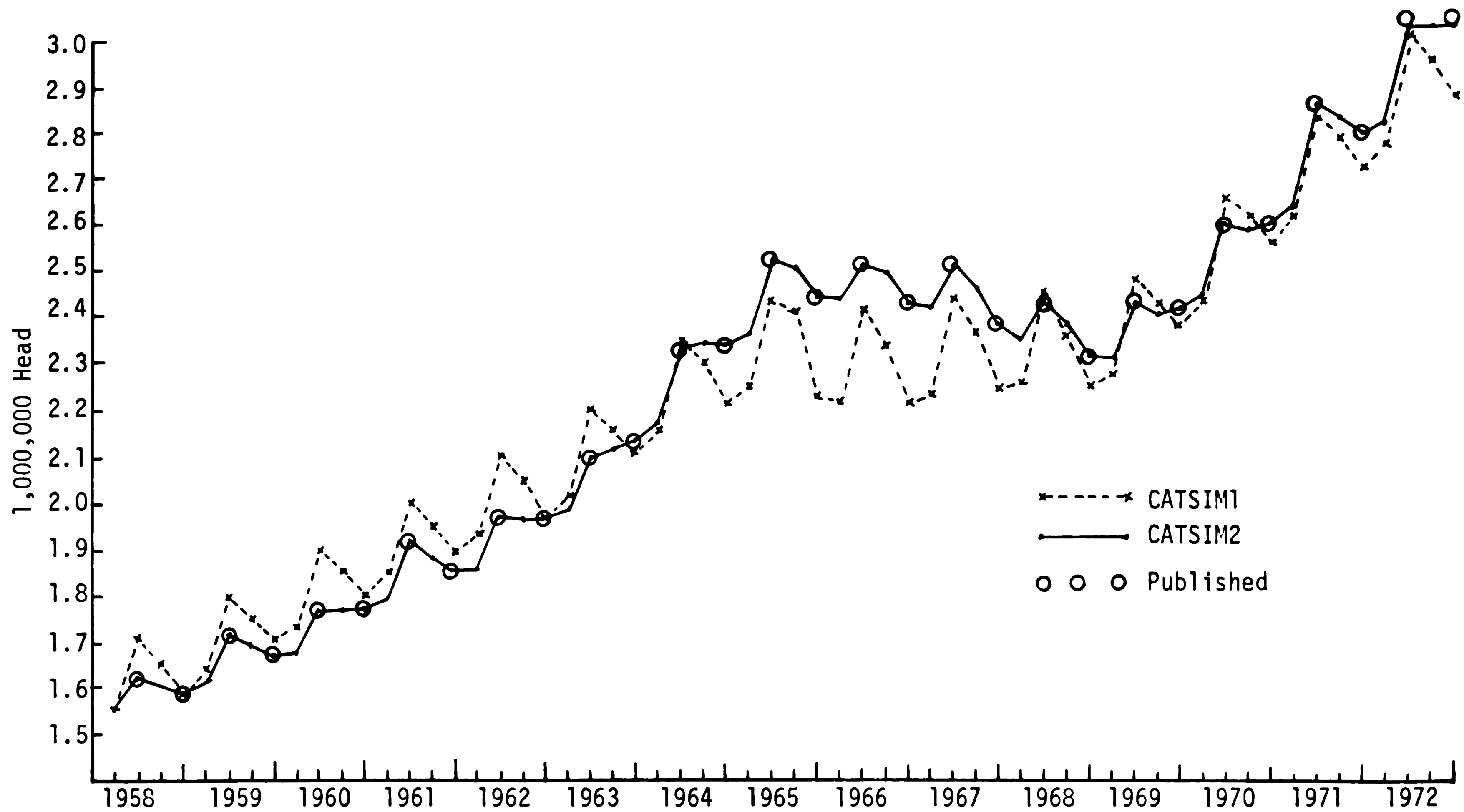

Figure 27. Quarterly Beef Cow Population, West, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

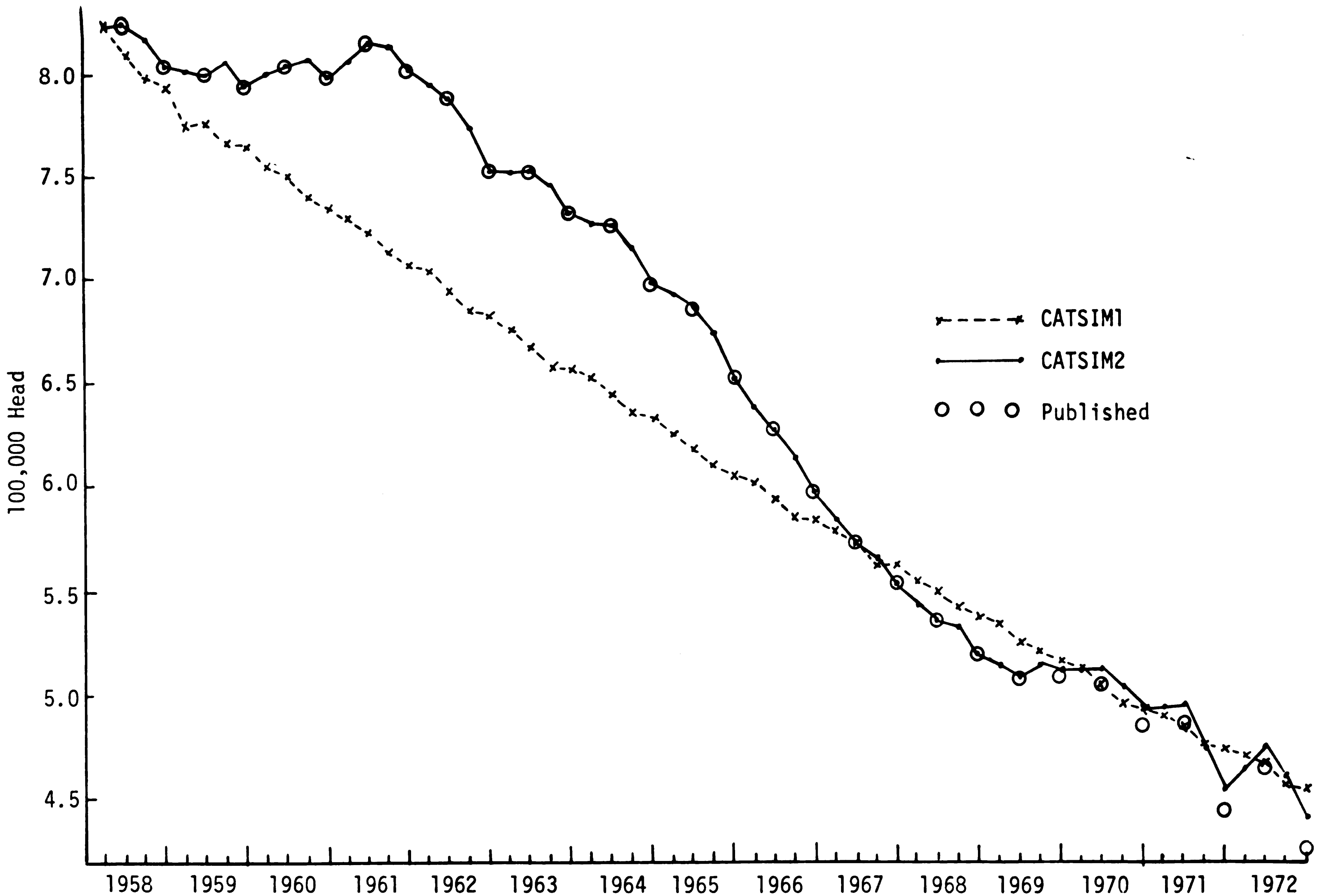

Figure 28. Quarterly Dairy Cow Population, West, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

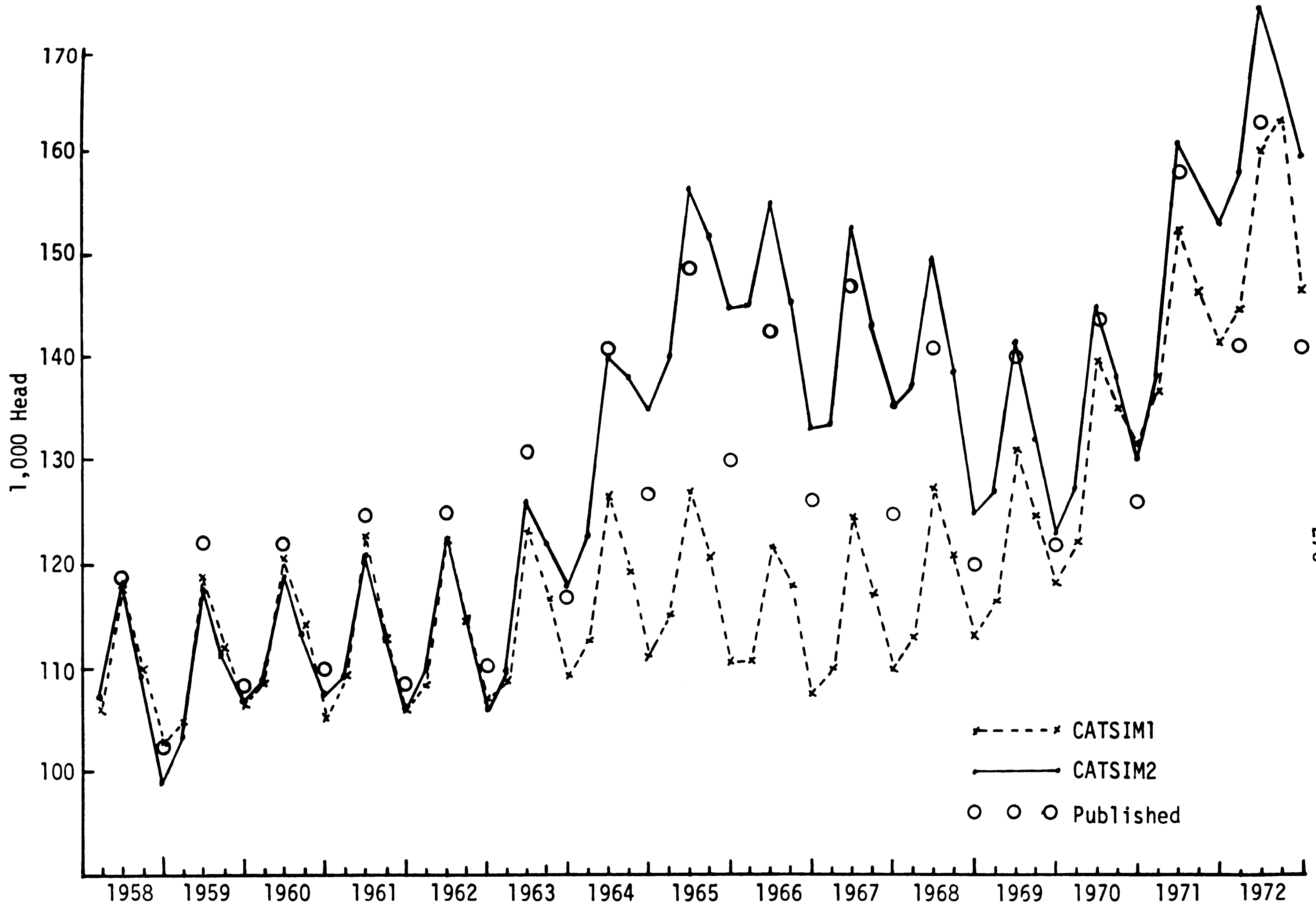

Figure 29. Quarterly Bull Population, West, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

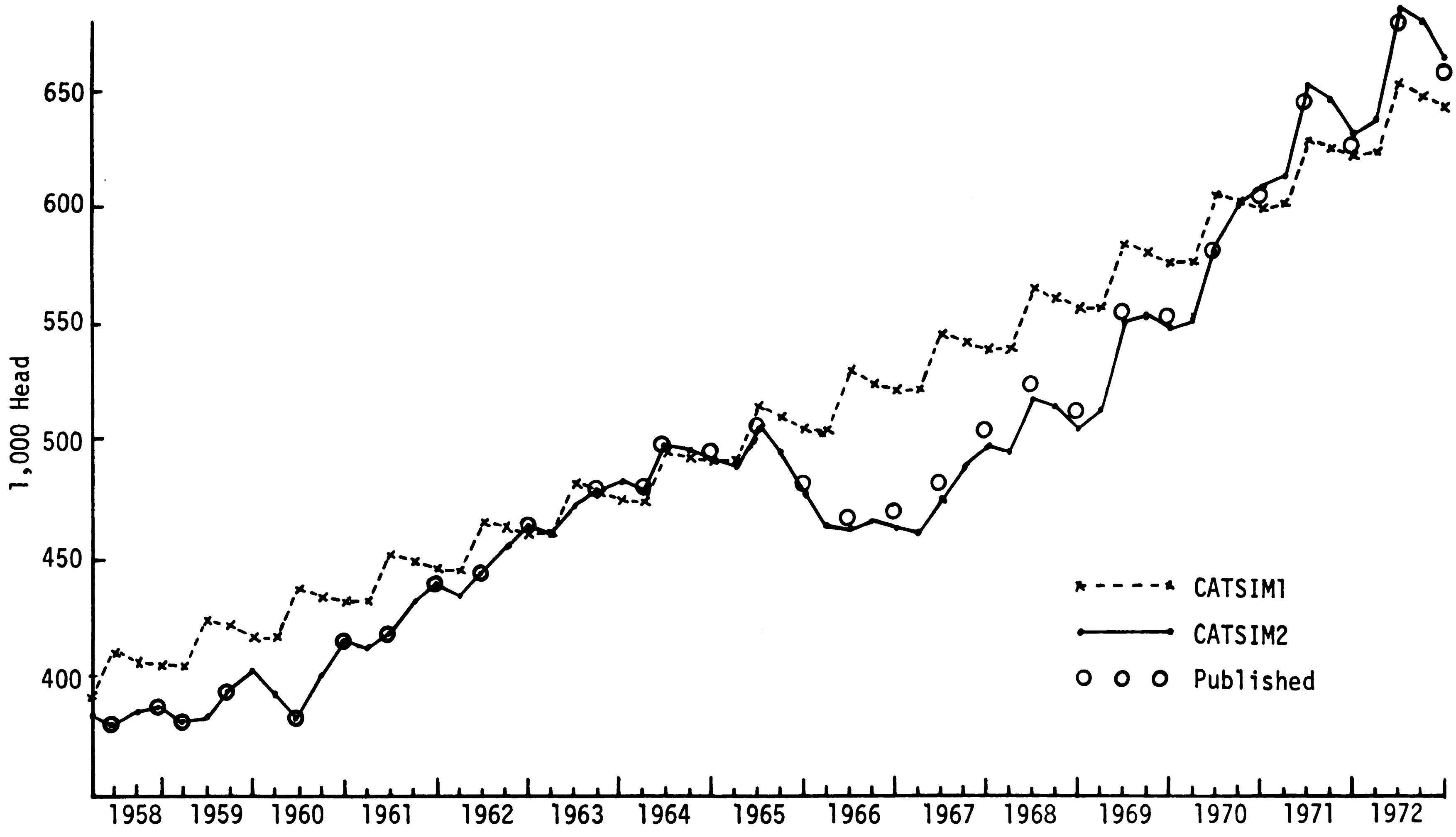

Figure 30. Quarterly Beef Cow Population, East, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

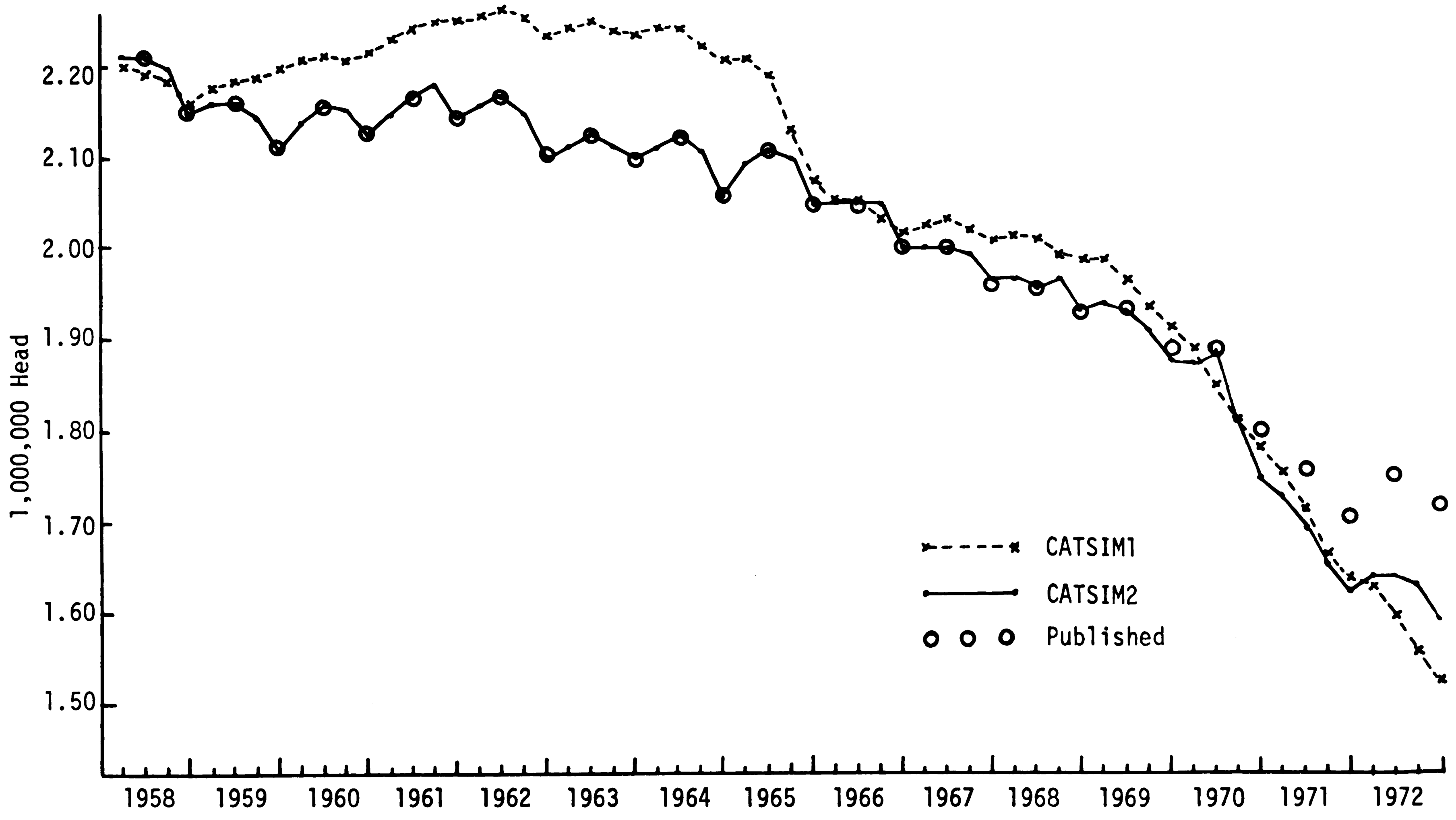

Figure 31. Quarterly Dairy Cow Population, East, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

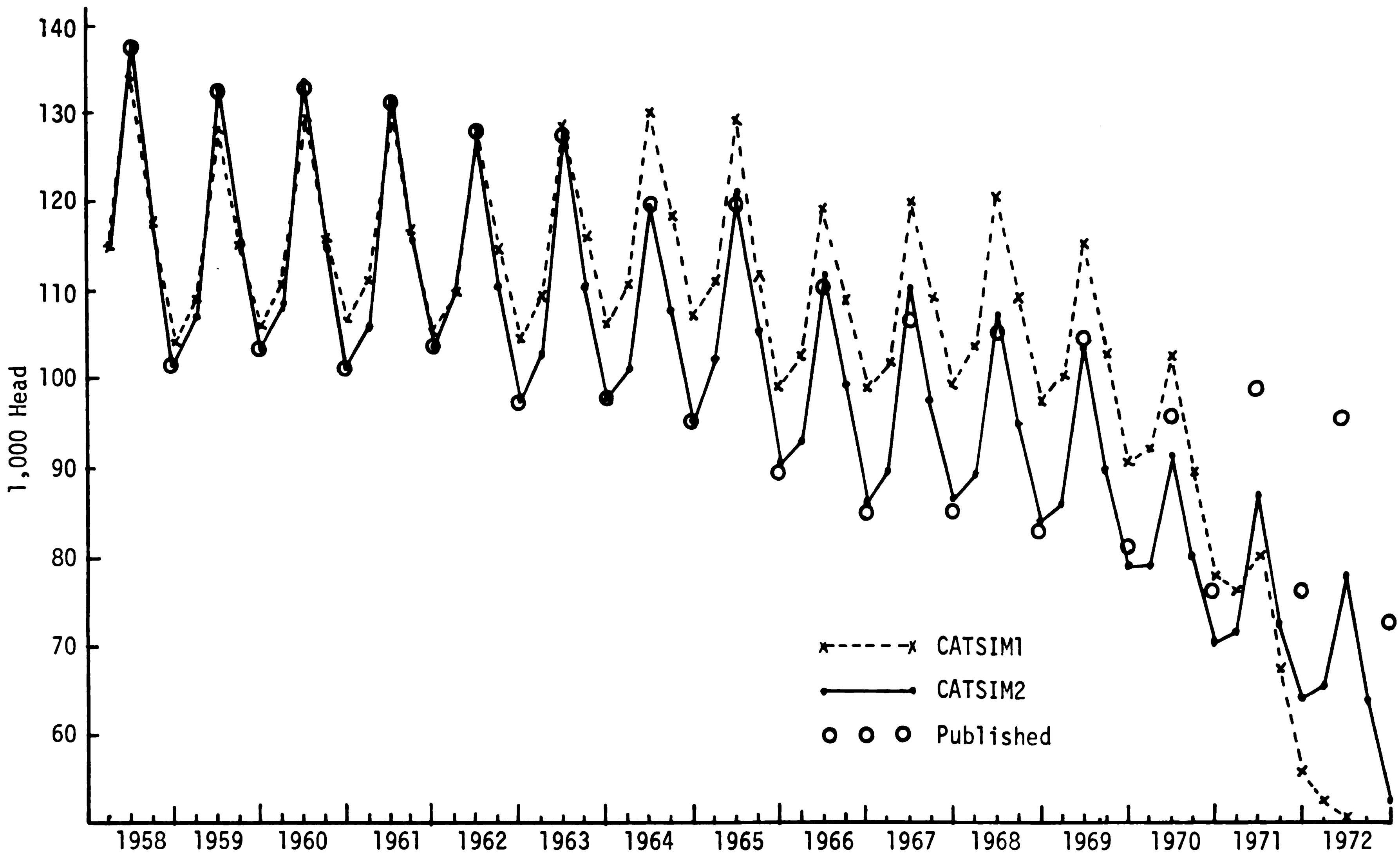

Figure 32. Quarterly Bull Population, East, 1958-1972, Published, and Estimated by CATSIM1 and CATSIM2.

behavioral models with respect to the above, plus the accuracy of Calf SLAUGHTER estimates.

With respect to Cow Population estimates (Figures 33 to 36), CATSIM3 provides acceptable estimates in comparison with CATSIM2. Most turning points are reflected; the magnitude of quarter to quarter and year to year adjustments are estimated quite accurately as well. A statement that generalizes CATSIM3 performance might be that it "moderates" cyclical adjustments.

The CATSIM3 estimates of INSPECTED SLAUGHTER (Figures 37 to 40), closely approximate those of CATSIM2. Steer SLAUGHTER estimates are particularly close; Heifer SLAUGHTER estimates show more deviation between CATSIM2 and CATSIM3 estimates. This might be explained in terms of the fact that Heifer SLAUGHTER is derived from those Heifers that are surplus or residual to REPLACEMENT needs. Since more Heifers are used for REPLACEMENT, any error in REPLACEMENT estimates generate a relatively much larger SLAUGHTER error.

Figures 37 to 40 compare SLAUGHTER estimates with official published statistics. The statement that SLAUGHTER is a residual applies to CATSIM, and, in fact, the real world. Thus, all flow errors are summed and are finally revealed in SLAUGHTER estimates. Generally speaking, the observed seasonal SLAUGHTER pattern is more variable than the somewhat fixed CATSIM seasonal SLAUGHTER.[1] For this reason, the turning points in the estimated and the official data series

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[1]The CATSIM seasonal pattern is fixed to the extent that the "K" and "DEL" parameters of the continuous delays are constant.

do not occur in the same quarter in every instance. The obvious conclusion is that the observed feeding-finishing lag fluctuates about the stable one built into CATSIM.

CATSIM tends to even out the observed peaks in SLAUGHTER. This would indicate the shape of the continuous delay's distribution is too flat.[1] A "best" fit is obtained by using this flat or smoothing distribution together with a "mean" delay in the feeding-finishing process. These two unrealistic fixed values (mean delay and delay distribution) tend to complement each other. If a more accurate delay were introduced, a more responsive (less flat) delay distribution could be used.

The second set of comments concerning SLAUGHTER estimates refer specifically to Heifer SLAUGHTER. These latter estimates deviate markedly from the observed or official Heifer SLAUGHTER. This deviation is a result of the two factors mentioned above, namely, (1) SLAUGHTER is a residual, and (2) the continuous delay element in the model does not accurately reflect actual conditions, but rather "mean" conditions. In Figure 38, estimated and official estimates differ widely during the 1962-1963 and 1966-1967 period. In Figure 40, this difference is noted in the 1964-1965 period. The 1965-1966 period is the first two years of the cattle cycle downswing. In many years, estimated Heifer SLAUGHTER is lower than official Heifer SLAUGHTER. A plausible explanation might be that official Heifer SLAUGHTER includes both Heifers,

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[1]The shape of the continuous delay's distribution, the erlang distribution, is determined by the parameter "K."

as defined in CATSIM, plus very young Cows. The latter would in many cases meet the physiological limits of a Heifer as defined for SLAUGHTER statistics purposes.

In summary, CATSIM3 appears to operate as well as CATSIM2 or stated in another fashion, introduction of the behavioral elements causes little, if any, loss in estimation accuracy, while introducing all the advantages of the price feedback and other interaction with the non-Cattle-Calves economy. The limitations of CATSIM2 are also the limitations of CATSIM3.

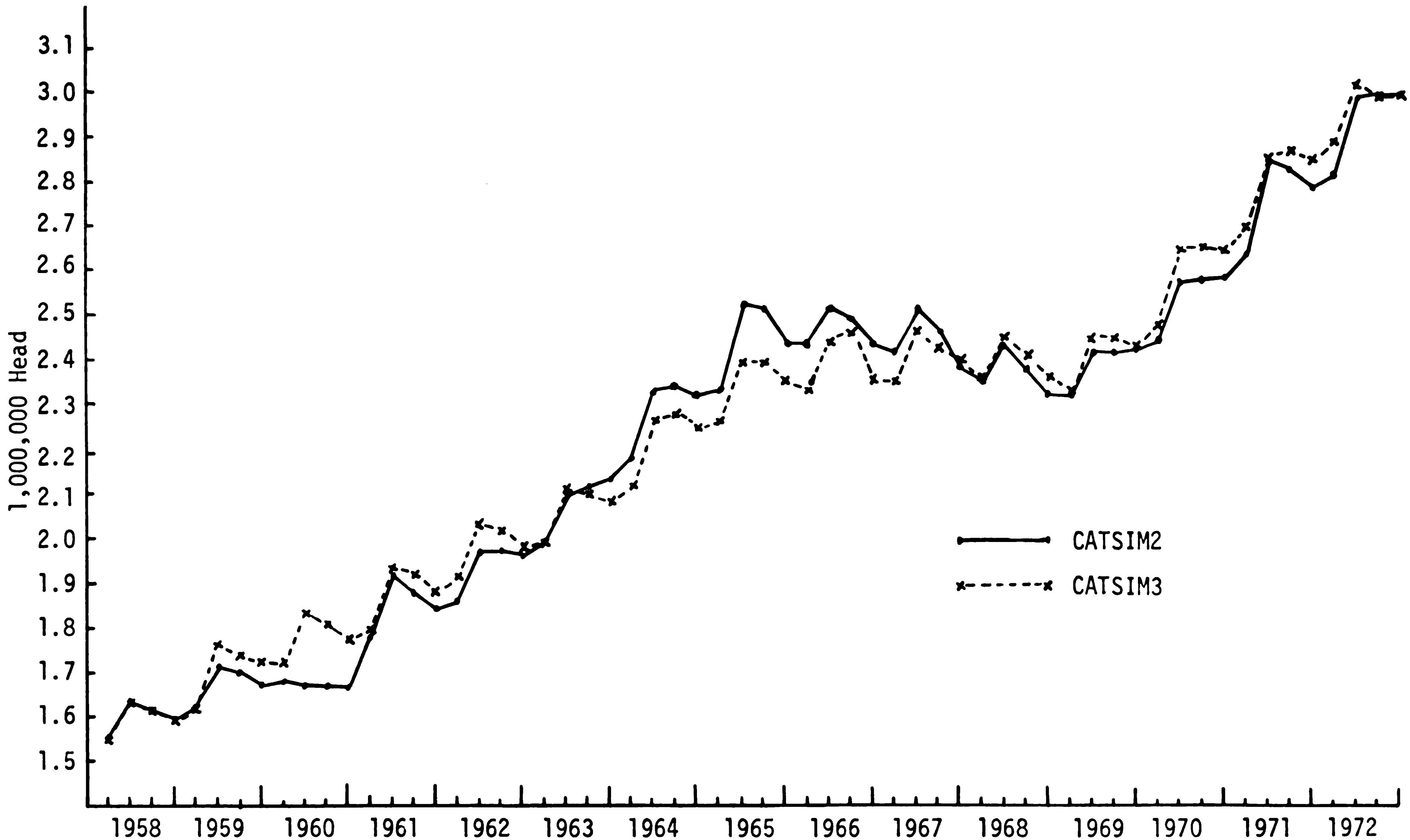

Figure 33. Quarterly Beef Cow Population, West, 1958-1972, Estimated by CATSIM2 and CATSIM3.

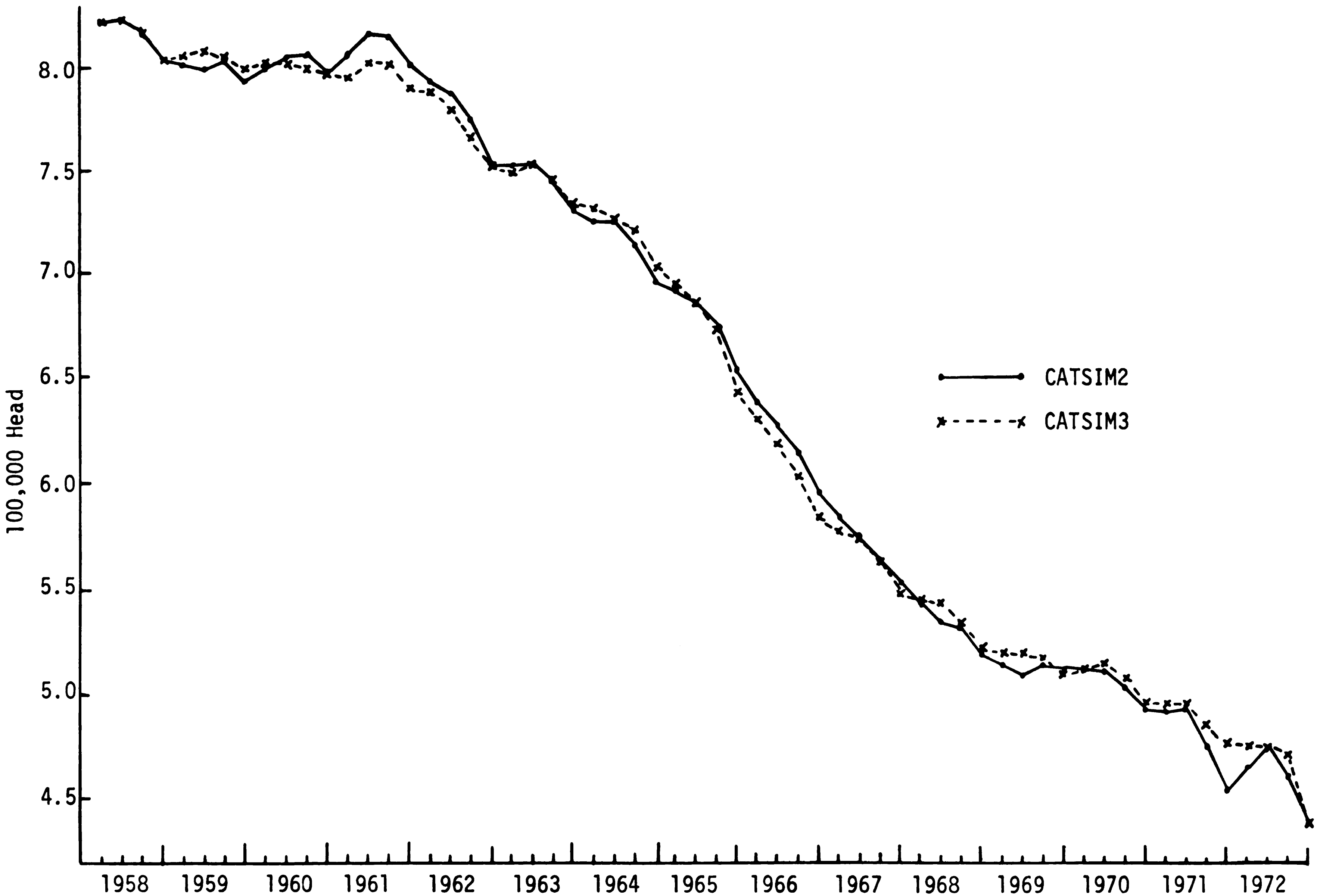

Figure 34. Quarterly Dairy Cow Population, West, 1958-1972, Estimated by CATSIM2 and CATSIM3.

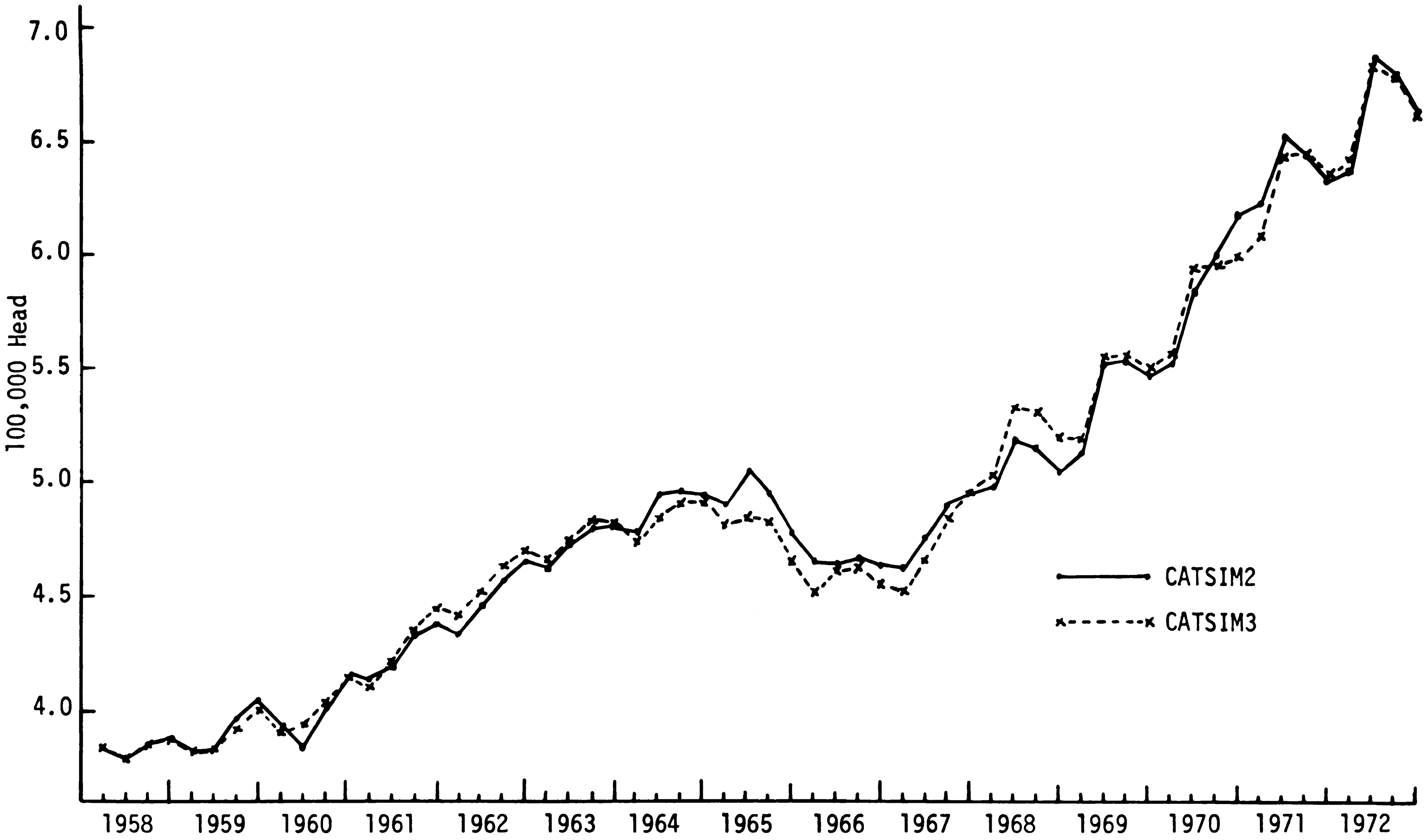

Figure 35. Quarterly Beef Cow Population, East, 1958-1972, Estimated by CATSIM2 and CATSIM3.

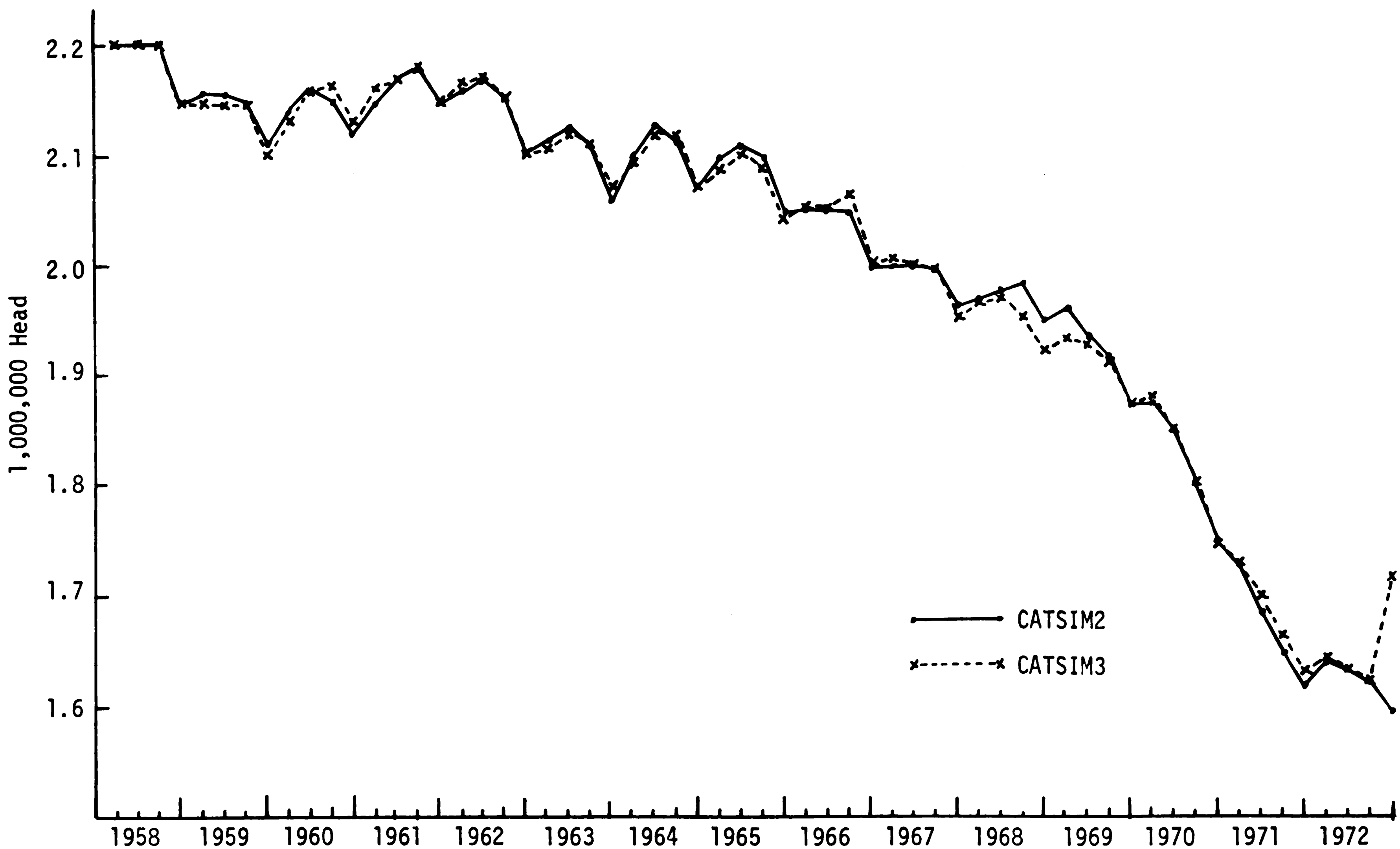

Figure 36. Quarterly Dairy Cow Population, East, 1958-1972, Estimated by CATSIM2 and CATSIM3.

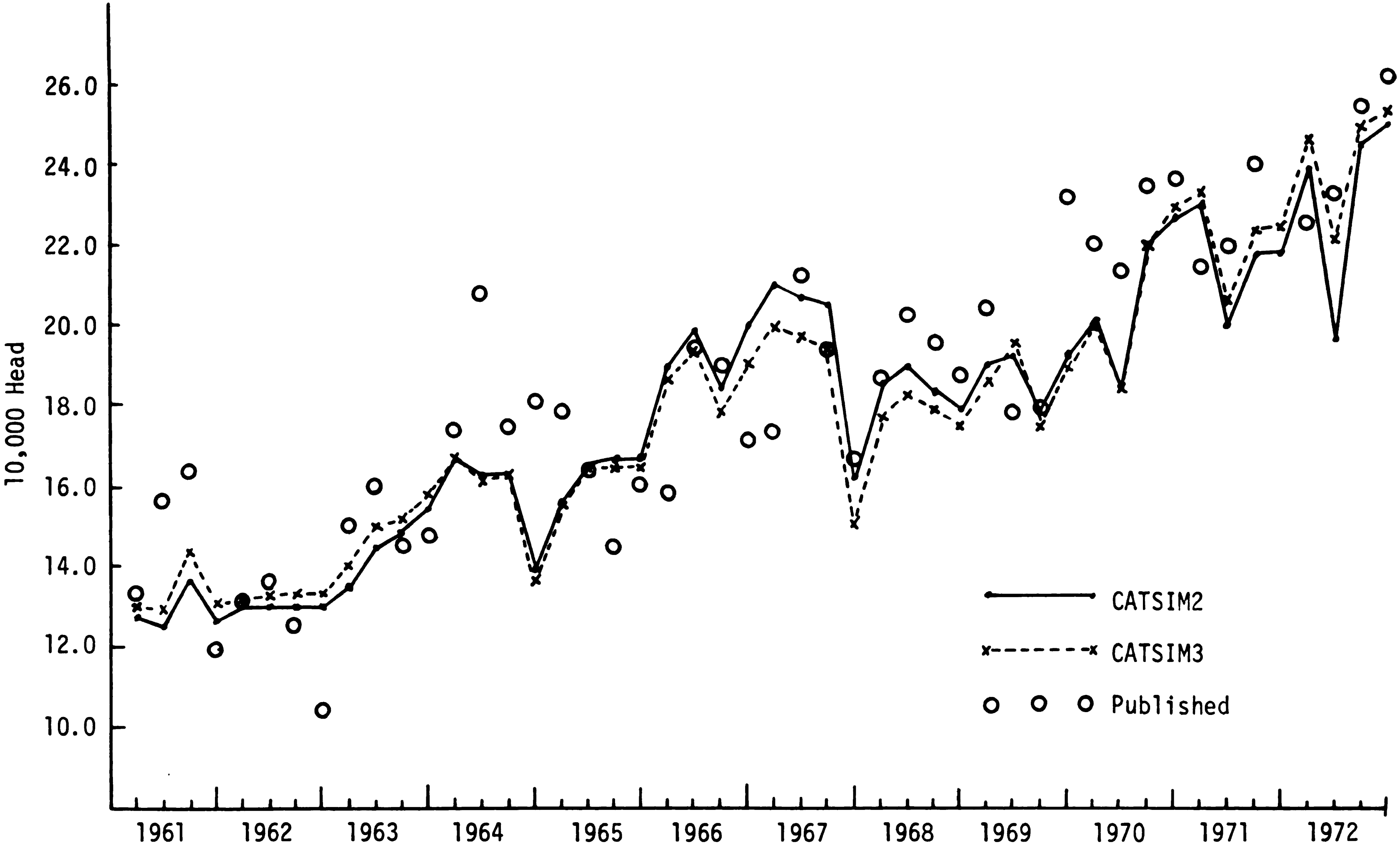

Figure 37. Quarterly INSPECTED Steer SLAUGHTER, West, 1961-1972, Published, and Estimated by CATSIM2 and CATSIM3.

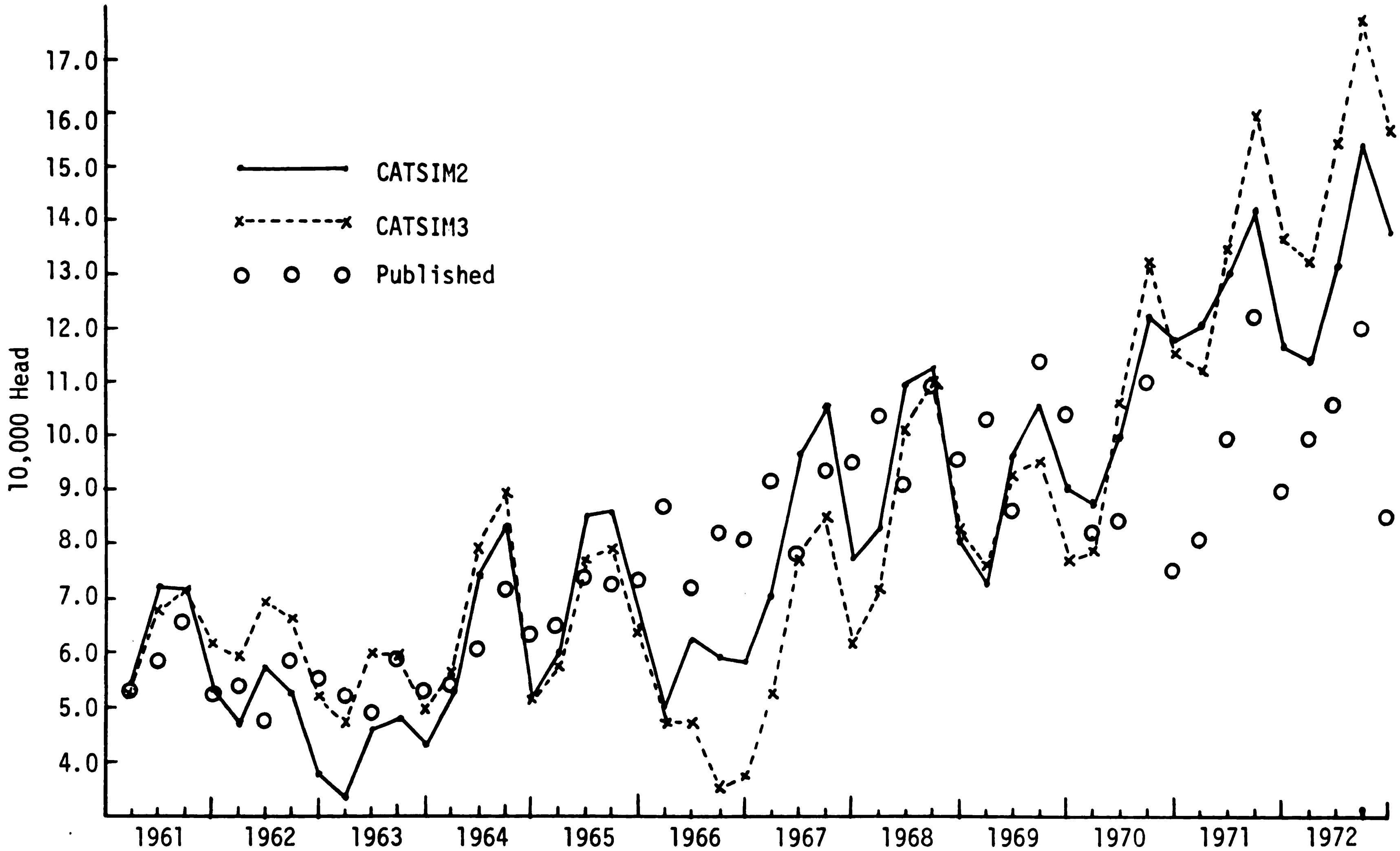

Figure 38. Quarterly INSPECTED Heifer SLAUGHTER, West, 1961-1972, Published, and Estimated by CATSIM2 and CATSIM3.

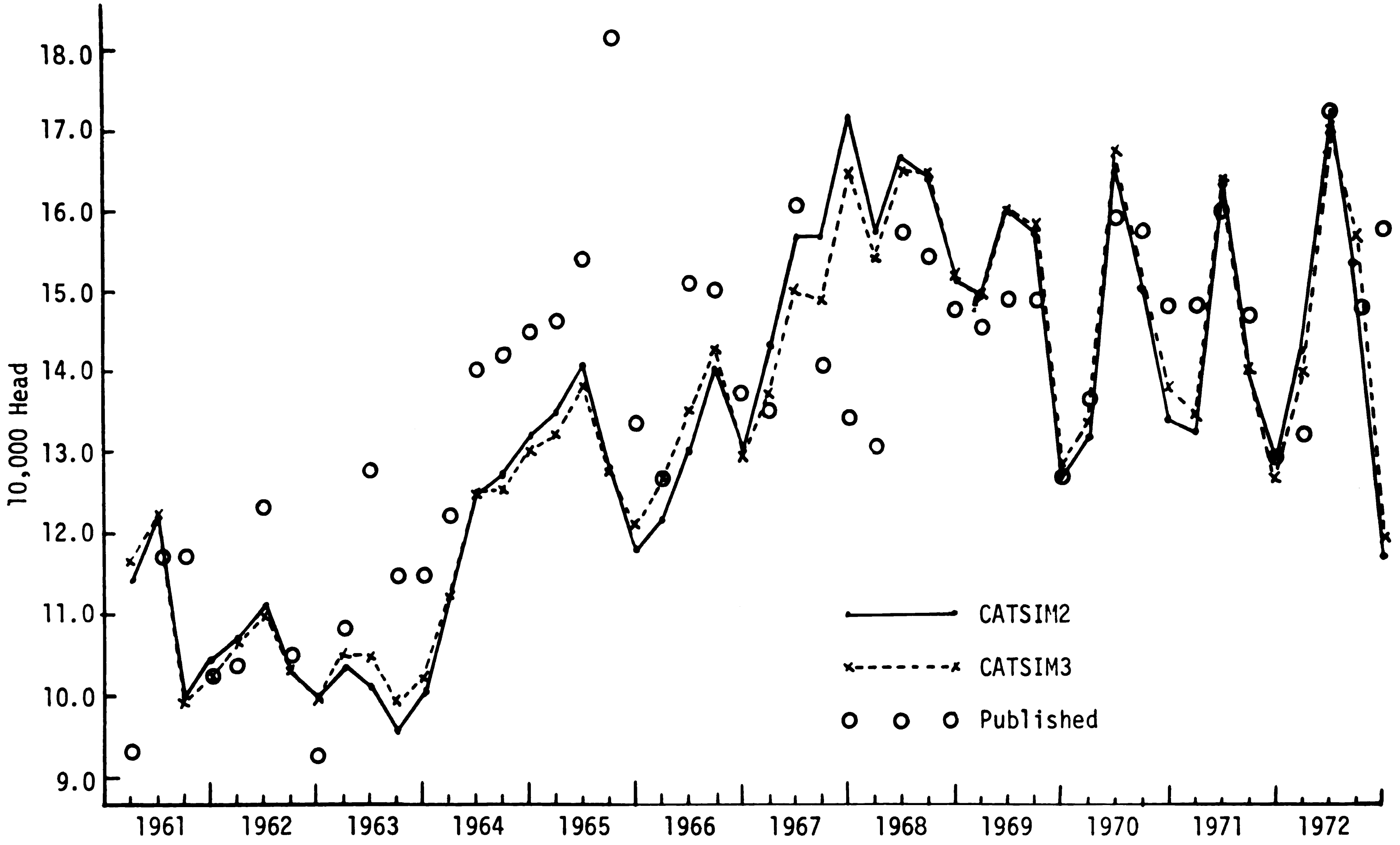

Figure 39. Quarterly INSPECTED Steer SLAUGHTER, East, 1961-1972, Published, and Estimated by CATSIM2 and CATSIM3.

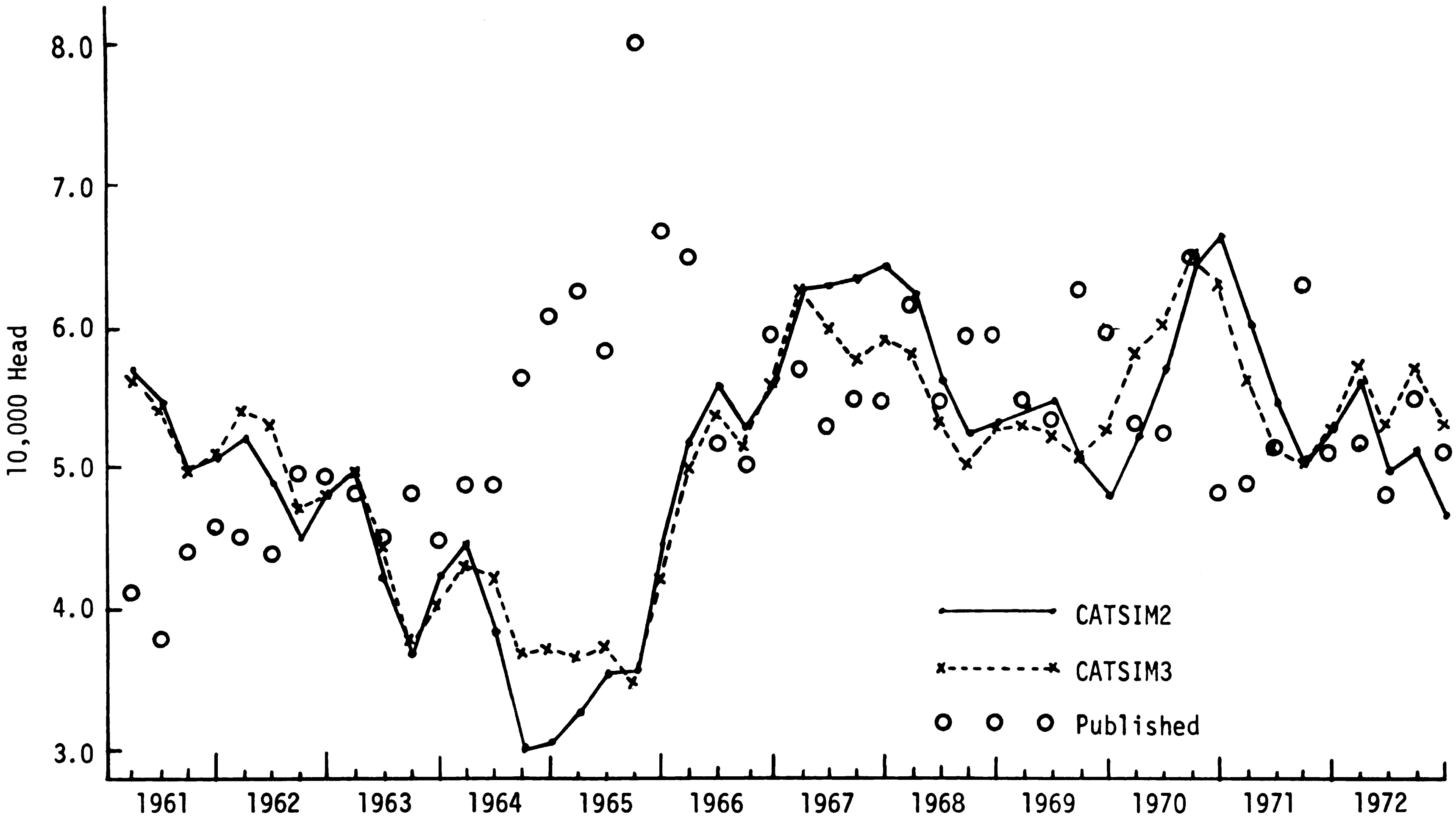

Figure 40. Quarterly Heifer SLAUGHTER, East, 1961-1972, Published, and Estimated by CATSIM2 and CATSIM3.

CHAPTER VII

SUMMARY AND APPLICATION

The most substantive results of the study are contained in the structure and assumptions of the various models which are built in the course of this investigation. These assumptions and the models structure are described in the body of the thesis and will not be reiterated in this final chapter.

The Cattle Herd simulator that was designed and built is called CATSIM. It is, however, the end result of a series of other subservient, but nevertheless, useful models. These latter models are used to estimate parameter values and generate data series that were not available, but are required to construct the Cattle Herd simulator.

The first section of this final chapter summarizes these various models, describes their purpose, relates the models to each other and to the study objectives as listed in Chapter I. In addition, chapters, figures, tables, and appendices are referenced where these describe various aspects of the model or its output.

Summary

In order to build the simulator, it was necessary to utilize existing official data that are descriptive of the Canadian Cattle Herd. These data become the stock and flow variable values for the simulator, as well as for all other models.[1] It was recognized at the onset that these official data were not necessarily accurate nor were the various series compatible with each other. In addition to these two shortcomings, these data are not comprehensive enough to support the proposed simulator. In order to assess the official data, a simple simulator was built. This simulator, called RECON, was built on the basis of a single identity. Some of the key results obtained from the use of RECON are described later in this section.

Parameter estimation is another major part of this study. One major set of parameters is estimated by ordinary least squares. This technique is applied to 16 behavioral relationships that were designed for CATSIM3. While many more behavioral and time variant relationships could have been considered, the scope of this study limited it to 16. The behavioral relationships serve to complete the price feedback loop that provides direction to the growth of the Cattle Herd. They also provide the connecting link between Cattle-Calves subsector and the wheat-feed grain sub-sector, as well as with the balance of the economy.

In order to fit these behavioral relationships, a set of time series data was required that was not available from published statistics. To generate these data, the endogenous variables, a third model was built. It is called MATRIX.

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[1]The notational convention employed to denote stock and flow variables is continued in this final chapter. This convention is outlined in Table 2, pages 50-51.

Additional parameter values were needed that could not easily be estimated by econometric techniques because of the lack of historical data series. In truth, often the purpose of obtaining parameter estimates was to generate the missing data series. In these instances, parameter estimates were obtained from a variety of sources including data compiled by various organizations, by extrapolation and by obtaining guesstimates from individuals who should be in a position to provide reliable information. The test of these parameter values is their objectivity in use in the various models.

All models are based in large part on judgment. The structure of these models is based on judgment; certain parameter values are based on informed judgment. In almost all cases, this judgment was given by individuals who had no subsequent opportunity to revise, clarify, or defend their subjective estimate. The stage of development of these models is such that refinement can only come through interaction between these subject matter specialists and the model. This will occur subsequent to this study.

Program MATRIX and the Behavioral Models

The model used to generate the endogenous data series for the behavioral models (and ultimately for version CATSIM3) is called MATRIX. These data series are used directly in version CATSIM2 as well. This model is described in Chapter III while its Fortran program is listed in Appendix C.

This model generates a time series of quarterly Dairy and Beef Cow SLAUGHTER (CULL) and REPLACEMENT data. These same data series are generated for Bulls. A listing of these data series, together with Male and Female Calf SLAUGHTER, is given in Tables 5 to 8.

One test of the reliability of these data series is to assess their performance in the simulator. Version CATSIM1 does not use these data series while CATSIM2 does. Figures 27 to 32 compare Cow and Bull Population estimates given by CATSIM1, CATSIM2, and the official published data. Since the only difference between CATSIM1 and CATSIM2 involves these data, their relative performance can be attributed to it. CATSIM2's superiority is marked; these data series are considered to perform satisfactorily.

MATRIX was designed so as not to generate a Western Dairy Cattle cycle while an Eastern cycle was built into the model's output. The results demonstrated in Figures 28 and 31 clearly demonstrate that such a cycle does exist in the West while it is overemphasized, as simulated, in the East.

A most annoying outcome of MATRIX is the presence of <u>negative</u> REPLACEMENT Bull flow during certain third and fourth quarters. Discussions with livestock officials could only produce very tentative explanations of this anomaly. It might be suspected that Bull SLAUGHTER data is in error or Bulls make up a disproportionately high element in UNINSPECTED Cattle SLAUGHTER or both.

The behavioral models employ an "excess price" model that abstracts from "own price." This model was developed to avoid the use of simultaneous equations as the simulator requires quantities only. The theoretical development of the excess price model is given in Chapter III as well as the development of the behavioral models which utilize it. The parameter estimates for the 16 behavioral models are given in Tables 9 to 11.

The excess price model served as a good predictor of quantities when evaluated in terms of the statistics R^2 and $\bar{R}^2$. This was the case in spite of the fact that "own price" was excluded in keeping with the theoretical model.

The excess price model proved to be particularly disappointing as it failed to provide the theoretically predicted sign for many regression coefficients. This model obviously requires additional development even though its preditive ability is very good in its present form.

A variation of the excess price model employing lagged endogenous variables was used in all behavioral models. These lagged endogenous variables entered most models at a highly significant level (1 percent level of significance). Because these estimators are quarterly and the cattle production cycle is annual, seasonal dummy variables were significant variables in most models.

A time trend or cycle was present in many models that was not otherwise accounted for by the exogenous and lagged endogenous variables. In some instances, especially Bull SLAUGHTER and REPLACEMENT, the trend or cycle was not removed. This resulted in significant serial correlation, however, it was not considered to be highly detrimental to their usefulness as quantity predictors in the context of program CATSIM.

Program RECON

The purpose of RECON was to attempt a dynamic reconciliation of the various published data series that describe the Canadian Cattle Herd. This model is described in Chapter IV while its Fortran program is listed in Appendix D. The model was used to gain knowledge of these data series and to obtain some preliminary estimates of parameter values. It is intended to be used to test hypotheses concerning parameter values and structure as well as hypotheses concerning the consistency or accuracy of the published data series. Several of these latter tests were made in this study.

Statistics Canada publishes semi-annual Calf BIRTH statistics. Western BIRTHS were found to be consistent with the Western Cow Population (plus a proportion of the Beef Heifer Population) when BIRTH Rates of 85 percent for Beef and 76.5 percent for Dairy were utilized. Year to year variation ranges from 1 percent high to 6 percent low for the official estimates.

In contrast, Statistics Canada's Eastern BIRTH estimates were 8-18 percent higher than RECON estimates when BIRTH Rates of 85 percent for Beef and 75 percent for Dairy were applied in a similar fashion. This discrepancy between official and estimated BIRTHS appears higher in later years.

An interesting observation is made that the discrepancy in the East and West move in opposite directions over time. In addition, the magnitude of the discrepancy appears somewhat correlated with the cattle cycle.

Another official data series and potential source of Dairy Calf BIRTH data is the Dairy Correspondent Survey. This Survey's data series, Cows and Heifers to FRESHEN This Month, overestimated RECON's estimated Dairy BIRTHS by 9-30 percent with the Eastern relative discrepancy being slightly larger than the Western.

Statistics Canada's December 1st Calf Population estimates proved to be reasonably consistent with RECON estimates in the case of the West, especially when considered in light of Western BIRTH discrepancy. In contrast, the Eastern official estimates were 9-24 percent below the RECON estimates. This discrepancy has tended to increase through time.

It was previously stated that Statistics Canada's Eastern BIRTH estimates were high and tending to get higher through time while December 1st official Eastern Calf Population estimates were low and getting lower through time. This inconsistency is the most marked result of the RECON analysis and the one most worthy of further study.

An analysis of REPLACEMENT Rate did not produce startling results when compared with a priori assumptions. The one possible exception is the case of Bull REPLACEMENTS. This latter Rate is much higher in the case of the West than the East. It would appear that a herd sire is used for two seasons on average in the West while being used for three seasons in the East.

The sex of EXPORTS and WEST-EAST Cattle Movements might be of interest but is not currently published; this information is required in model RECON as well as in CATSIM. RECON was used to explore several possibilities; however, the information available constituted an overidentified set. Additional information must be brought to bear on the problem before a dynamic picture of these sex ratios can emerge. The outcome of RECON suggested that both Western EXPORTS Cattle 200-700 Pounds and UNINSPECTED Cattle SLAUGHTER contain a very high portion of Heifers.

RECON was used to examine Ending Population of Yearlings. In most cases the results could be rationalized. One result might be interpreted to indicate that Western Steers are slaughtered at 18 months of age while Eastern Steers are slaughtered at 22 months, on average. If this information cannot be reconciled with other information held to be true, then official Ending Steer Population is suspect.

RECON also provided insight into possible Dairy Heifer SLAUGHTER. First, it appeared consistent with the balance of the model that some Dairy Heifer SLAUGHTER does occur in both the East and West. A typical Eastern proportion of Dairy Heifers (1-2 years) is 25 percent but ranges from minus 7 percent (due to model design) to 39 percent over the 1958-1972 period. The proportion in the West has a wider range; it is thought that this might result from some "reclassification" of Heifers from Dairy to Beef with changing economic outlook.

Program CATSIM

Program CATSIM is the main or focal model of this study. It is described in detail in Chapter V; Chapter VI discusses sensitivity tests and model stability. It compares CATSIM1, CATSIM2, and CATSIM3 with each other and their output with the comparable published statistics, as well.

In their present state, CATSIM is a very general model and does not provide specific answers to specific problems. The results of the study, with respect to CATSIM, are contained in its structure, parameter values, and the assumptions that are made in its construction.

The comparison of the output of CATSIM1, CATSIM2, and CATSIM3 is given in Figures 27 to 40. A complete listing of disaggregate quarterly Cattle Population and Steer and Heifer SLAUGHTER data is presented in Appendices F and G. Appendix F gives Population figures for the years 1958 to 1972, inclusive, while Appendix G lists SLAUGHTER data for 1961 and 1972.

All versions of CATSIM demonstrated reasonable ability to "track" past Cow Population data. The more sophisticated versions, CATSIM2 and CATSIM3, proved to be superior to CATSIM1 in this regard as expected. CATSIM1 proved to be very sensitive to changes in critical parameter values and without a corrective feedback mechanism was unstable. This proved to be useful in fine tuning the model; it can be used to advantage in further fine tuning.

All versions of CATSIM proved to be inconsistently good predictors of Steer and Heifer SLAUGHTER, although the discrepancy (estimated compared with published) was low in most years. Over the 1961 to 1972 period, CATSIM2 estimated published Steer SLAUGHTER by 97 percent in the West and 97 percent in the East. The comparable

Heifer figures are 94 percent in the East and 100 percent in the West, but Heifer estimates show more year to year variation.[1] This can be rationalized by the fact that Heifer SLAUGHTER is a residual after EXPORT and REPLACEMENT demands have been satisfied. Lack of precision in the estimation of either of these flows adversely influences Heifer SLAUGHTER estimates.

In spite of this lack of precision in estimating Steer and Heifer SLAUGHTER, most quarter to quarter turning points are estimated correctly, although they are often slightly out of phase with the published SLAUGHTER data. The explanation for this is that CATSIM uses a fixed expected feeding-finishing period while the length of the actual period is responsive to economic conditions.

One of the most interesting structural elements of CATSIM is the BIRTH generation process. Since BIRTHS are produced by both Mature Cows and First Calf Heifers, a knowledge of the stock of both is critical. In the case of Beef, annual calving distribution statistics are inadequate. Also, the calving age distribution of First Calf Heifers is critical. Both of these features are included in CATSIM and discussed in detail in Chapter VI.

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[1]If an Eastern Dairy BIRTH Rate of BREDC = .738, and a Western Beef BIRTH Rate of BRWBC = .85 were used, most of these average discrepancies would be removed. These Rates would then be more consistent with those used in RECON.

Adaptation to Potential Applications

The Cattle Herd simulator developed in this dissertation is a very general model. It requires the refinement that can come only through interaction among researchers, policy makers, and statisticians. To become useful, it must be adapted to specifically defined problems, the sorts of problems that might be identified by researchers, policy makers, and statisticians who have a practical interest in the problem of the Canadian Cattle-Calves sub-sector. The above discussion applies equally to models RECON and MATRIX.

Any discussion of specific applications would be both lengthly and incomplete. Five general types of applications are listed in Chapter I; these provide examples of anticipated applications. The changes or additions required to accommodate these applications include the following.

1. Provision for structural change. Researchers may wish to change or improve the structure of the model. Some elements that require further development are discussed in the next section. Structural changes might be exploratory in nature and thus treated as hypotheses.

2. Addition of a "front end."[1] The specific application may identify a few key variables, possibly policy variables that are of particular interest. The front end would allow easy manipulation of these key variables.

3. Addition of a report writer. Once again, the specific application will dictate the output information that is

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[1]A "front end" accepts data and instructions from the user in a form most easily understood by the user and converts them to a form usable by the algorithm.

required. The report written presents the output information in an easily read form.

4. Control mechanisms and mode of operation. While the price feedback mechanism is the major element in the cattle-calves economy, providing it with direction, there are many policy alternatives that may be superimposed on it. A specific rule, or controller, can be designed into the model or the model may be controlled manually.

The Cattle Herd simulator was specifically designed to accommodate biological as well as economic parameters. The above types of changes or additions apply equally to model applications developed to solve practical problems suggested by animal scientists as well as to those suggested by economists and policy makers.

Future Model Development

The building of MATRIX, RECON and especially CATSIM, helped identify gaps in the descriptive knowledge of the dynamics of the Canadian Cattle-Calves sub-sector. The problems associated with the published statistical data, descriptive of this sub-sector have been discussed in detail in most chapters. Lack of adequate data made it necessary to develop a set of data assumptions in order to build the various models. These assumptions represent a list of areas where the data base may be altered, redefined, or expanded.

A second type of data was found to be unavailable or inadequate; this data can be adequately determined only through further research and statistical analysis. A third limiting area, not unrelated to either the first or second, is described by the term, structural design.

These last two limiting features, requiring additional research and development, occupy the balance of this section.

A refinement in the structure of the feeding-finishing process is required if CATSIM is to adequately predict the supply of Slaughter Steers and Heifers. As currently modeled, this process is not a function of relative prices, feed quality, climatic or any other factors that might influence the weight and the quality of the carcass. Attempt to predict the quantity supplied of various qualities of beef and veal should consider these factors.

INSPECTED Heifer SLAUGHTER is a residual after EXPORTS, IMPORTS, WEST-EAST Movements, UNINSPECTED SLAUGHTER, and especially REPLACEMENTS. CATSIM suffers from an inability to determine the Female portion of the former flows. While the estimates of REPLACEMENT flows, estimated by MATRIX and the behavioral models, performed well on the average, the model's inability to predict Slaughter Heifer flows with accuracy leaves these estimates as suspect.

Both calving distributions and the distribution of the age of calving for First Calf Heifers, proved to be limiting. These distributions require additional research as they influence predictions of the Calf Crop.

It is also suggested that BIRTH and DEATH Rates are functions of economic and climative influence, among others. The variation noted between the RECON and CATSIM Calf Crops and the official Calf Crop, might be explained, in part, by these influences.

CATSIM identifies two feeding-finishing processes and allocates Calves between them in a manner that is proportionally non-variant. In actual practice, there is a spectrum of feeding-finishing processes, but, more important, the allocation to these two (or more) processes is a management decision based on current and expected future relative prices, feed quality, and availability. This aspect of CATSIM should be developed.

In addition to refinement to the current model, additions could be suggested. The first addition must be that of a price determining mechanism and mechanisms determining trade flows. These additions might involve interfacing CATSIM with a second model that performs these functions.

A second addition might involve adding a feed demand vector that interacts with CATSIM's Cattle Population vector. In this way, estimates of total feed requirements could be determined for any given size and age composition of the Canadian Herd.

The behavioral models and the theoretical excess price model developed in Chapter III have potential for further development. Four potential variations of the theoretical excess price were developed. These four variations could form the bases for a statistical study; the application to the subject matter of this dissertation would still remain appropriate. The excess price model's predictive performance in this study is very encouraging even though it did not consistently yield the predicted sign for the regression coefficients.

The behavioral models themselves form the bases for many interesting statistical tests with policy implications. A refinement of these models would benefit model CATSIM. In particular, the problems of serial correlation remain, as do the inadequate structure of the models with respect to farm wages, interest rates, and grain stocks.

The basic models represented by MATRIX, RECON, and CATSIM represent a first attempt to simulate the Canadian Cattle Herd. Additional research and adaptation to practical problems can make them valuable teaching, research, and policy tools.

APPENDICES

APPENDIX A

PARAMETER INITIAL VALUES

Appendix A deals with the support and derivation of the initial values for the various models' parameters and such other data analysis as might be useful in building the model. Since program MATRIX, RECON, and CATSIM all model some aspect of the same Cattle Population, this discussion refers equally to all models.

Parameters are of two types. The first may be called characteristics of the cattle production process as practiced and experienced in Canada. These parameters have to do with the birth and death process, as well as the growth and maturation process.

The second set of parameters disaggregate published data series. The level of disaggregation at which all models are constructed, especially program CATSIM, exceed the limits of the published data. This disaggregation may involve breaking out the Male/Female component, Dairy/Beef component, seasonal component, or one of several others. These data, in disaggregate form, are required to provide a major and often only source of the critical flow elements for these models.

All initial parameter values are viewed as hypotheses; this means that they may subsequently be accepted or rejected on the basis of the four tests of objectivity when used in the models. Some of these parameter values can be determined fairly accurately from prior sources, others are guesses only. It is planned that the operation and optimization of these models will reveal estimates that approach the true values. This is especially true in the case of those parameters to which the model proves to be sensitive.

Birth Rate

(a) STATCAN's statistics for BIRTHS and Cow Population are used to compute a BIRTH Rate estimate. The formula used is as follows:

$$\text{BIRTH Rate} = \frac{\text{June 1 BIRTHS}_t + \text{December 1 BIRTHS}_t}{\text{Total Cow Population Dec. 1}_{t-1} + \text{Total Cow Population June 1}_t}$$

The results:

Year	Calculated BIRTH Rate WEST	Calculated BIRTH Rate EAST
1972	.95385	.90815
1971	.98400	.92400
1970	.96170	.94029
1969	.93481	.93828
1968	.93009	.93777
1965	.89776	.91858
1962	.92817	.82239
1959	.92876	.81541

(b) Dairy Correspondent Survey data was also examined. Total Cows and Heifers were compared with Cows and Heifers to FRESHEN This Month, on a monthly basis. The sum of the 12 monthly ratios provides the elements in the following matrix.

Year	Ontario	Calculated BIRTH Rate Quebec	Alberta
1972	.8604	.9268	.8931
1971	.8658	.9542	.9136
1970	.8458	.9034	.9132
1969	.8490	.9187	.9633
1968	.8390	.9214	.8814
1965	.9112	1.0132	.8980
1963	.8678	.9399	.9533
1961	.9088	1.0310	.9598

(c) ROP data suggests that the average period between calvings for Dairy Cows is 13 months. This would place an upper bound of $\frac{12}{13}$ = .923 on Dairy BIRTH Rate.

Calving Distribution

(a) The ROP Section, Agriculture Canada provided an estimate of dairy birth distribution based on their data base.

Month	Monthly proportion of Annual BIRTHS
January	.09236
February	.06761
March	.11133
April	.08768
May	.06404
June	.05321
July	.06601
August	.07635
September	.09606
October	.09532
November	.09261
December	.08670

(b) The Dairy Correspondent Survey also provides an estimate. Two years were sampled for the Eastern (mainly Dairy) region.

Month	Monthly Dairy Birth Distribution, selected years 1962	1966	1970
January	.05231	.05071	.05229
February	.05215	.05836	.05678
March	.06443	.06160	.06066
April	.12254	.12246	.10790
May	.18981	.19269	.18094
June	.11784	.13472	.11361
July	.07806	.07872	.06805
August	.05735	.04912	.06260
September	.04478	.03947	.04022
October	.04485	.03913	.04185
November	.05080	.04655	.04260
December	.05028	.05007	.04918

The same years were also sampled for the Western region.

Month	Monthly Dairy Birth Distribution, selected years 1962	1966	1970
January	.07676	.06912	.07125
February	.08035	.07784	.07960
March	.08754	.08851	.08518
April	.09785	.10311	.09441
May	.11459	.11879	.10322
June	.09764	.10043	.09082
July	.06950	.07402	.06852
August	.05580	.06123	.05645
September	.05521	.05561	.05534
October	.05285	.05405	.06160
November	.05642	.05182	.05849
December	.06404	.05737	.06568

(c) The Alberta Department of Agriculture provided an estimate of the Western beef cow calving distribution on a weekly basis for the first 37 weeks of the year (until mid-September). This distribution was broken down into commercial and purebred components. It is based on ROP records for 1972 and 1973.

Both distributions are heavily concentrated in March, April, and May. Very little calving occurred in the Beef Herd after July 15th according to their analysis. The distributions provided show that the commercial Herd reaches peak calving rate during the April 19-25 period while the purebred Herd peaks during April 2-8 period.

One Alberta official also added that he feels the calving distribution has shifted toward earlier calving by 15-30 days over the past 15 years.

Period	Alberta Beef Birth Distribution, 1972-1973	
	(head)	(%)
First 13 weeks	12,930	30.5
Second 13 weeks	28,500	67.5
Third 11 weeks	925	2.2
Total	42,355	100.0

(d) While no estimates were obtained for Eastern beef cow calvings, it is felt that this distribution is less concentrated in the first two quarters due to year round and especially fall calving.

(e) The semi-annual calving distribution can be obtained by comparing the December-June BIRTHS and June-December BIRTHS with Total BIRTHS as published by STATCAN.

Semi-Annual Birth Distribution, selected years

Year	West: December-June	West: June-December	East: December-June	East: June-December
1958	.70	.30	.67	.33
1960	.71	.29	.67	.33
1962	.74	.26	.67	.33
1964	.755	.245	.675	.325
1966	.77	.23	.665	.335
1968	.78	.22	.655	.335
1970	.78	.22	.65	.35
1972	.78	.22	.65	.35

DEATH Rates

The estimates of DEATH Rates are taken from a study by W. Y. Yang, A Statistical Analysis of Death Rates of Farm Animals in Canada, Research Division, Economics Branch, Canada Department of Agriculture, 1969. The data in the following table is taken from Yang's Table 2-1, p. 19.

DEATHS per 1,000 Head, 1950-1967

Region	Semi-Annual: December-May	Semi-Annual: June-November	Annual
Calves:			
Atlantic	16.74	10.49	27.04
Quebec	29.40	10.40	38.53
Ontario	19.07	13.30	32.36
Prairies	20.64	9.84	29.88
B.C.	15.94	10.65	26.30
Canada	21.24	10.74	31.43
Cattle:			
Atlantic	7.57	6.02	13.52
Quebec	8.28	5.70	13.80
Ontario	6.27	6.49	12.76
Prairies	8.21	5.88	13.94
B.C.	8.60	7.04	15.57
Canada	7.57	6.02	13.52

SLAUGHTER and UNINSPECTED SLAUGHTER

The disaggregation of SLAUGHTER and UNINSPECTED SLAUGHTER may be inaccurate at best due to a lack of statistical data. The initial estimated parameter values may have to be revised as a result of inconsistencies noted when the models are applied to practical problems.

The first assumption made is that UNINSPECTED SLAUGHTER of Calves is proportional to INSPECTED SLAUGHTER. This approach is used in MATRIX; this program calculates the relevant ratios semi-annually and applies them to the UNINSPECTED data.

The following table provides some analysis of the INSPECTED SLAUGHTER data for Calves.

INSPECTED Calf SLAUGHTER

Year	Total	Prop. Male	Quarterly distributions 1st	2nd	3rd	4th
	(head)		(proportion)			
East:						
1958	568,486	.7025	.1950	.4114	.2164	.1771
1960	511,962	.7196	.2143	.3766	.2240	.1848
1962	528,280	.7176	.1937	.3658	.2336	.2067
1964	572,511	.6913	.1817	.3712	.2316	.2154
1966	576,432	.6884	.2601	.3808	.1815	.1769
1968	509,393	.6985	.2358	.3668	.2040	.1933
1970	448,930	.7005	.2550	.3654	.1983	.1813
1972	461,630	.7052	.2617	.3826	.1762	.1794
West:						
1958	215,981	.5938	.2247	.2647	.2812	.2308
1960	200,138	.5058	.2145	.2361	.2752	.2742
1962	180,949	.4719	.2238	.2177	.2514	.3070
1964	177,808	.4619	.1619	.1995	.2695	.3690
1966	189,164	.4205	.2443	.2266	.2098	.3194
1968	159,018	.3870	.2295	.2214	.2660	.2831
1970	50,232	.4490	.2618	.2440	.2368	.2573
1972	40,740	.4597	.2669	.2374	.2209	.2748

A similar analysis is also made of INSPECTED Cattle SLAUGHTER with the intent of providing initial estimates for UNINSPECTED Cattle SLAUGHTER.

INSPECTED Cattle SLAUGHTER

Year	Total	Bulls	Cows	Heifers	Steers
	(head)		(proportion)		
East:					
1958	971,356	.0466	.2793	.1897	.4025
1960	932,676	.0391	.2992	.1929	.4688
1962	958,978	.0378	.3228	.1962	.4430
1964	1,134,670	.0314	.2917	.1911	.4859
1966	1,173,379	.0265	.2974	.1930	.4831
1968	1,163,369	.0285	.2629	.2024	.5062
1970	1,167,962	.0274	.2742	.1838	.5147
1972	1,126,890	.0267	.2491	.1830	.5411
West:					
1958	917,924	.0318	.3304	.2181	.4196
1960	1,009,077	.0264	.2775	.2208	.4754
1962	1,069,181	.0251	.3079	.2002	.4667
1964	1,287,590	.0204	.2394	.1989	.5503
1966	1,531,760	.0180	.3033	.2102	.4684
1968	1,621,010	.0146	.2691	.2478	.4685
1970	1,532,871	.0123	.1685	.2305	.5887
1972	1,751,701	.0168	.1860	.2352	.5619

IMPORT-EXPORT

The best evidence of import-export distribution is obtained by analyzing disaggregate 1969-1972 STATCAN data.

Purebred EXPORTS

Year	West Proportion Beef	East Proportion Dairy
1966	.782	.947
1967	.798	.943
1968	.700	.918
1969	.619	.944
1970	.775	.966
1971	.704	.946
1972	.932	.950

Year	Purebred IMPORTS West Proportion Beef	Purebred IMPORTS East Proportion Dairy
1969	.911	.286
1970	.899	.287
1971	.761	.229
1972	.898	.403

Quarterly Distribution of Purebred Dairy IMPORTS (1969-1972)

Quarter	East	West	Canada
1st quarter	.20	.11	.161
2nd quarter	.29	.46	.362
3rd quarter	.26	.32	.284
4th quarter	.25	.10	.193

Quarterly Distribution of Purebred Beef IMPORTS (1969-1972)

Quarter	East	West	Canada
1st quarter	.14	.25	.214
2nd quarter	.41	.26	.310
3rd quarter	.19	.14	.160
4th quarter	.26	.34	.315

Quarterly Distribution of Other IMPORTS (1969-1972)

Quarter	East	West	Canada
1st quarter	.32	.29	.308
2nd quarter	.20	.36	.260
3rd quarter	.04	.01	.030
4th quarter	.44	.34	.402

Quarterly Distribution of Purebred Dairy EXPORTS (1969-1972)

Quarter	East	West	Canada
1st quarter	.20	.20	.204
2nd quarter	.11	.23	.204
3rd quarter	.20	.14	.149
4th quarter	.49	.43	.443

Quarterly Distribution of Other Dairy EXPORTS (1969-1972)

Quarter	East	West	Canada
1st quarter	.16	.18	.162
2nd quarter	.32	.26	.318
3rd quarter	.30	.25	.300
4th quarter	.21	.30	.220

Quarterly Distribution Total Purebred IMPORTS-EXPORTS (1969-1972)

Quarter	Imports	Exports
1st quarter	.206	.179
2nd quarter	.317	.284
3rd quarter	.185	.235
4th quarter	.292	.300

Quarterly Distribution of EXPORTS Under 200 Pounds (1969-1972)

Quarter	East	West	Canada
1st quarter	.200	.09	.200
2nd quarter	.517	.27	.517
3rd quarter	.183	.365	.183
4th quarter	.100	.27	.100

Quarterly Distribution of EXPORTS 200-700 Pounds (1969-1972)

Quarter	East	West	Canada
1st quarter	.137	.039	.056
2nd quarter	.161	.036	.058
3rd quarter	.289	.076	.108
4th quarter	.412	.850	.778

Quarterly Distribution of EXPORTS Over 700 Pounds (1969-1972)

Quarter	East	West	Canada
1st quarter	.135	.312	.273
2nd quarter	.339	.221	.247
3rd quarter	.265	.178	.198
4th quarter	.260	.287	.281

The Canada Livestock and Meat Trade Report provides the following disaggregation of EXPORTS to United States.

EXPORTS to United States		Dairy Females, grade	Dairy Females, purebred	Dairy Bulls, purebred	Beef Females, grade	Beef Females, purebred	Beef Bulls, purebred	SLAUGHTER over 700 lbs.	Feeder over 700 lbs.
		EXPORT Category							
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1973	East	20,972	11,163	776	9,233	3,817	414	6,776	1,443
	West	1,422	202	11	3,885	2,974	3,814	6,521	28,271
1972	East	31,074	16,006	1,426	1,719	465	164	3,079	112
	West	2,143	427	14	3,012	2.764	2,701	7,127	2,731
1971	East	36,441	22,440					3,160	129
	West	2,334	294					7,967	182
1970	East	33,069	22,283					2,677	129
	West	2,930	327					12,876	3,397
1969	East	19,673	19,148					1,626	119
	West	2,226	660					23,936	14,546
1968	East	13,965	13,286					6,488	86
	West	585	217					26,295	21,456
1967	East	11,810	11,569					2,334	106
	West	301	180					7,223	10,736
1966	East	19,389	18,772					8,441	258
	West	486	275					28,133	61,692
1965	East	14,178	17,952					23,766	788
	West	896	494					31,101	94,193
1964	East	12,965	16,283					14,952	513
	West	1,085	542					12,162	17,516
1963	East	11,244	16,607					7,862	141
	West	281	318					9,188	28,916
1962	East	14,639	15,509					7,558	34
	West	296	269					19,649	44,624
1961	East	16,889	19,140					450	125
	West	14	97					28,812	86,595

Allocation to Ration B

The best evidence of the proportion of Cattle placed on a high energy ration might be given by an examination of the proportion of Slaughter Steers and Heifers falling in the top two grades (choice, good). This analysis is given in the following table.

Year	Proportion of Slaughter Steers Heifers in top two grades
1961	.7472
1962	.7177
1963	.7520
1964	.7644
1965	.7413
1966	.7622
1967	.7742
1968	.7968
1969	.8339
1970	.8479
1971	.8449

Allocation of REPLACEMENTS

The following table shows the annual change in the Dairy Cow Population (June 1 data).

Annual change in Dairy Cow Population--June 1

Year	Change in Eastern Cow Herd (head)	Change in Western Cow Herd (head)	Canada
1957	-149,500	-51,500	
1958	-7,300	-10,500	
1959	-8,400	-13,000	
1960	52,200	2,000	
1961	59,000	15,000	
1962	-227,500	-53,000	
1963	-46,500	-36,000	
1964	-2,000	-26,000	
1965	-11,000	-38,000	
1966	-61,100	-60,000	
1967	-50,900	-54,000	
1968	-43,000	-37,000	
1969	-19,000	-28,000	
1970	-50,000	-3,000	
1971	-115,500	-18,400	
1972	-20,500	-23,800	
1973	-36,000	-22,800	
Annual % change 1957-1973	-1.821	-3.98	-2.337

The following table calculated the ratios for selected years.

$$A = \frac{\text{INSPECTED Cow SLAUGHTER}}{\text{Average Cow Population}}$$

Year	Ratio A East	Ratio A West
1964	.1279	.1036
1969	.1264	.1070
1972	.1167	.0945

$$B = \frac{\text{INSPECTED Cow SLAUGHTER}}{\text{Average Heifer Population}}$$

Year	Ratio B East	Ratio B West
1964	.4185	.381
1969	.3861	.423
1972	.354	.339

$$C = \frac{\text{INSPECTED Bull SLAUGHTER}}{\text{Average Bull Population}}$$

	Ratio C	
Year	East	West
1964	.288	.208
1969	.347	.175
1972	.358	.193

$$D = \frac{\text{INSPECTED Bull SLAUGHTER}}{\text{Average Steer Population}}$$

	Ratio D	
Year	East	West
1964	.052	.0354
1969	.0464	.0314
1972	.0434	.0365

Delay Parameters

The calculation of the parameters for the continuous delays are based in most part on a set of more or less realistic assumptions concerning the process being simulated. The exception is the simulation of First Calf Dairy Heifer BIRTHS--a distribution was obtained from ROP in this instance.

The parameters in question are DEL and K. These are described in Appendix B. Given the erlang distribution, the purpose of this section is to consider initial expected values and distributions.

Ration A and B Delays

Initial assumption--Calves weaned at 180 days

Male Calf weaning weight 375 pounds
Female Calf weaning weight 350 pounds

Ration B--on full feed

Males to 1,050 pounds
ADG range 1.9 to 2.4 pounds
Days on feed 281 to 355

Females to 950 pounds

ADG range	1.7 to 2.1 pounds
Days on feed	285 to 352

Ration A--low energy ration for all or part

Assume at 365 days	Males	600 pounds
	Females	550 pounds

At one year these Cattle may be placed in a feedlot or may be placed on grass for a further four to six months. This option increases the ADG range; thus, the distribution being simulated is flatter than the above "full feed" distribution.

Males to 1,100 pounds

ADG range	1.5 to 2.25 pounds
Days on ration A	222 to 333

Females to 1,000 pounds

ADG range	1.4 to 2.00 pounds
Days on feed	225 to 321

The above ranges provide a bound for expected value; it might also be expected that at least two-thirds of the distribution would fall in this range. The shape of the distribution might be expected to be skewed to the right possibly suggesting an order (K) of five.

In the case of Ration B, this provides

mean of	3.33 DT's or .82 years
variance of	2.22 DT's
standard deviation of	1.25 DT's or .3125 years

The distribution associated with Ration A might be expected to be flatter--an order of three is suggested.

mean of	3 DT's or .75 years
variance of	3 DT's
standard deviation of	1.75 DT's or .4375 years

Dairy Heifer Birth Delay

The ROP Section of Agriculture Canada provided the following age distribution for First Calf Heifer FRESHENINGS.

Age Range (months)	Proportion of Total
under 21	.00278
21-24	.01719
24-27	.10542
27-30	.16005
30-33	.15536
33-36	.11261
36-39	.09634
39-42	.12149
42-45	.12652
45-48	.10078

The distribution rises rapidly, then slowly tails off. It is quite flat and is in fact bi-modal suggesting two distributions.

Half this distribution falls below the mid-point of the 33-36 month range. The flatness of the distribution suggests the order (K) of three. These parameters would provide:

mean of about	3.5 DT's or .85 years
variance of about	4.1 DT's
standard deviation of about	2 DT's or .5 years

APPENDIX B

SIMULATION

Appendix B describes several different aspects of simulation pertinent to an understanding of this thesis. The first section describes the implied mathematical model and the exact block diagram. The second section describes several common simulation building components used in the models.

Simulation of the Modeled System

The simulation model is the second level of abstraction from reality. The sequence is:

THE REAL WORLD

↓

MATHEMATICAL MODEL

↓

SIMULATION MODEL

There is thus an implied or possibly explicitly expressed mathematical model of the system under investigation. The mathematical model in turn is the model that is simulated. In actual practice, exact expression of the system in mathematical form is most often skipped. The development, performance, consideration, and theoretical discussion of the simulation components, however, takes place in exact mathematical form.

The dynamic aspects of a biological growth process, such as a cattle herd, probably can most precisely be expressed in non-linear differential equations. Their solution, however, even with advanced numerical techniques, can be unduly complex. If the relationship is essentially a function of time, it is usually possible to pick a time period of short enough duration so that the non-linear system can be modeled in linear terms.

The basic mathematical representation of the cattle population is developed in terms of linear differential equations and the related first order difference equations. The matrix representation of a first order linear differential equation could be given as follows:

$$\frac{dx(t)}{dt} = \underline{A}\, x(t) + \underline{B}\, U(t) \tag{86}$$

where

$x(t)$ = a vector of state variables

$U(t)$ = a vector of rate or stimulus vectors

$\underline{A}$, $\underline{B}$ = matrices

Or in first order difference equation form as:

$$X(t+1) = \underline{A}\, x(t) + \underline{B}\, U(t) \tag{87}$$

where the symbols have the same meaning as above.

The terms state and rate variables are used in systems parlance to represent stock and flow variables, respectively. The state variables are described as the product of the integration of rate variables. In the specific terminology of this study, stock (or state) variables refer to cattle numbers at a point in time; flow (or rate) variables refer to number of head per unit of time.

An nth order linear differential equation is used to represent lagged response to a stimulus. This can generally be represented as:

$$(88) \qquad a_n \frac{d^n y(t)}{dt^n} + a_{n-1} \frac{d^{n-1} y(t)}{dt^{n-1}} + ,\ldots\ldots, a_0 Y(t) = b_m \frac{d^m U(t)}{dt^m} + ,\ldots\ldots, + b_0 U(t)$$

where

$x(t)$ = the stimulus,

$y(t)$ = the response.

Since differential equations are difficult to solve or manipulate, a method is used by engineers, called Laplace Transformations.[1] This is a transformation whereby differential equations can be converted to ordinary algebraic equations, manipulated, and then transformed back to differential equation form by an inverse Laplace Transformation.

---

[1]The basic Laplace Transformation is by definition

$$L[x(t)] = x(s) = \int_{o}^{o} x(t) e^{-st} dt$$

All other transformations are derivatives of this formula.

If a Laplace Transformation is performed on equation (87), the following form is obtained

$$(89) \qquad Y(s) = \left(\frac{b_m S^m + ,\ldots, + b_o}{a_n S^m + ,\ldots, + a_o}\right) X(s) + \frac{I.C.(s)}{a_n S^m + ,\ldots, + a_o}$$

where

I.C. = the initial conditions.

If I.C. = 0, then

$$(90) \qquad Y(s) = G(s)X(s)$$

where

G(s) = ratio of two polinomials known as the transfer function, itself a polynomial.

The transfer function, G(s), determines the response of the system being modeled by the nth order differential equation and thus the model's dynamic properties. This transfer function is used to design into the model both stability and the required response characteristics.[1]

With respect to the overall Cattle Herd simulator, the foregoing discussion is strictly theoretical as the system is much too complex to be modeled in terms of differential and difference equations and assessed

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[1]For a detailed discussion of Laplace transformations and the dynamic properties of differential and system control equations, see T. J. Manetsch and G. L. Park, op. cit., especially Chapters IV and VII.

in terms of their Laplace transformations. Rather, the system is simulated using system components with known properties and the complete model is then subjected to a series of validation, sensitivity, and stability tests to assess its dynamic properties and to fine tune it accordingly.

The simulation of these linear differential equations that represent the dynamics of the Cattle Herd essentially involve solving them at discrete points in time. Such a model is called a discrete model and the simulation essentially becomes a difference equation model.

Block and exact (mathematical) block diagrams are commonly used to display and represent the system being modeled. These diagrams allow lines and direction of causation to be shown, feedback loops to be displayed, as well as stock and flow variables to be represented. The exact block diagram displays the simulation components that are the differential (difference) equations or transfer functions.

For demonstration purposes, a simple block diagram is shown below. It involves a vector of state variables, X, an exogenous rate vector, μ, and an output rate vector, y. In addition, the model has a feedback loop.

Feedback involves an output of the system influencing an input, usually a delayed influence. Most, if not all, real world systems involve feedback loops together with controller mechanisms. A system without a feedback loop is called an open loop system, a system with a feedback loop is a closed loop system. A complex system may involve both open and closed loop components.

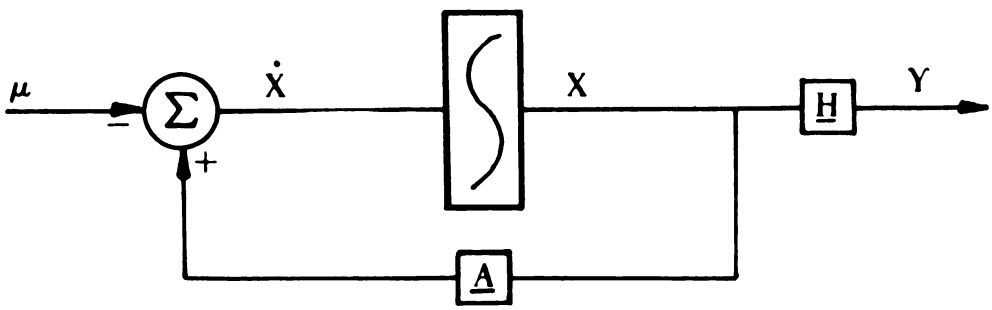
The feedback mechanism is closely associated with system performance and stability. If changes in a system's output are felt almost immediately through a short "delay process," then the controller can act quickly and so provide smooth performance as does a governor on an engine. If the system has long delays and slow controller response, as does the price mechanism in the economic system, then cyclical motion may result. With poor feedback and an ineffective control mechanism, explosive behavior or a complete collapse may be observed.

Feedback can be of either a positive or of a normative nature--usually both are present in a system of any complexity. The behavioral response of individuals and firms in the economic system represent a positive response to largely normative stimuli. When certain outcomes are observed and evaluated as being good or bad (with respect to some welfare function, largely unspecified), specific adjustments are observed. Thus, in this model, beef farmers represent the controller, adjusting Herd investment and disinvestment as well as Calf SLAUGHTER and certain other variables under their control. A larger model can be visualized representing the aggregation of all beef farmers, as well as other immediate elements in the economic system. In the larger model, the Federal government, their advisors, and operating agencies are the controller.

Let x represent the vector of the various age cohorts in the Cattle Population, μ represent the vector of EXPORTS, and y, the vector of Slaughter Cattle. Then H is a matrix of SLAUGHTER Rates and $\underline{A}$, a matrix of BIRTH and DEATH Rates. In differential equation and exact block diagram form, the model may be represented as follows:

$$\frac{dx}{dt} = \underline{A}\ x + U$$

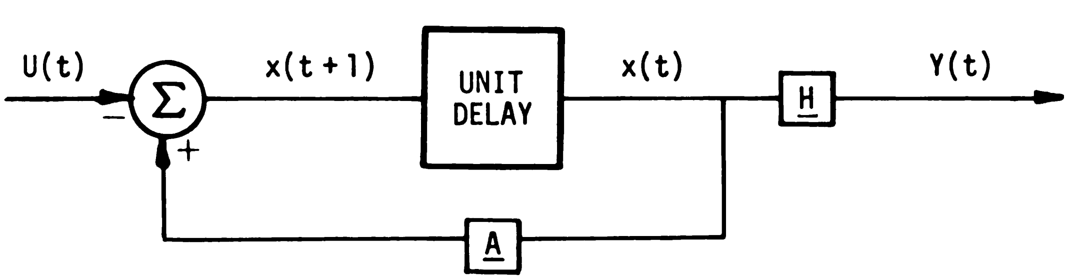
$$y = \underline{H}\ x$$



In difference equation form, the model is

$$x(t+1) = \underline{A}\ x(t) + U(t)$$

$$Y(t) = \underline{H}\ x(t)$$



The symbols used in representing a model in exact block diagram form are

Σ	summation (negation)
$\boxed{\pi}$	product
$\div$	division
$\boxed{\int}$	integration
$\boxed{\text{delay}}$	delay
$\xrightarrow{\text{name}}$	variable name, stock or flow

Simulation Building Components

Integration

The dynamics of the Cattle Population can be visualized as a series of stocks and flows. Stocks are quantities at a point in time, flows are quantities per unit of time. Stocks result from the integration of flows.

Mathematically, this process can be modeled by differential equations such as:

(91) $$\frac{dF(x)}{dt} = f(x)$$

where

$F(x)$ = a stock,

$f(x)$ = a flow.

Differential equation (91) states that the change in the stock is a function of the flow. If both sides of (91) are integrated from time 0 to time t+DT, the following is obtained.

$$F(t+DT) - F(0) = \int_{0}^{t+DT} f(x)dx. \tag{92}$$

Assume F(0) to be zero and rewrite the right hand side

$$F(t+DT) = \int_{0}^{t} f(x)dx + \int_{t}^{t+DT} f(x)dx. \tag{93}$$

This form, (92), can be related directly to cattle population by specifying:

$F(t+DT)$ = cattle population at time t+DT,

$\int_{0}^{t} f(x)dx$ = cattle population at time t,

$\int_{0}^{t+DT} f(x)dx$ = the flow of cattle over the period t, t+DT.

This in turn can be rewritten as:

$$F(t+DT) = F(t) + \int_{t}^{t+DT} f(x)dx. \tag{94}$$

Expression (94) can be simulated by a series of integral simulators that vary in degree of accuracy.[1] For the application used in this study, the simplest possible formula was used initially. It is called Euler integration and assumes: (1) DT is small, and (2) f(x) is constant over the interval (t, t+DT). Since neither of these conditions hold, some inaccuracy may result.[2] The form of the Euler integral is:

$$F(t+DT) = F(t) + DT \cdot (f(x)). \tag{95}$$

Delays

The second major building block is the delay. The delays, as used in this study, are of two basic types. The first is "discrete," where a flow is delayed for a finite or discrete period while a process or function takes place. The second basic type is called "continuous" or "distributed." In this instance, the delay is of variable length; however, the output is of a fixed distributional character.

Discrete delays.--Delays are associated with flow variables. A discrete delay may be represented by

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[1]T. J. Manetsch and G. L. Park, op. cit., pp. 9-19 to 9-43.

[2]Euler integration was only used in CATSIM to calculate Cow and Bull Population; in all other possible instances it was found to be inaccurate. Rather than employ a more sophisticated integration, all other Populations were calculated by summing the storage (Train Values) in the delay sub-routines.

(96) $$O(t) = I(t-DT)$$

where

$O(t)$ = output of the delay in period (t); and

$I(t-DT)$ = the input to the delay in period (t-DT).

For a poli-period delay, a series of such delays would be utilized.

$$O(t) = I_1(t-DT)$$

$$O_1(t) = I_2(t-DT)$$

$$O_{n-1}(t) = I_n(t-DT)$$

where

$O_1(t)$ to $O_{n-t}(t)$ are intermediate values.

This delay procedure is simulated by the BOXC subroutine. The call statement for BOXC is as follows:

```
SUBROUTINE BOXC (BINR, BOUTR, TRAIN, NCOUNT, N CY, LT, SUMIN)
```

where

BINR = the unlagged value, $I(t)$;

BOUTR = the lagged value, $O(t)$;

TRAIN = the array of LT-1 intermediate values $O_1(t)$,....., $O_{LT-1}(t)$;

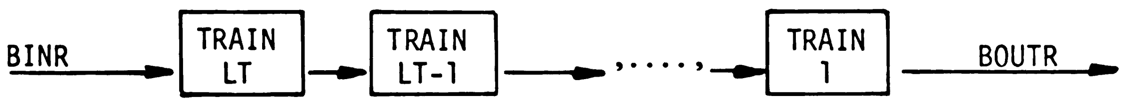
NCOUNT = number of DT's since last indexing of the TRAIN;

NOCY = number of DT's per indexing of the TRAIN;

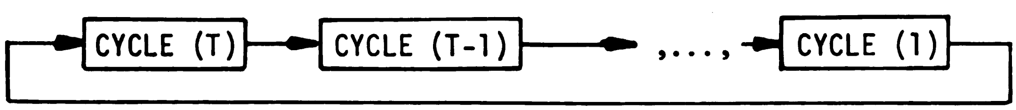
LT = number of sub-delays in the total delay; and

SUMIN = sum of the inputs since the last indexing.

This delay might be demonstrated graphically as



A second discrete delay is used called CBOX. It is used to cycle a series of values such as seasonal or monthly values. It might be depicted graphically as:



The call statement for CBOX is

```
SUBROUTINE CBOX(CYCLE, LT, NCY, NK)
```

where

CYCLE = an array of LT values;

LT = the number of elements in the array;

NCY = the number of DT between indexings;

NK = a counter that records the number of DT's since the last indexing.

Both subroutines, BOXC and CBOX are described and the programs listed by Llewellyn.[1]

Continuous delays.--A continuous delay can be defined as a linear differential equation.

$$(97) \qquad x(t) = a_k \frac{d^k y(t)}{dt^k} + a_{k-1} \frac{d^{k-1} y(t)}{dt^{k-1}} + ,\ldots, + a_1 y(t)$$

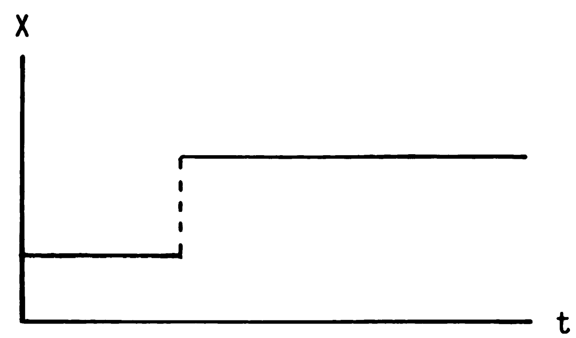
where

$x(t)$ = the unlagged value, and

$y(t)$ = the lagged value.

This delay is defined by its order, or the size of K. The output of this type of delay is distributed over several periods; the output $y(t)$ thus adjusts slowly to changes in input $x(t)$.

The difference between the output of a discrete as compared to a continuous delay may be demonstrated by the following diagrams, where $x(t)$ is input, $y_1(t)$ is the discrete response, and $y_2(t)$ is the continuous response.



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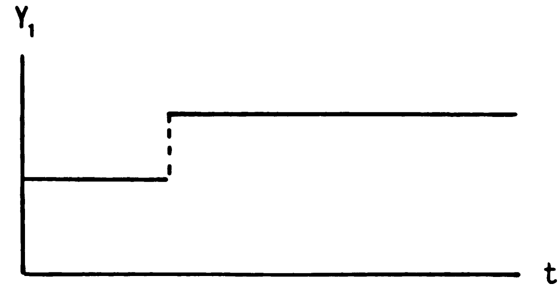
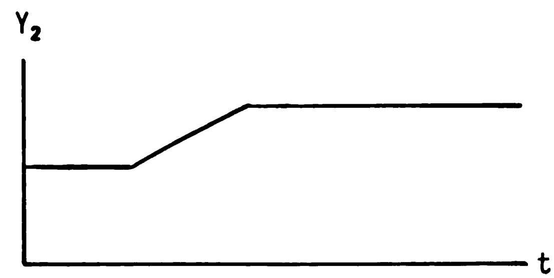
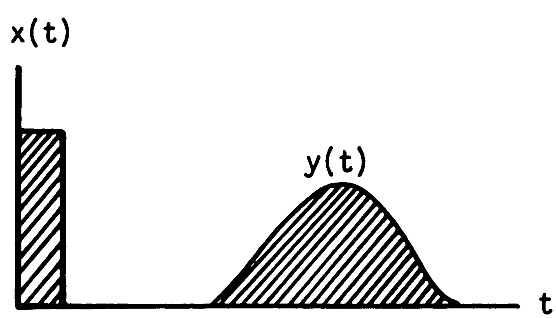
[1] R. W. Llewellyn, op. cit., pp. 7-50 to 7-54.





If x(t) were a non-sustained flow, then the y(t) function might look like the following:



The shape of the y(t) distribution depends on the order of the differential equation (97) that represents the delay.

The delayed output has an erlang distribution[1] with parameters a and k, k being the order of the delay.

$$f(x) = \frac{(ak)^k \, x^{(k-1)} e^{-kax}}{(k-1)\,!}$$ defines the erlang distribution.

where

$$E(x) = \frac{1}{a} \; ;$$

$$V(x) = \frac{1}{ka^2} \; ; \text{ and}$$

$$\text{mode} = \frac{k-1}{ak} \; .$$

The parameter k allows this distribution to represent a whole family of distributions. The following figure provides examples.

A rather sophisticated continuous delay subroutine is used in CATSIM to simulate continuous delays that have an erlang distribution. The subroutine is VDELDT.

```
SUBROUTINE VDELDT(RINR, ROUTR, CROUTR, DEL, DELP, IDT, DT, K)
```

where

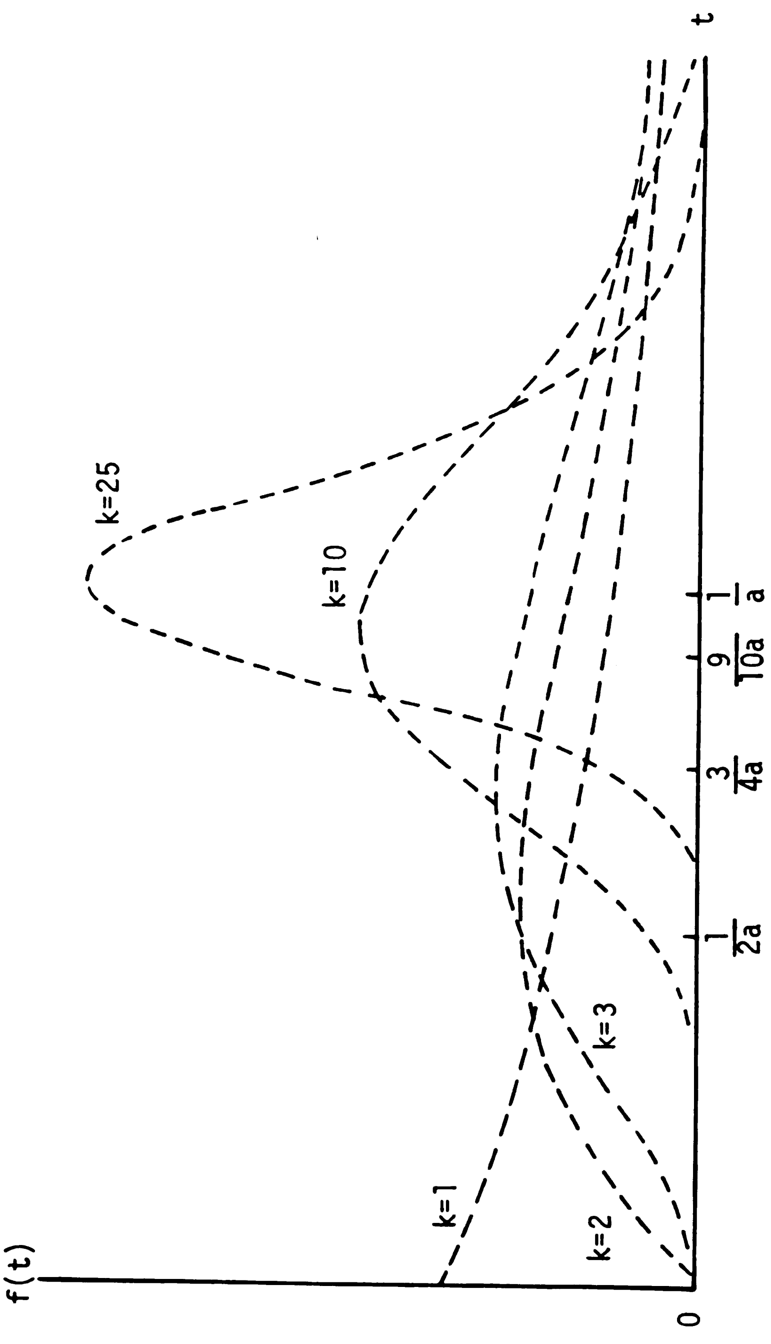
RINR = the unlagged value x(t)

ROUTR = the lagged value Y(t)

CROUTR = the array of intermediate values

---

[1] T. J. Manetsch and G. L. Park, op. cit., pp. 12-9 to 12-11.



The Erlang Family of Density Functions

DEL = the mean delay at (t);

DELP = the mean delay at (t-DT);

IDT = a parameter to subdivide DT;

DT = the increment in the model; and

K = the order of the delay.

DEL is related to "a" of the erlang distribution by the relation $DEL = \frac{1}{a}$. The DEL, DELP feature allows the average length of the delay to change each DT. The IDT subdivides DT; the purpose of this feature is to provide for stability in the model,[1] by meeting the stability conditions for distributed delays. The K defines the order of the underlying differential equation and is the same parameter as used in the erlang distributions.

Stability of Delay Subroutines

One source of instability in a simulator is the continuous delay. The nature of the continuous delay subroutine must correspond to the size of the DT or the model will be unstable. This source of instability is derived from the size of the DT and the order of continuous delays and integrators. There are no hard and fast rules, however, various authors[2] have given rules of thumb that are calculated to minimize the probability of instability.

---

[1]Manetsch *et al.*, *op. cit.*, pp. 11-1 to 11-15.

[2]These authors would include J. W. Forrester, *Industrial Dynamics*, Cambridge, The Massachusetts Institute of Technology Press, 1961; T. J. Manetsch and G. I. Park, *op. cit.*, Chapter VIII; and R. W. Llewellyn, *op. cit.*, Chapter VI.

For Euler integration, Forrester's criterion is:[1]

$$DT \leq \frac{DEL}{2K}$$

Manetsch and Park indicate that for Euler integration the rule should be:

$$\underset{j = 1, \ldots, p}{\text{Min}} \left[\frac{DEL_j}{2K_j} \right] > DT > 0$$

which is the same as Forrester's rule except that it is extended to include all the delays in a more complex system.

Llewellyn states his criterion as:

$$\underset{j = 1, \ldots, p}{\text{Min}} \left[\frac{DEL \times IDT}{2K} \right] > DT > 0$$

where IDT is a parameter used in certain continuous delays to subdivide DT.[2]

A different stability rule is required if a higher order integrator (higher than an Euler integrator) is imployed. These stability criterion are a function of the roots of the differential equations underlying the model.

---

[1]DEL and K are parameters of the continuous delay.

[2]CATSIM utilizes the continuous delay subroutine VDELDT which has the parameter IDT. This subroutine was used to retain stability while employing a relatively large DT.

CATSIM proved to be stable under all conditions imposed during construction including the sensitivity tests.[1]

The INGRAT Subroutine

This sub-function integrates over a distribution and is used in this model to calculate the quarterly calving distribution. The call statement is:

INGRAT (IBEG, IEND, VAL)

where

IBEG = the lower bound of the integral;

IEND = the upper bound of the integral; and

VAL = the array describing the distribution.

---

[1]As an example, in the sensitivity tests, the largest K employed was K = 7, the smallest DEL was DEL = .59. Since IDT = 10 for all delays, the stability formula is:

$$\frac{.59 \times 10}{2 \times 7} = .4214 > .25.$$

APPENDIX C

PROGRAM MATRIX

Appendix C provides a listing of program MATRIX. This program shares the matrix of published statistical cattle-calves data with program RECON and CATSIM; the statement required to dimension core storage and to read this data matrix into core are common to all three programs.[1]

Because this matrix of published data is central to this study, as well as to all programs, the variable names of these data are listed below. A description of these data is provided in Chapter II, the third section.

<u>June 1 and December 1 Population Data</u>

K = year; 1946 = 0; L = quarter; 1st quarter = 1

CALVE, CALVW, CALVT = Calves Under One Year Old, East, West, Total

STRSE, STRSW, STRST = Steer One Year Old or Older, East, West, Total

BHFRE, BHFRW, BHFRT = Beef Heifers, East, West, Total

BCOWE, BCOWW, BCOWT = Beef Cows, East, West, Total

DHFRE, DHFRW, DHFRT = Dairy Heifers, East, West, Total

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[1]All programs were written in FORTRAN IV compatible with Michigan State University's CDC 6500 computer system.

DCOWE, DCOWW, DCOWT = Dairy Cows, East, West, Total

BULLE, BULLW, BULLT = Bulls, East, West, Total

June 1 and December 1 Calf BIRTH Data

K = year; 1946 = 0; L = quarter; 1st quarter = 1

BIRTHE, BIRTHW, BIRTHT = Calf BIRTHS, East, West, Total

INSPECTED SLAUGHTER Data

I = year; 1946 = 0; J = month; January = 1

SCAVE, SCAVW = SLAUGHTER, Calves, East, West

SCATE, SCATW = SLAUGHTER, Cattle, East, West

SBULLE, SBULLW = SLAUGHTER, Bulls, East, West

K = year; 1946 = 0; L = month; January = 1

SMCAVE, SMCAVW = SLAUGHTER, Male Calves, East, West

SFCAVE, SFCAVW = SLAUGHTER, Female Calves, East, West

SSTRE, SSTRW = SLAUGHTER, Steers, East, West

SHFRE, SHFRW = SLAUGHTER, Heifers, East, West

SCOWE, SCOWW = SLAUGHTER, Cows, East, West

SBULLE, SBULLW = SLAUGHTER, Bulls, East, West

WEST-EAST Cattle-Calf Movement Data

K = year; 1946 = 0; L = month; January = 1

ZCTSLR, ZCTFD, ZCTSTK, ZCTTOT = Cattle Movements for SLAUGHTER, FEEDLOT, STOCKYARDS, and TOTAL

ZCVSLR, ZCVFD, ZCVSTK, ZCVTOT = Calf Movements for SLAUGHTER, FEEDLOT, STOCKYARDS, and TOTAL

Dairy Correspondent Study Data

I = year; 1946 = 0; J = month; January = 1

FARME = Number of Farms Reporting

TCAHE = Total Cows and Heifers for Milk

CAHMKE = Cows MILKED Yesterday

CAHCVE = Cows and Heifers in Calf

CAHFSE = Cows and Heifers to FRESHEN This Month

CWBCHE = Milk Cows BUTCHERED This Month

UNINSPECTED SLAUGHTER Data

I = year; 1946 = 0; J = quarter; 1st quarter = 1

USRTQE, USRTQW = UNINSPECTED Cattle SLAUGHTER, East, West (excludes the following sub-categories)

USTKEE, USTKEW = Farm Killed and Eaten (Quarterly)

USTKSE, USTKSW = Farm Killed and Sold (Quarterly)

USRTQE, USRTQW = Farm Killed, Eaten, Sold (Quarterly)

USRTAE, USRTAW = Farm Killed, Eaten, Sold (Annually)

USRVQE, USRVQW = UNINSPECTED Calf SLAUGHTER, East, West (excludes the following sub-categories)

USVKEE, USVKEW = Farm Killed and Eaten (Quarterly)

USVKSE, USVKSW = Farm Killed and Sold (Quarterly)

USRTQE, USRTQW = Farm Killed, Eaten, Sold (Quarterly)

USRVAE, USRVAW = Farm Killed, Eaten, Sold (Annually)

Annual IMPORT Data

I = year; 1946 = 0

VPBRDE, VPBRDW = Purebred IMPORTS, East, West

VOTHRE, VOTHRW = Other IMPORTS, East, West

Monthly IMPORT Data

I = year; 1946 = 0; J = month, January = 1

YPDRYE, YPDRYW = Purebred Dairy IMPORTS, East, West

YPBFE, YPBFW = Purebred Beef IMPORTS, East, West

YOTHRE, YOTHRW = Non-Purebred IMPORTS, East, West

Annual EXPORT Data

I = year; 1946 = 0

WPDRYE, WPDRYW = Purebred Dairy EXPORTS, East, West

WPDBFE, WPDBFW = Purebred Beef EXPORTS, East, West

WPBRDE, WPBRDW = Purebred Total EXPORTS, East, West

WODRYE, WODRYW = Dairy, NES, Weight 200 Pounds and Over

WCAVE2, WCAVW2 = Cattle, NES, Weight Less than 200 Pounds

WCAVE7, WCAVW7 = Cattle, NES, Weight 200-700 Pounds

WCATE9, WCATW9 = Cattle, NES, Weight Over 700 Pounds

Monthly EXPORT Data

I = year; 1946 = 0; J = month; January = 1

XCAVE2, XCAVW2 = Cattle NES, Weight Less than 200 Pounds

XCAVE7, XCAVE7 = Cattle, NES, Weight 200-700 Pounds

XCATE9, XCATW9 = Cattle, NES, Weight Over 700 Pounds

XOTDYE, XOTDYW = Dairy, NES, Weight 200 Pounds and Over

XPDRYE, XPDRYW = Purebred Dairy EXPORTS, East, West

XPBFE, XPBFW = Purebred Beef EXPORTS, East, West

The model parameters, their descriptions, and initial values are listed next; further explanation is provided in Chapter III.

A number of intermediate values are calculated requiring a set of variables. While these will not be described, the output variables are listed below.

HFRDE1 = REPLACEMENTS, Dairy Heifers, East
HFRDW1 = REPLACEMENTS, Dairy Heifers, West
HFRBE1 = REPLACEMENTS, Beef Heifers, East
HFRBW1 = REPLACEMENTS, Beef Heifers, West

BULLE1 = REPLACEMENTS, Bulls, East
BULLW1 = REPLACEMENTS, Bulls, West
SBULE1 = SLAUGHTER, Bulls, East
SBULW1 = SLAUGHTER, Bulls, West

SCVME1 = SLAUGHTER, Male Calves, East
SCVMW1 = SLAUGHTER, Male Calves, West
SCVFE1 = SLAUGHTER, Female Calves, East
SCVFW1 = SLAUGHTER, Female Calves, West

BCSCE1 = SLAUGHTER, Beef Cows, East
BCSCW1 = SLAUGHTER, Beef Cows, West
DCSLE1 = SLAUGHTER, Dairy Cows, East
DCSLW1 = SLAUGHTER, Dairy Cows, West

The last element in the variable name, a "1" or "2," refers to the quarter. In the first half of the program "1" and "2" refer to the first and second quarter while in the last part of the program they refer to quarters three and four.

```
      PROGRAM MATRIX(INPUT,OUTPUT,TAPE1)
C
      COMMON VALD(4),VALDE(4),VALDT(4)
C
C DIMENSION THE MATRIX OF PUBLISHED STATISTICAL DATA
C
      COMMON     BCOWE(27,4),BCOWW(27,4),BCOWT(27,4),BHFRE(27,4),BHFRW(27
     1,4),BHFRT(27,4),DCOWE(27,4),DCOWW(27,4),DCOWT(27,4),DHFRE(27,4),
     2DHFRW(27,4),DHFRT(27,4),STRSE(27,4),STRSW(27,4),STRST(27,4),CALVE(
     327,4),CALVW(27,4),CALVT(27,4),BULLE(27,4),BULLW(27,4),BULLT(27,4),
     4BIRTHE(27,4),BIRTHW(27,4),BIRTHT(27,4), SCAVE(27,12),SCAVW(27,12),
     5SMCAVE(27,12),SFCAVE(27,12),SMCAVW(27,12),SFCAVW(27,12),
     6SCOWE(27,12),SCOWW(27,12),SBULLE(27,12),SBULLW(27,12),SHFRE(27,12
     7),SSTRE(27,12),SSTRW(27,12),SCATE(27,12),SCATW(27,12),SHFRW(27,12)
     8,ZCTSLR(27,12),ZCTFD(27,12),ZCTSTK(27,12),ZCTTOT(27,12),ZCVSLR(27,
     912),ZCVFD(27,12),ZCVSTK(27,12),ZCVTOT(27,12)
C
      COMMON VPBROW(27),VPBROE(27),VOTHRW(27),VOTHRE(27),WPORYW(27),
     1WPORYE(27),WPORFW(27),WPORFE(27),WOORYW(27),WOORYE(27),WCAVW2(27),
     2WCAVE2(27),WCAVW7(27),WCAVE7(27),WCATW9(27),WCATE9(27),WPBROE(27),
     3WPBROW(27),WORYW2(27),WORYE2(27),WORYW3(27),WORYE3(27),
     2USTKEE(27),USTKSE(27),USPTAE(27,4),USPTAE(27),USTKEW(27),USTKSW(
     327),USPTOW(27,4),USPTAW(27),USVKEE(27),USVKSE(27),USRVOE(27,4),
     4USRVAE(27),USVKEW(27),USVKSW(27),USRVOW(27,4),USRVAW(27)
C
      COMMON         YPORYE(27,12),YPORYW(27,12),YPBFE(27,12),YPBFW(27,12),
     1YOTHRE(27,12),YOTHRW(27,12),XCAVE2(27,12),XCAVW2(27,12),XCAVW7(27
     2,12),XCAVE7(27,12),XCATE9(27,12),XCATW9(27,12),XPORYE(27,12),XPBF
     3E(27,12),XPBFW(27,12),XPORYW(27,12),XOTOYE(27,12),XOTOYW(27,12),
     4FARME(27,12),FARMW(27,12),TCAHE(27,12),TCAHW(27,12),CAHMKE(27,12),
     5CAHMKW(27,12),CAHCVE(27,12),CAHCVW(27,12),CAHFSE(27,12),CAHFSW(27,
     612),CWRCHE(27,12),CWRCHW(27,12)
C
C READ JUNE 1 AND DEC 1 POPULATION DATA
C
      SWITCH=1.0
      DO 2 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 3
      L=2
      READ(1,4)      CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
    4 FORMAT(11X,12F9.0)
    3 L=4
      READ(1,4)      CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
      SWITCH=0.0
    2 CONTINUE
C
      SWITCH=1.0
      DO 7 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 9
      L=2
      READ(1,8)      DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,
     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
    8 FORMAT(11X,9F9.0)
    9 L=4
      READ(1,8)      DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,
     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
      SWITCH=0.0
    7 CONTINUE
C
C READ JUNE 1 AND DEC 1 CALF BIRTH DATA
C
      DO 13 K=2,27
      L=2
      READ(1,14)     BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   14 FORMAT(11X,3F10.0)
      L=4
      READ(1,14)     BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   13 CONTINUE
C
C READ INSPECTED SLAUGHTER DATA
C
      DO 11 I=3,12
      DO 12 J=1,12
      READ(1,15)SCAVE(I,J),SCAVW(I,J),SCATE(I,J),SCATW(I,J),SBULLE(I,J),

     1SBULLW(I,J)
   15 FORMAT(8X,2F10.0,10X,2F10.0,10X,2F10.0)
   12 CONTINUE
   11 CONTINUE
C
      DO 18 K=12,26
      DO 19 L=1,12
      READ(1,21)SMCAVE(K,L),SMCAVW(K,L),SFCAVE(K,L),SFCAVW(K,L)
   21 FORMAT(11X,2F10.0,10X,2F10.0)
   19 CONTINUE
   18 CONTINUE
C
      DO 24 K=12,26
      DO 25 L=1,12
      READ(1,27)     SSTRE(K,L),SSTRW(K,L),SHFRE(K,L),SHFRW(K,L),SCOWE(
     1K,L),SCOWW(K,L),SBULLE(K,L),SBULLW(K,L)
   27 FORMAT(11X,9F10.0)
   25 CONTINUE
   24 CONTINUE
```

```
C
C READ WEST-EAST CATTLE-CALF MOVEMENT DATA
C
      DO 31 K=2,26
      DO 32 L=1,12
      READ(1,34)       ZCTSLR(K,L),ZCTFD(K,L),ZCTSTK(K,L),ZCTTOT(K,L),ZCV
     1SLR(K,L),ZCVFD(K,L),ZCVSTK(K,L),ZCVTOT(K,L)
   34 FORMAT(11X,8F12.0)
   32 CONTINUE
   31 CONTINUE
C
C READ DAIRY CORRESPONDENTS STUDY DATA
C
      DO 38 I=10,27
      DO 39 J=1,12
      READ(1,42)       FARME(I,J),TCAHE(I,J),CAHMKE(I,J),CAHCVE(I,J),CAH
     1FSE(I,J),CWBCHE(I,J)
   42 FORMAT(11X,F15.0,5F20.0)
   39 CONTINUE
   38 CONTINUE
C
      DO 45 I=10,27
      DO 46 J=1,12
      READ(1,42)       FARMW(I,J),TCAHW(I,J),CAHMKW(I,J),CAHCVW(I,J),CAH
     1FSW(I,J),CWBCHW(I,J)
   46 CONTINUE
   45 CONTINUE
C
C READ UNINSPECTED SLAUGHTER DATA
C
      DO 53 I=10,26
      DO 54 J=1,4
      IF(J.EQ.4.0)GO TO 58
      READ(1,55)       USRTQE(I,J),USRTQW(I,J)
   55 FORMAT(17X,40X,2F10.1)
      GO TO 54
   58 READ(1,59)       USTKEE(I),USTKEW(I),USTKSE(I),USTKSW(I),USRTQE(I,J)
     1,USRTQW(I,J),USRTAE(I),USRTAW(I)
   59 FORMAT(17X,8F10.1)
   54 CONTINUE
   53 CONTINUE
C
      DO 82 I=10,26
      DO 88 J=1,4
      IF(J.EQ.4.0)GO TO 92
      READ(1,55)       USRVQE(I,J),USRVQW(I,J)
      GO TO 88
   92 READ(1,59)       USVKEE(I),USVKEW(I),USVKSE(I),USVKSW(I),USRVQE(I,J)
     1,USRVQW(I,J),USRVAE(I),USRVAW(I)
   88 CONTINUE
   82 CONTINUE
C
C READ ANNUAL IMPORT DATA
C
      DO 72 I=2,26
      READ(1,73)VPORDW(I),VPBRDE(I),VOTHRW(I),VOTHRE(I)
   73 FORMAT(5X,2F15.0,15X,2F15.0)
   72 CONTINUE

C READ MONTHLY IMPORT DATA
C
      DO 77 I=23,26
      DO 78 J=1,12
      READ(1,76)       YPORYE(I,J),YPORYW(I,J),YPBFE(I,J),YPBFW(I,J),YOTH
     2RE(I,J),YOTHRW(I,J)
   76 FORMAT(5X,6F12.0)
   78 CONTINUE
   77 CONTINUE
C
C READ ANNUAL EXPORT DATA
C
      DO 67 I=2,19
      READ(1,61)WPORYE(I),WPOBFE(I),WPBRDE(I),WPORYW(I),WPOBFW(I),
     1WPBROW(I)
   61 FORMAT(5X,6F15.0)
   67 CONTINUE
C
      DO 60 I=20,26
      READ(1,61)WPORYW(I),WPOBFW(I),WPBROW(I),WPORYE(I),WPOBFE(I),
     1WPBRDE(I)
   60 CONTINUE
C
      DO 62 I=2,26
      READ(1,63)WOORYW(I),WOORYE(I),WCAVW2(I),WCAVE2(I),WCAVW7(I),
     1WCAVE7(I),WCATW9(I),WCATE9(I)
   63 FORMAT(5X,8F15.0)
   62 CONTINUE
C
C READ MONTHLY EXPORT DATA
C
      DO 64 I=23,26
      DO 65 J=1,12
      READ(1,66)       XCAVE2(I,J),XCAVW2(I,J),XCAVE7(I,J),XCAVW7(I,J),XC
     1ATE9(I,J),XCATW9(I,J),XOTOYE(I,J),XOTOYW(I,J),XPORYE(I,J),XPORYW
     2(I,J),XPBFE(I,J),XPBFW(I,J)
   66 FORMAT(8X,12F9.0)
   65 CONTINUE
   64 CONTINUE
```

```
C
C PROGRAM MATRIX
C
C PARAMETER DESCRIPTIONS
C
C      V22       PUREBRED IMPORTS 1ST HALF
C      V24       PUREBRED IMPORTS 2ND HALF
C      V3        PUREBRED IMPORTS FEMALE
C      V10       PUREBRED IMPORTS DAIRY
C
C      V72       PUREBRED EXPORTS 1ST HALF
C      V74       PUREBRED EXPORTS 2ND HALF
C      V8        PUREBRED EXPORTS FEMALE
C      V9        PUREBRED EXPORTS DAIRY
C
C      V11       PROPORTION OF COWS IN XCAT9,UNDER A CRITICAL LIMIT
C      V111      PROPORTION OF COWS IN XCAT9,OVER A CRITICAL LIMIT,EAST
C      V112      PROPORTION OF COWS IN XCAT9,OVER A CRITICAL LIMIT,WEST
C      V29       CRITICAL XCAT9 EXPORT LIMIT,EAST
C      V30       CRITICAL XCAT9 EXPORT LIMIT,WEST
C      V82       PROPORTION OF SLAUGHTER COW EXPORTS,1ST HALF
C      V84       PROPORTION OF SLAUGHTER COW EXPORTS,2ND HALF
C
C      V13       UNINSPECTED SLR CALVES EAST 1ST HALF
C      V15       UNINSPECTED SLR CALVES EAST 2ND HALF
C      V14       UNINSPECTED SLR CALVES WEST 1ST HALF
C      V16       UNINSPECTED SLR CALVES WEST 2ND HALF
C
C      V23       PROPORTION OF COWS IN UNINSPECTED SLAUGHTER,EAST
C      V19       PROPORTION OF COWS  IN UNINSPECTED SLAUGHTER,WEST
C      V25       PROPORTION OF BULLS IN UNINSPECTED SLAUGHTER,EAST
C      V26       PROPORTION OF BULLS IN UNINSPECTED SLAUGHTER,WEST
C
C      V27       DAIRY COW SLAUGHTER RATE WEST-1ST HALF
C      V28       DAIRY COW SLAUGHTER RATE WEST-2ND HALF
C      V20       BEEF COW SLAUGHTER RATE EAST-1ST HALF
C      V21       BEEF COW SLAUGHTER RATE EAST-2ND HALF
C
C
C      BRBF      BEEF COW BIRTH RATE
C      BRDY      DAIRY COW BIRTH RATE
C
C      VALBF(4)   QUARTERLY DISTRIBUTION OF BEEF COW BIRTHS,EAST
C      VALBW(4)   QUARTERLY DISTRIBUTION OF BEEF COW BIRTHS,WEST
C      VALD(4)    QUARTERLY DISTRIBUTION OR DAIRY CALF BIRTHS
C
C      DR1       FIRST HALF DEATH RATE
C      DR2       SECOND HALF DEATH RATES
C
C INITIALIZE PARAMETER VALUES
C
       V22=.526
       V24=.474
       V3=.90
       V72=.50
       V74=.50
       V8=.85
       V9=.926
       V10=.20
       V11=.80
       V111=.10
       V112=.05
       V13=.60
       V14=.44
       V15=1.-V13
       V16=1.-V14
       V17=.18
       V18=1.0
       V19=.25
       V20=.045
       V21=.055
       V23=.28
       V25=.06
       V26=.06
       V27=.08
       V28=.10
       V82=.57
       V84=.43
       DR1=.008
       DR2=.006
       VALD(1)=.262
       VALD(2)=.258
       VALD(3)=.222
       VALD(4)=.252
       VALBF(1)=.20
       VALBF(2)=.50
       VALBF(3)=.15
       VALBF(4)=.15
       VALBW(1)=.29
       VALBW(2)=.64
       VALBW(3)=.05
       VALBW(4)=.02
C
       PRINT 300
  300  FORMAT(*1*,*YEAR*,4X,*REPLACEMENT*,5X,*REPLACEMENT*,6X,*REPLACEMEN
      1T*,6X,*SLAUGHTER*,3X,*SLAUGHTER*,7X,*SLAUGHTER*,4X,*SLAUGHTER*,7X,
      2*SLAUGHTER*,/,7X,*DAIRY HEIFERS*,4X,*BEEF HEIFERS*,3X,*BULLS*,11X,
      3*BULLS*,3X,*MALE CALVES*,3X,*FEMALE CALVES*,7X,*BEEF COWS*,5X,
      4*DAIRY COWS*,/,7X,*EAST*,5X,*WEST*,4X,*EAST*,4X,*WEST*,5X,*EAST*,
      54X,*WEST*,4X,*EAST*,4X,*WEST*,5X,*EAST*,4X,*WEST*,4X,*EAST*,4X,
      6*WEST*,5X,*EAST*,4X,*WEST*,6X,*EAST*,4X,*WEST*)
```

```
C
C EXECUTION PHASE
C
C CALCULATE THE FIRST TWO QUARTERS
C
      DO 310 JJ=12,26
      SCWE1=0.0
      SCWW1=0.0
      SBLE1=0.0
      SBLW1=0.0
      SMCVE1=0.0
      SFCVE1=0.0
      SMCVW1=0.0
      SFCVW1=0.0
C
      SCWE2=0.0

      SCWW2=0.0
      SBLE2=0.0
      SBLW2=0.0
      SMCVE2=0.0
      SFCVE2=0.0
      SMCVW2=0.0
      SFCVW2=0.0
C
C CALCULATE COW,BULL AND INSPECTED CALF SLAUGHTER
C
      DO 311 J=1,3
      SCWE1=SCWE1+SCOWE(JJ,J)
     1+((USTKEE(JJ)+USTKSE(JJ))/12+USRTQE(JJ,1)/3)*V23
      SCWE2=SCWE2+SCOWE(JJ,J+3)
     1+((USTKEE(JJ)+USTKSE(JJ))/12+USRTQE(JJ,2)/3)*V23
      SCWW1=SCWW1+SCOWW(JJ,J)
     1+((USTKEW(JJ)+USTKSW(JJ))/12+USRTQW(JJ,1)/3)*V19
      SCWW2=SCWW2+SCOWW(JJ,J+3)
     1+((USTKEW(JJ)+USTKSW(JJ))/12+USRTQW(JJ,2)/3)*V19
      SBLE1=SBLE1+SBULLE(JJ,J)+USRTQE(JJ,1)/3*V25
C
      SBLE2=SBLE2+SBULLE(JJ,J+3)+USRTQE(JJ,2)/3*V25
      SBLW1=SBLW1+SBULLW(JJ,J)+USRTQW(JJ,1)/3*V26
      SBLW2=SBLW2+SBULLW(JJ,J+3)+USRTQW(JJ,2)/3*V26
C
      SMCVE1=SMCVE1+SMCAVE(JJ,J)
      SMCVE2=SMCVE2+SMCAVE(JJ,J+3)
      SFCVE1=SFCVE1+SFCAVE(JJ,J)
      SFCVE2=SFCVE2+SFCAVE(JJ,J+3)
      SMCVW1=SMCVW1+SMCAVW(JJ,J)
      SMCVW2=SMCVW2+SMCAVW(JJ,J+3)
      SFCVW1=SFCVW1+SFCAVW(JJ,J)
      SFCVW2=SFCVW2+SFCAVW(JJ,J+3)
  311 CONTINUE
C
C CALCULATE BEEF AND DAIRY COW SLAUGHTER
C
      DCWE=DCOWE(JJ-1,4)+DCOWE(JJ,2)
      BCWE=BCOWE(JJ-1,4)+BCOWE(JJ,2)
      RATIO1=DCWE/(DCWE+BCWE)
C
      DCWW=DCOWW(JJ-1,4)+DCOWW(JJ,2)
      BCWW=BCOWW(JJ-1,4)+BCOWW(JJ,2)
      RATIO2=DCWW/(DCWW+BCWW)
C
      TOTALE=WCATE9(JJ)*V82
      TOTALW=WCATW9(JJ)*V82
      IF(TOTALE.LE.1700.0) EXPORTE=TOTALE*V11
      IF(TOTALE.GT.1700.0) EXPORTE=1360+(TOTALE-1360)*V111
      IF(TOTALW.LE.4560.0) EXPORTW=TOTALW*V11
      IF(TOTALW.GT.4560.0) EXPORTW=3650+(TOTALW-3650)*V112
C
      BCSLE1=BCOWE(JJ-1,4)*V20*.55
      DCSLE1=SCWE1-BCSLE1
C
      BCSLE2=BCOWE(JJ-1,4)*V20*.45
      DCSLE2=SCWE2-BCSLE2
C
      DCSLW1=DCOWW(JJ-1,4)*V27*.53
      DCSLW2=DCOWW(JJ-1,4)*V27*.47
C
      BCSLW1=SCWW1-DCSLW1
      BCSLW2=SCWW2-DCSLW2
C
C CALCULATE REPLACEMENT HEIFERS
C
      HFRDE1=(DCOWE(JJ,2)-DCOWE(JJ-1,4)+DR1*DCOWE(JJ-1,4)+DCSLE1+DCSLE2
     1+EXPORTE*RATIO1-V21RDE(JJ)*V22*V3*V10+WODRYE(JJ)*V72+W2BRDE(JJ)
     2*V72*V8*V9)*VALD(4)/(VALD(1)+VALD(4))
C
      HFRDE2=(DCOWE(JJ,2)-DCOWE(JJ-1,4)+DR1*DCOWE(JJ-1,4)+DCSLE1+DCSLE2
     1+EXPORTE*RATIO1-V21RDE(JJ)*V22*V3*V10+WODRYE(JJ)*V72+W2BRDE(JJ)
     2*V72*V8*V9)*VALD(1)/(VALD(1)+VALD(4))
C
      HFRDW1=(DCOWW(JJ,2)-DCOWW(JJ-1,4)+DR1*DCOWW(JJ-1,4)+DCSLW1+DCSLW2
     1+EXPORTW*RATIO2-V21RDW(JJ)*V22*V3*V10+WODRYW(JJ)*V72+W2BRDW(JJ)
     2*V72*V8*V9)*VALD(4)/(VALD(1)+VALD(4))
C
```

```
      HFRDW2=(DCOWW(JJ,2)-DCOWW(JJ-1,4)+DR1*DCOWW(JJ-1,4)+DCSLW1+DCSLW2
     1+EXPORTW*RATIO2-VPDRDW(JJ)*V22*V3*V10+WODRYW(JJ)*V72+WPDRDW(JJ)
     2*V72*V8*V9)*VALD(1)/(VALD(1)+VALD(4))
C
      HFRBE1=(BCOWE(JJ,2)-BCOWE(JJ-1,4)+DR1*BCOWE(JJ-1,4)+(BCSLE1+BCSLE2
     1)-VPBRDE(JJ)*V22*V3*(1.-V10)+WPBRDE(JJ)*V72*V8*(1.-V9)+EXPORTE*
     2(1.-RATIO1))*VALBE(1)/(VALBE(1)+VALBE(2))
C
      HFRBE2=(BCOWE(JJ,2)-BCOWE(JJ-1,4)+DR1*BCOWE(JJ-1,4)+(BCSLE1+BCSLE2
     1)-VPBRDE(JJ)*V22*V3*(1.-V10)+WPBRDE(JJ)*V72*V8*(1.-V9)+EXPORTE*
     2(1.-RATIO1))*VALBE(2)/(VALBE(1)+VALBE(2))
C
      HFRBW1=(BCOWW(JJ,2)-BCOWW(JJ-1,4)+DR1*BCOWW(JJ-1,4)+(BCSLW1+BCSLW2
     1)-VPBRDW(JJ)*V22*V3*(1.-V10)+WPBRDW(JJ)*V72*V8*(1.-V9)+EXPORTW*
     2(1.-RATIO2))*VALBW(1)/(VALBW(1)+VALBW(2))
C
      HFRBW2=(BCOWW(JJ,2)-BCOWW(JJ-1,4)+DR1*BCOWW(JJ-1,4)+(BCSLW1+BCSLW2
     1)-VPBRDW(JJ)*V22*V3*(1.-V10)+WPBRDW(JJ)*V72*V8*(1.-V9)+EXPORTW*
     2(1.-RATIO2))*VALBW(2)/(VALBW(1)+VALBW(2))
C
C CALCULATE BULL REPLACEMENTS
C
      BULF=BULLE(JJ,2)-VPBRDE(JJ)*V22*(1.-V3)+(SBLE1+SBLE2)+WPBRDE(JJ)
     1*V72*(1.-V8)-BULLE(JJ-1,4)*(1.-DR1)
C
      BULW=BULLW(JJ,2)-VPBRDW(JJ)*V22*(1.-V3)+(SBLW1+SBLW2)+WPBRDW(JJ)
     1*V72*(1.-V8)-BULLW(JJ-1,4)*(1.-DR1)
C
      BULLE1=BULF*VALBE(1)/(VALBE(1)+VALBE(2))
      BULLE2=BULF*VALBE(2)/(VALBE(1)+VALBE(2))
      BULLW1=BULW*VALBW(1)/(VALBW(1)+VALBW(2))
      BULLW2=BULW*VALBW(2)/(VALBW(1)+VALBW(2))
C
C CALCULATE INSPECTED PLUS UNINSPECTED CALF SLAUGHTER
C
      UNSLRE=(USVKFE(JJ)+USVKSE(JJ))      +USRVAE(JJ)
      UNSLRW=(USVKFW(JJ)+USVKSW(JJ))      +USRVAW(JJ)
C
      RATIO3=(SMCVE1+SMCVE2)/(SMCVE1+SMCVE2+SFCVE1+SFCVE2)
      RATIO4=(SMCVW1+SMCVW2)/(SMCVW1+SMCVW2+SFCVW1+SFCVW2)
C
      RATIO5=(SMCVE1+SFCVE1)/(SMCVE1+SMCVE2+SFCVE1+SFCVE2)
      RATIO6=(SMCVW1+SFCVW1)/(SMCVW1+SMCVW2+SFCVW1+SFCVW2)
C
      SCVME1=SMCVE1+UNSLRE*V13*RATIO3*RATIO5
      SCVMW1=SMCVW1+UNSLRW*V14*RATIO4*RATIO6
      SCVFE1=SFCVE1+UNSLRE*V13*(1.-RATIO3)*RATIO5
      SCVFW1=SFCVW1+UNSLRW*V14*(1.-RATIO4)*RATIO6
C
      SCVME2=SMCVE2+UNSLRE*V13*RATIO3*(1.-RATIO5)
      SCVMW2=SMCVW2+UNSLRW*V14*RATIO4*(1.-RATIO6)
      SCVFE2=SFCVE2+UNSLRE*V13*(1.-RATIO3)*(1.-RATIO5)
      SCVFW2=SFCVW2+UNSLRW*V14*(1.-RATIO4)*(1.-RATIO6)
C
C PRINT THE FIRST TWO QUARTERS
C
      KK=JJ+46
      L=1
      PRINT 302,KK,L,HFRDE1,HFRDW1,HFRBE1,HFRBW1,BULLE1,BULLW1,SBLE1,
     1SBLW1, SCVME1,SCVMW1,SCVFE1,SCVFW1,DCSLE1,DCSLW1,BCSLE1,BCSLW1
  302 FORMAT('-',2I2,4F8.0,F9.0,3F8.0,F9.0,3F8.0,F9.0,3F8.0)
C
      L=2
      PRINT 303,    L,HFRDE2,HFRDW2,HFRBE2,HFRBW2,BULLE2,BULLW2,SBLE2,
     1SBLW2, SCVME2,SCVMW2,SCVFE2,SCVFW2,BCSLE2,BCSLW2,DCSLE2,DCSLW2
  303 FORMAT('0', I4,4F8.0,F9.0,3F8.0,F9.0,3F8.0,F9.0,3F8.0)
C
      WRITE(10,315)DCSLE1,DCSLW1,BCSLE1,BCSLW1,HFRDE1,HFRDW1,HFRBE1,
     1HFRBW1,SBLE1,SBLW1,BULLE1,BULLW1
  315 FORMAT(8F10.0,/,4F10.0)
C
      WRITE(10,315)DCSLE2,DCSLW2,BCSLE2,BCSLW2,HFRDE2,HFRDW2,HFRBE2,
     1HFRBW2,SBLE2,SBLW2,BULLE2,BULLW2
C
C
C CALCULATE THE LAST TWO QUARTERS
C
      SCWE1=0.0

      SCWW1=0.0
      SBLE1=0.0
      SBLW1=0.0
      SMCVE1=0.0
      SFCVE1=0.0
      SMCVW1=0.0
      SFCVW1=0.0
C
      SCWE2=0.0
      SCWW2=0.0
      SBLE2=0.0
      SBLW2=0.0
      SMCVE2=0.0
      SFCVE2=0.0
      SMCVW2=0.0
      SFCVW2=0.0
```

```
C
C CALCULATE COW,BULL AND INSPECTED CALF SLAUGHTER
C
      DO 312 J=7,9
      SCWE1=SCWE1+SCOWE(JJ,J)
     1+((USTKEF(JJ)+USTKSF(JJ))/12+USRTOE(JJ,3)/3)*V23
      SCWE2=SCWE2+SCOWE(JJ,J+3)
     1+((USTKEE(JJ)+USTKSF(JJ))/12+USRTOE(JJ,4)/3)*V23
      SCWW1=SCWW1+SCOWW(JJ,J)
     1+((USTKEW(JJ)+USTKSW(JJ))/12+USRTOW(JJ,3)/3)*V19
      SCWW2=SCWW2+SCOWW(JJ,J+3)
     1+((USTKEW(JJ)+USTKSW(JJ))/12+USRTOW(JJ,4)/3)*V19
      SBLE1=SBLE1+SBULLE(JJ,J)+USRTOE(JJ,3)/3*V25
      SBLE2=SBLE2+SBULLE(JJ,J+3)+USRTOE(JJ,4)/3*V25
C
      SBLW1=SBLW1+SBULLW(JJ,J)+USRTOW(JJ,3)/3*V26
      SBLW2=SBLW2+SBULLW(JJ,J+3)+USRTOW(JJ,4)/3*V26
C
      SMCVE1=SMCVE1+SMCAVE(JJ,J)
      SMCVE2=SMCVE2+SMCAVE(JJ,J+3)
      SFCVE1=SFCVE1+SFCAVE(JJ,J)
      SFCVE2=SFCVE2+SFCAVE(JJ,J+3)
      SMCVW1=SMCVW1+SMCAVW(JJ,J)
      SMCVW2=SMCVW2+SMCAVW(JJ,J+3)
      SFCVW1=SFCVW1+SFCAVW(JJ,J)
      SFCVW2=SFCVW2+SFCAVW(JJ,J+3)
  312 CONTINUE
C
C CALCULATE BEFF AND DAIRY COW SLAUGHTER
C
      DCWE=DCOWE(JJ,  2)+DCOWE(JJ,4)
      BCWE=BCOWE(JJ,  2)+BCOWE(JJ,4)
      RATIO1=DCWE/(DCWE+BCWE)
C
      DCWW=DCOWW(JJ,  2)+DCOWW(JJ,4)
      BCWW=BCOWW(JJ,  2)+BCOWW(JJ,4)
      RATIO2=DCWW/(DCWW+BCWW)
C
      TOTALE=HCATE9(JJ)*V94
      TOTALW=HCATW9(JJ)*V94
      IF(TOTALE.LE.1300.0) EXPORTE=TOTALE*V11
      IF(TOTALE.GT.1300.0) EXPORTE=1040+(TOTALE-1040)*V111
      IF(TOTALW.LE.3440.0) EXPORTW=TOTALW*V11
      IF(TOTALW.GT.3440.0) EXPORTW=2750+(TOTALW-2750)*V112
C
      BCSLE1=BCOWE(JJ,2)*V21*.45
      DCSLE1=SCWE1-BCSLE1
C
      BCSLE2=BCOWE(JJ,2)*V21*.55
      DCSLE2=SCWE2-BCSLE2
C
      DCSLW1=DCOWW(JJ,2)*V29*.47
      DCSLW2=DCOWW(JJ,2)*V29*.53
C
      BCSLW1=SCWW1-DCSLW1
      BCSLW2=SCWW2-DCSLW2
C
C CALCULATE REPLACEMENT HEIFERS
C
      HFRDE1=(DCOWE(JJ,4)-DCOWE(JJ,  2)+DR2*DCOWE(JJ,  2)+DCSLE1+DCSLE2
     1+EXPORTE*RATIO1-VPHRDE(JJ)*V24*V3*V10+WODRYE(JJ)*V74+WPBRDE(JJ)
     2*V74*V8*V9)*VALD(2)/(VALD(2)+VALD(3))
C
      HFRDE2=(DCOWE(JJ,4)-DCOWE(JJ,  2)+DR2*DCOWE(JJ,  2)+DCSLE1+DCSLE2
     1+EXPORTE*RATIO1-VPHRDE(JJ)*V24*V3*V10+WODRYE(JJ)*V74+WPBRDE(JJ)
     2*V74*V8*V9)*VALD(3)/(VALD(2)+VALD(3))
C
      HFRDW1=(DCOWW(JJ,4)-DCOWW(JJ,  2)+DR2*DCOWW(JJ,  2)+DCSLW1+DCSLW2
     1+EXPORTW*RATIO2-VPHRDW(JJ)*V24*V3*V10+WODRYW(JJ)*V74+WPBRDW(JJ)
     2*V74*V8*V9)*VALD(2)/(VALD(2)+VALD(3))
C
      HFRDW2=(DCOWW(JJ,4)-DCOWW(JJ,  2)+DR2*DCOWW(JJ,  2)+DCSLW1+DCSLW2
     1+EXPORTW*RATIO2-VPHRDW(JJ)*V24*V3*V10+WODRYW(JJ)*V74+WPBRDW(JJ)
     2*V74*V8*V9)*VALD(3)/(VALD(2)+VALD(3))
C
      HFRBE1=(BCOWE(JJ  ,4)-BCOWE(JJ,2)+DR2*BCOWE(JJ  ,2)+(BCSLE1+BCSLE2
     1)-VPHRBE(JJ)*V24*V3*(1.-V10)+WPBRBE(JJ)*V74*V8*(1.-V9)+EXPORTE*
     2(1.-RATIO1))*VALBE(3)/(VALBE(3)+VALBE(4))
C
      HFRBE2=(BCOWE(JJ  ,4)-BCOWE(JJ,2)-DR2*BCOWE(JJ  ,2)+(BCSLE1+BCSLE2
     1)-VPHRBE(JJ)*V24*V3*(1.-V10)+WPBRBE(JJ)*V74*V8*(1.-V9)+EXPORTE*
     2(1.-RATIO1))*VALBE(4)/(VALBE(3)+VALBE(4))
C
      HFRBW1=(BCOWW(JJ  ,4)-BCOWW(JJ,2)+DR2*BCOWW(JJ  ,2)+(BCSLW1+BCSLW2
     1)-VPHRBW(JJ)*V24*V3*(1.-V10)+WPBRBW(JJ)*V74*V8*(1.-V9)+EXPORTW*
     2(1.-RATIO2))*VALBW(3)/(VALBW(3)+VALBW(4))
C
      HFRBW2=(BCOWW(JJ  ,4)-BCOWW(JJ,2)+DR2*BCOWW(JJ  ,2)+(BCSLW1+BCSLW2
     1)-VPHRBW(JJ)*V24*V3*(1.-V10)+WPBRBW(JJ)*V74*V8*(1.-V9)+EXPORTW*
     2(1.-RATIO2))*VALBW(4)/(VALBW(3)+VALBW(4))
```

```
C
C CALCULATE BULL REPLACEMENTS
C
      BULE=BULLF(JJ,4)-VPRODE(JJ)*V24*(1.-V3)+(SBLE1+SBLE2)+WPARDE(JJ)
     1*V74*(1.-V8)-BULLE(JJ  ,2)*(1.-DR2)
C
      BULW=BULLW(JJ,4)-VPRODW(JJ)*V24*(1.-V3)+(SBLW1+SBLW2)+WPARDW(JJ)
     1*V74*(1.-V8)-BULLW(JJ-1,2)*(1.-DR2)
C
      BULLE1=BULE*VALBE(3)/(VALBE(3)+VALBE(4))
      BULLE2=BULE*VALBE(4)/(VALBE(3)+VALBE(4))
      BULLW1=BULW*VALBW(3)/(VALBW(3)+VALBW(4))
      BULLW2=BULW*VALBW(4)/(VALBW(3)+VALBW(4))
C
C CALCULATE INSPECTED PLUS UNINSPECTED CALF SLAUGHTER
C
      RATIO3=(SMCVE1+SMCVE2)/(SMCVE1+SMCVE2+SFCVE1+SFCVE2)
      RATIO4=(SMCVW1+SMCVW2)/(SMCVW1+SMCVW2+SFCVW1+SFCVW2)
C
      RATIO5=(SMCVE1+SFCVE1)/(SMCVE1+SMCVE2+SFCVE1+SFCVE2)
      RATIO6=(SMCVW1+SFCVW1)/(SMCVW1+SMCVW2+SFCVW1+SFCVW2)
C
      SCVME1=SMCVE1+UNSLRE*V15*RATIO3*RATIO5
      SCVMW1=SMCVW1+UNSLRW*V15*RATIO4*RATIO6
      SCVFE1=SFCVE1+UNSLRE*V15*(1.-RATIO3)*RATIO5
      SCVFW1=SFCVW1+UNSLRW*V16*(1.-RATIO4)*RATIO5
C
      SCVME2=SMCVE2+UNSLRE*V15*RATIO3*(1.-RATIO5)
      SCVMW2=SMCVW2+UNSLRW*V15*RATIO4*(1.-RATIO6)
      SCVFE2=SFCVE2+UNSLRE*V15*(1.-RATIO3)*(1.-RATIO5)
      SCVFW2=SFCVW2+UNSLRW*V16*(1.-RATIO4)*(1.-RATIO6)
C
C PRINT THE LAST TWO QUARTERS
C
      L=3
      PRINT 303,    L,HFRDE1,HFRDW1,HFRBE1,HFRBW1,BULLE1,BULLW1,SBLE1,
     1SBLW1, SCVME1,SCVMW1,SCVFE1,SCVFW1,BCSLE1,BCSLW1,DCSLE1,DCSLW1
C
      L=4
      PRINT 303,    L,HFRDE2,HFRDW2,HFRBE2,HFRBW2,BULLE2,BULLW2,SBLE2,
     1SBLW2, SCVME2,SCVMW2,SCVFE2,SCVFW2,BCSLE2,BCSLW2,DCSLE2,DCSLW2
C
      WRITE(10,315)DCSLE1,DCSLW1,BCSLE1,BCSLW1,HFRDE1,HFRDW1,HFRBE1,
     1HFRBW1,SBLE1,SBLW1,BULLE1,BULLW1
C
      WRITE(10,315)DCSLE2,DCSLW2,BCSLE2,BCSLW2,HFRDE2,HFRDW2,HFRBE2,
     1HFRBW2,SBLE2,SBLW2,BULLE2,BULLW2
C
  310 CONTINUE
      END
```

APPENDIX D

PROGRAM RECON

Appendix D provides a listing of program RECON. The first statements in the program dimension the output variables, as well as the variables that are the matrix of published statistical data described in Chapter II, the third section. The variable names used to describe these data are listed in Appendix C. The next set of program statements read the published statistical data matrix into core.

The parameters of program RECON are briefly described in comment statements; the initialization of these parameters occupy the next set of program statements.

The number of intermediate and output variables preclude their listing, however, the logic of the output variable names is given below.

The program calculates the elements in the output format matrix displayed in Table 15; each row of this matrix is an adaptation of identity (83). The first part of the program calculates the four "Calves Born This Year" rows on the XCAV stream elements.

These row elements are:

XBMCV + E or W + 1 to 9 or P or M	Male Beef Calves
XBFCV + E or W + 1 to 9 or P or M	Female Beef Calves
XDMCV + E or W + 1 to 9 or P or M	Male Dairy Calves
XDFCV + E or W + 1 to 9 or P or M	Female Dairy Calves.

The E or W refers to East or West while the 1 to 9 or P or M refers to columns of the output format matrix. These columns are:

1	Beginning Inventory
2	BORN
3	TRANSFER IN
4	IMPORT
P	TOTAL SOURCES
5	DIED
6	SLAUGHTER
7	EXPORT
8	TRANSFER OUT
9	Ending Inventory
M	TOTAL DISPOSITION

The second part of the program calculates the "Calves On Hand" rows or YCAV stream elements.

YBMW	Male Beef Calves
YBFW	Female Beef Calves
YDMW	Male Dairy Calves
YDMW	Female Dairy Calves

E and W as well as 1 to 9, M and P make up the last two characters of the variable name.

Using these same last two elements in the variable name, the remaining rows of the matrix are listed.

BULL	Bulls
DCOW	Dairy Cows
DHFR	Dairy Heifer
BCOW	Beef Cows
BHFRR	Beef Heifers--Replacement
BHFRF	Beef Heifers--Feeding
STRS	Steers

```
      PROGRAM RECON(INPUT,OUTPUT,TAPE1)
C
C DIMENSION THE MATRIX OF OUTPUT VARIABLES
C
      COMMON BULLE1(27),BULLE3(27),BULLE4(27),BULLEP(27),BULLE5(27),
     1BULLE6(27),BULLE7(27),BULLE9(27),BULLEM(27),DCOWE1(27),DCOWE3(27),
     2DCOWE4(27),DCOWEP(27),DCOWE5(27),DCOWE6(27),DCOWE7(27),DCOWE9(27),
     3DCOWEM(27),DHFRE1(27),DHFRE3(27),DHFREP(27),DHFRE5(27),DHFRE6(27),
     4DHFRE8(27),DHFRE9(27),DHFREM(27),BCOWE1(27),BCOWE3(27),BCOWE4(27),
     5BCOWEP(27),BCOWE5(27),BCOWE6(27),BCOWE7(27),BCOWE9(27),BCOWEM(27),
     6BHFRRE3(27),BHFRREP(27),BHFRRE5(27),BHFRRE8(27),BHFRREM(27),BHFRFE
     71(27),BHFRFE3(27),BHFRFE4(27),BHFRFEP(27),BHFRFE5(27),BHFRFE6(27),
     8BHFRFE7(27),BHFRFE8(27),BHFRFE9(27),BHFRFEM(27),STRSE1(27),STRSE3(
     927),STRSE4(27),STRSEP(27),STRSE5(27),TBIRTHE(27),TBIRTHW(27)
C
      COMMON STRSE6(27),STRSE7(27),STRSE9(27),STRSEM(27),BEGINVE(27),
     1TRANINE(27),TIMPTE(27),SOURCE(27),TDIEDE(27),TSLRE(27),TEXPTE(27),
     2TRNOUTE(27),ENDINVE(27),TDSPNE(27),DBIRTHE(27),DBIRTHW(27),
     3XBMCVE2(27),XBMCVEP(27),XBMCVE5(27),XBMCVE6(27),XBMCVE7(27),XBMCVE
     49(27),XBMCVEM(27),XBFCVE2(27),XBFCVEP(27),XBFCVE5(27),XBFCVE6(27),
     5XBFCVE7(27),XBFCVE9(27),XBFCVEM(27),XDMCVE2(27),XDMCVEP(27),XDMCVE
     65(27),XDMCVE6(27),XDMCVE7(27),XDMCVE9(27),XDMCVEM(27),XDFCVE2(27),
     7XDFCVEP(27),XDFCVE5(27),XDFCVE6(27),XDFCVE7(27),XDFCVE9(27),XDFCVE
     8M(27),XXCAVE2(27),XXCAVEP(27),XXCAVE5(27),XXCAVE6(27),XXCAVE7(27),
     9XXCAVE9(27),XXCAVEM(27),XBMCVE3(27),XBFCVE3(27),BHFRRE6(27)
C
      COMMON YBMCVE1(27),YBMCVE3(27),YBMCVEP(27),YBMCVE5(27),YBMCVE6(27)
     1,YBMCVE7(27),YBMCVE8(27),YBMCVEM(27),YBFCVE1(27),YBFCVE3(27),YBFCV
     2EP(27),YBFCVE5(27),YBFCVE6(27),YBFCVE7(27),YBFCVE8(27),YBFCVEM(27)
     3,YDMCVE1(27),YDMCVEP(27),YDMCVE5(27),YDMCVE6(27),YDMCVE7(27),
     4YDMCVE8(27),YDMCVEM(27),YDFCVE1(27),YDFCVEP(27),YDFCVE5(27),
     5YDFCVE6(27),YDFCVE7(27),YDFCVE8(27),YDFCVEM(27),YYCAVE1(27),
     6YYCAVE3(27),YYCAVEP(27),YYCAVE5(27),YYCAVE6(27),YYCAVE7(27),
     7YYCAVE8(27),YYCAVEM(27),XXCAVE3(27),YDMCVE3(27),YDFCVE3(27)
C
      COMMON BULLW1(27),BULLW3(27),BULLW4(27),BULLWP(27),BULLW5(27),
     1BULLW6(27),BULLW7(27),BULLW9(27),BULLWM(27),DCOWW1(27),DCOWW3(27),
     2DCOWW4(27),DCOWWP(27),DCOWW5(27),DCOWW6(27),DCOWW7(27),DCOWW9(27),
     3DCOWWM(27),DHFRW1(27),DHFRW3(27),DHFRWP(27),DHFRW5(27),DHFRW6(27),
     4DHFRW8(27),DHFRW9(27),DHFRWM(27),BCOWW1(27),BCOWW3(27),BCOWW4(27),
     5BCOWWP(27),BCOWW5(27),BCOWW6(27),BCOWW7(27),BCOWW9(27),BCOWWM(27),
     6BHFRRW3(27),BHFRRWP(27),BHFRRW5(27),BHFRRW8(27),BHFRRWM(27),BHFRFW
     71(27),BHFWFW3(27),BHFRFW4(27),BHFRFWP(27),BHFRFW5(27),BHFRFW6(27),
     8BHFRFW7(27),BHFRFW8(27),BHFRFW9(27),BHFRFWM(27),STRSW1(27),STRSW3(
     927),STRSW4(27),STRSWP(27),STRSW5(27),BHFRRW6(27),BHFRFW3(27)
C
      COMMON STRSW6(27),STRSW7(27),STRSW9(27),STRSWM(27),BEGINVW(27),
     1TRANINW(27),TIMPTW(27),SOURCW(27),TDIFDW(27),TSLRW(27),TEXPTW(27),
     2TRNOUTW(27),ENDINVW(27),TDSPNW(27),STRSW8(27),
     3XBMCVW2(27),XBMCVWP(27),XBMCVW5(27),XBMCVW6(27),XBMCVW7(27),XBMCVW
     49(27),XBMCVWM(27),XBFCVW2(27),XBFCVWP(27),XBFCVW5(27),XBFCVW6(27),
     5XBFCVW7(27),XBFCVW9(27),XBFCVWM(27),XDMCVW2(27),XDMCVWP(27),XDMCVW
     65(27),XDMCVW6(27),XDMCVW7(27),XDMCVW9(27),XDMCVWM(27),XDFCVW2(27),
     7XDFCVWP(27),XDFCVW5(27),XDFCVW6(27),XDFCVW7(27),XDFCVW9(27),XDFCVW
     8M(27),XXCAVW2(27),XXCAVWP(27),XXCAVW5(27),XXCAVW6(27),XXCAVW7(27),
     9XXCAVW9(27),XXCAVWM(27),XBMCVW8(27),XBFCVW8(27),XXCAVW8(27)
C
      COMMON YBMCVW1(27),YBMCVW3(27),YBMCVWP(27),YBMCVW5(27),YBMCVW6(27)
     1,YBMCVW7(27),YBMCVW8(27),YBMCVWM(27),YBFCVW1(27),YBFCVW3(27),YBFCV
     2WP(27),YBFCVW5(27),YBFCVW6(27),YBFCVW7(27),YBFCVW8(27),YBFCVWM(27)
     3,YDMCVW1(27),YDMCVWP(27),YDMCVW5(27),YDMCVW6(27),YDMCVW7(27),
     4YDMCVW8(27),YDMCVWM(27),YDFCVW1(27),YDFCVWP(27),YDFCVW5(27),
     5YDFCVW6(27),YDFCVW7(27),YDFCVW8(27),YDFCVWM(27),YYCAVW1(27),
     6YYCAVW3(27),YYCAVWP(27),YYCAVW5(27),YYCAVW6(27),YYCAVW7(27),
     7YYCAVW8(27),YYCAVWM(27)
```

```
C
C DIMENSION THE MATRIX OF PUBLISHED STATISTICAL DATA
C
      COMMON    BCCWE(27,4),BCOWW(27,4),BCOWT(27,4),BHFRE(27,4),BHFRW(27
     1,4),BHFRT(27,4),DCOWE(27,4),DCOWW(27,4),DCOWT(27,4),DHFRE(27,4),
     2DHFRW(27,4),DHFRT(27,4),STRSE(27,4),STRSW(27,4),STRST(27,4),CALVE(
     327,4),CALVW(27,4),CALVT(27,4),BULLE(27,4),BULLW(27,4),BULLT(27,4),
     4BIRTHE(27,4),BIRTHW(27,4),BIRTHT(27,4), SCAVE(27,12),SCAVW(27,12),
     5SMCAVE(27,12),SFCAVE(27,12),SMCAVW(27,12),SFCAVW(27,12),
     6SCOWE(27,12),SCOWW(27,12),SBULLE(27,12),SBULLW(27,12),SHFRE(27,12
     7),SSTRE(27,12),SSTRW(27,12),SCATE(27,12),SCATW(27,12),SHFRW(27,12)
     8,ZCTSLR(27,12),ZCTFD(27,12),ZCTSTK(27,12),ZCTTOT(27,12),ZCVSLR(27,
     912),ZCVFD(27,12),ZCVSTK(27,12),ZCVTOT(27,12)

C
      COMMON VPBRDW(27),VPBRDE(27),VOTHRW(27),VOTHRE(27),WPDRYW(27),
     1WPDRYE(27),WPDBFW(27),WPDBFE(27),WODRYW(27),WODRYE(27),WCAVW2(27),
     2WCAVE2(27),WCAVW7(27),WCAVE7(27),WCATW9(27),WCATE9(27),WPBRDE(27),
     3WPBRDW(27),WDRYW2(27),WDRYE2(27),WDRYW9(27),WDRYE9(27),
     2USTKEE(27),USTKSE(27),USRTOE(27,4),USRTAE(27),USTKEW(27),USTKSW(
     327),USRTOW(27,4),USRTAW(27),USVKEE(27),USVKSE(27),USRVOE(27,4),
     4USRVAE(27),USVKEW(27),USVKSW(27),USRVOW(27,4),USRVAW(27)
C
      COMMON       YPDRYE(27,12),YPDRYW(27,12),YPBFE(27,12),YPBFW(27,12),
     1YOTHRE(27,12),YOTHRW(27,12),XCAVE2(27,12),XCAVW2(27,12),XCAVW7(27
     2,12),XCAVE7(27,12),XCATE9(27,12),XCATW9(27,12),XPDRYE(27,12),XPBF
     3E(27,12),XPBFW(27,12),XPDRYW(27,12),XOTDYE(27,12),XOTDYW(27,12),
     4FARME(27,12),FARMW(27,12),TCAHE(27,12),TCAHW(27,12),CAHMKE(27,12),
     5CAHMKW(27,12),CAHCVE(27,12),CAHCVW(27,12),CAHFSE(27,12),CAHFSW(27,
     612),CWBCHE(27,12),CWBCHW(27,12),AA(27),BB(27),CC(27),DD(27)
C
C READ JUNE 1 AND DEC 1 POPULATION DATA.
C
      SWITCH=1.0
      DO 2 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 3
      L=2
      READ(1,4)      CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
    4 FORMAT(11X,12F9.0)
    3 L=4
      READ(1,4)      CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
      SWITCH=0.0
    2 CONTINUE
C
      SWITCH=1.0
      DO 7 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 9
      L=2
      READ(1,8)      DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,
     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
    8 FORMAT(11X,9F9.0)
    9 L=4
      READ(1,8)      DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,

     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
      SWITCH=0.0
    7 CONTINUE
C
C READ JUNE 1 AND DEC 1 CALF BIRTH DATA.
C
      DO 13 K=2,27
      L=2
      READ(1,14)     BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   14 FORMAT(11X,3F10.0)
      L=4
      READ(1,14)     BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   13 CONTINUE
```

```
C
C READ INSPECTED SLAUGHTER DATA
C
      DO 11 I=3,12
      DO 12 J=1,12
      READ(1,15)SCAVE(I,J),SCAVW(I,J),SCATE(I,J),SCATW(I,J),SBULLE(I,J),
     1SBULLW(I,J)
   15 FORMAT(8X,2F10.0,10X,2F10.0,10X,2F10.0)
   12 CONTINUE
   11 CONTINUE
C
      DO 18 K=12,26
      DO 19 L=1,12
      READ(1,21)SMCAVE(K,L),SMCAVW(K,L),SFCAVE(K,L),SFCAVW(K,L)
   21 FORMAT(11X,2F10.0,10X,2F10.0)
   19 CONTINUE
   18 CONTINUE
C
      DO 24 K=12,26
      DO 25 L=1,12
      READ(1,27)     SSTRE(K,L),SSTRW(K,L),SHFRE(K,L),SHFRW(K,L),SCOWE(
     1K,L),SCOWW(K,L),SBULLE(K,L),SBULLW(K,L)

   27 FORMAT(11X,8F10.0)
   25 CONTINUE
   24 CONTINUE
C
C READ WEST-EAST CATTLE-CALF MOVEMENT DATA
C
      DO 31 K=2,26
      DO 32 L=1,12
      READ(1,34)     ZCTSLR(K,L),ZCTFD(K,L),ZCTSTK(K,L),ZCTTOT(K,L),ZCV
     1SLR(K,L),ZCVFD(K,L),ZCVSTK(K,L),ZCVTOT(K,L)
   34 FORMAT(11X,8F12.0)
   32 CONTINUE
   31 CONTINUE
C
C READ DAIRY CORRESPONDENTS STUDY DATA
C
      DO 38 I=10,27
      DO 39 J=1,12
      READ(1,42)     FARMF(I,J),TCAME(I,J),CAMMKE(I,J),CAMCVE(I,J),CAM
     1FSE(I,J),CWRCHE(I,J)
   42 FORMAT(11X,F15.0,5F20.0)
   39 CONTINUE
   38 CONTINUE
C
      DO 45 I=10,27
      DO 46 J=1,12
      READ(1,42)     FARMW(I,J),TCAMW(I,J),CAMMKW(I,J),CAMCVW(I,J),CAM
     1FSW(I,J),CWRCHW(I,J)
   46 CONTINUE
   45 CONTINUE
C
C READ UNINSPECTED SLAUGHTER DATA
C
      DO 53 I=10,26
      DO 54 J=1,4
      IF(J.EQ.4.0)GO TO 58
      READ(1,55)     USRTOE(I,J),USRTOW(I,J)
   55 FORMAT(17X,40X,2F10.1)
      GO TO 54
   58 READ(1,59)     USTKFE(I),USTKEW(I),USTKSE(I),USTKSW(I),USRTOE(I,J)
     1,USRTOW(I,J),USRTAE(I),USRTAW(I)
   59 FORMAT(17X,8F10.1)
   54 CONTINUE
   53 CONTINUE
C
      DO 82 I=10,26
      DO 88 J=1,4
      IF(J.EQ.4.0)GO TO 92
      READ(1,55)     USRVOE(I,J),USRVOW(I,J)
      GO TO 88
   92 READ(1,59)     USVKFE(I),USVKEW(I),USVKSE(I),USVKSW(I),USRVOE(I,J)
     1,USRVOW(I,J),USRVAE(I),USRVAW(I)
   88 CONTINUE
   82 CONTINUE
```

```
C
C READ ANNUAL IMPORT DATA
C
      DO 72 I=2,26
      READ(1,73)VPBRDW(I),VPBRDE(I),VOTHRW(I),VOTHRE(I)
   73 FORMAT(6X,2F15.0,15X,2F15.0)
   72 CONTINUE
C
C READ MONTHLY IMPORT DATA
C
      DO 77 I=23,26
      DO 78 J=1,12
      READ(1,76)      YPDRYE(I,J),YPDRYW(I,J),YPBFE(I,J),YPBFW(I,J),YOTH
     2RE(I,J),YOTHRW(I,J)
   76 FORMAT(5X,6F12.0)
   78 CONTINUE
   77 CONTINUE
C
C READ ANNUAL EXPORT DATA
C
      DO 67 I=2,19
      READ(1,61)WPDRYE(I),WPDBFE(I),WPBRDE(I),WPDRYW(I),WPDBFW(I),
     1WPBPDW(I)
   61 FORMAT(6X,6F15.0)

   67 CONTINUE
C
      DO 60 I=20,26
      READ(1,61)WPDRYW(I),WPDBFW(I),WPBRDW(I),WPDRYE(I),WPDBFE(I),
     1WPBPDE(I)

   60 CONTINUE
C
      DO 62 I=2,26
      READ(1,63)WODRYW(I),WODRYE(I),WCAVW2(I),WCAVE2(I),WCAVW7(I),
     1WCAVE7(I),WCATW9(I),WCATE9(I)
   63 FORMAT(6X,8F15.0)
   62 CONTINUE
C
C READ MONTHLY EXPORT DATA
C
      DO 64 I=23,26
      DO 65 J=1,12
      READ(1,66)      XCAVE2(I,J),XCAVW2(I,J),XCAVE7(I,J),XCAVW7(I,J),XC
     1ATE9(I,J),XCATW9(I,J),XOTDYE(I,J),XOTDYW(I,J),XPDRYE(I,J),XPDRYW
     2(I,J),XPBFE(I,J),XPBFW(I,J)
   66 FORMAT(5X,12F9.0)
   65 CONTINUE
   64 CONTINUE
C
C PROGRAM RECON
C
C PARAMETER DESCRIPTIONS
C
C     V1        PROPORTION OF CALF EXPORTS FROM THE XCAV STREAM
C     V2        PROPORTION OF MALE CALVES IN EXPORTS 200-700LBS.
C
C     V3        PROPORTION OF FEMALES IN PUREBRED EXPORTS,EAST
C     V4        PROPORTION OF FEMALES IN PUREBRED EXPORTS,WEST
C     V5        PROPORTION OF FEMALES IN PUREBRED IMPORTS,EAST
C     V6        PROPORTION OF FEMALES IN PUREBRED IMPORTS,WEST
C
C     V7        PROPORTION OF DAIRY IN PUREBRED EXPORTS,EAST
C     V8        PROPORTION OF DAIRY IN PUREBRED EXPORTS,WEST
C     V9        PROPORTION OF DAIRY IN PUREBRED IMPORTS,EAST
C     V10       PROPORTION OF DAIRY IN PUREBRED IMPORTS,WEST
C
C     V12       PROPORTION OF STEERS IN OTHR IMPORTS
C     V14       PROPORTION OF STEERS IN NON-COW XCAT9
C     V15       PROPORTION OF CULL COWS IN XCAT9,UNDER CRITICAL LIMIT,EAST
C     V16       PROPORTION OF CULL COWS IN XCAT9,OVER CRITICAL LIMIT,EAST
C     V17       PROPORTION OF CULL COWS IN XCAT9,OVER CRITICAL LIMIT,WEST
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C
C      V20      PROPORTION OF BEEF COWS SLAUGHTERED,EAST
C      V21      PROPORTION OF DAIRY COWS SLAUGHTERED,WEST
C      V22      PROPORTION OF MALES IN UNINSPECTED CALF SLAUGHTER,EAST
C      V23      PROPORTION OF MALES IN UNINSPECTED CALF SLAUGHTER,WEST
C      V24      PROPORTION OF STEERS IN UNINSPECTED CATTLE SLR,EAST
C      V25      PROPORTION OF STEERS IN UNINSPECTED CATTLE SLR,WEST
C      V26      PROPORTION OF COWS IN UNINSPECTED CATTLE SLR,EAST
C      V27      PROPORTION OF COWS IN UNINSPECTED CATTLE SLR,WEST
C      V28      PROPORTION OF BULLS IN UNINSPECTED CATTLE SLR,EAST
C      V29      PROPORTION OF BULLS IN UNINSPECTED CATTLE SLR,WEST
C
C      V32      PROPORTION OF MALES IN ZCVSTK AND ZCVFD
C      V33      PROPORTION OF MALES IN ZCVSLR
C      V34      PROPORTION OF MALES IN ZCTSTK AND ZCTFD
C      V35      PROPORTION OF MALES IN ZCTSLR
C      V40      SCALE FACTOR FOR WEST-EAST TRANSFERS
C
C      XDRME    DEATH RATE OF MALES,XCAV STREAM,EAST
C      XDRMW    DEATH RATE OF MALES,XCAV STREAM,WEST
C      XDRFE    DEATH RATE OF FEMALES,XCAV STREAM,EAST
C      XDRFW    DEATH RATE OF FEMALES,XCAV STREAM,WEST
C
C      YDRME    DEATH RATE OF MALES,YCAV STREAM,EAST
C      YDRMW    DEATH RATE OF MALES,YCAV STREAM,WEST
C      YDRFE    DEATH RATE OF FEMALES,YCAV STREAM,EAST
C      YDRFW    DEATH RATE OF FEMALES,YCAV STREAM,WEST
C      DRE      DEATH RATE OF ALL CATTLE 1YR AND OVER,EAST
C      V38      PROPORTION OF 1ST YR CALF DEATHS OCCURING IN THE XCAV STREAM
C      DRW      DEATH RATE OF ALL CATTLE 1YR AND OVER,WEST
C
C      BRBFE    BIRTH RATE BEEF COWS,EAST
C      BRBFW    BIRTH RATE BEEF COWS,WEST
C      BRDYE    BIRTH RATE DAIRY COWS,EAST
C      BRDYW    BIRTH RATE DAIRY COWS,WEST
C
C INITIALIZE PARAMETER VALUES
C
       V1=.90
       V2=.135
       V3=.90
       V4=.90
       V5=.80
       V6=.80
       V7=.826
       V8=.826
       V9=.20
       V10=.20
       V12=.65
       V14=.35
       V15=.80
       V16=.10
       V17=.05
       V20=.10
       V21=.10
       V22=.65
       V23=.50
       V24=.615
       V25=.30
       V26=.20
       V27=.25
       V28=.06
       V29=.06
       V32=.800
       V33=0.95
       V34=.800
       V35=0.95
       V38=.60
       V40=1.07
       XDRME=.03
       XDRMW=.03
       XDRFE=.03
       XDRFW=.03
       YDRME=.03
       YDRMW=.03
       YDRFE=.03
       YDRFW=.03
       DRE=.015
       DRW=.015
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      BRBFE=.85
      BRBFW=.85
      BRDYE=.75
      BRDYW=.765
C
C
C PRINT PARAMETER VALUES
C
      PRINT 300
  300 FORMAT(*1*,*VARIABLE SETTINGS UTILIZED IN THIS RUN*)
C
      PRINT 301,V1,V2,V3,V4,V5,V6,V7,V8,V9,V10
  301 FORMAT(*0*,4X,F5.3,3X,*PROPORTION OF CALF EXPORT FROM XCAV STREAM*
     1,/,5X,F5,3,3X,*PROPORTION OF MALE CALVES IN EXPORTS 200-700LBS*
     2,/,5X,F5,3,3X,*PROPORTION OF FEMALES IN PUREBRED EXPORTS,EAST*
     3,/,5X,F5,3,3X,*PROPORTION OF FEMALES IN PUREBRED EXPORTS,WEST*
     4,/,5X,F5,3,3X,*PROPORTION OF FEMALES IN PUREBRED IMPORTS,EAST*
     5,/,5X,F5,3,3X,*PROPORTION OF FEMALES IN PUREBRED IMPORTS,WEST*
     6,//,5X,F5,3,3X,*PROPORTION OF DAIRY IN PUREBRED EXPORTS,EAST*
     7,/,5X,F5,3,3X,*PROPORTION OF DAIRY IN PUREBRED EXPORTS,WEST*
     8,/,5X,F5,3,3X,*PROPORTION OF DAIRY IN PUREBRED IMPORTS,EAST*
     9,/,5X,F5,3,3X,*PROPORTION OF DAIRY IN PUREBRED IMPORTS,WEST*)
C
      PRINT 302,V12,V14,V15,V16,V20,V21,V22,V23
  302 FORMAT(*0*,4X,F5,3,3X,*PROPORTION OF STEERS IN OTHR IMPORTS*
     1,/,5X,F5,3,3X,*PROPORTION OF STEERS IN NON-COW XCAT9*
     2,/,5X,F5,3,3X,*PROPORTION OF CULL COWS IN XCAT9,UNDER LIMIT,EAST*
     3,/,5X,F5,3,3X,*PROPORTION OF CULL COWS IN XCAT9,OVER LIMIT,EAST*
     4,/,5X,F5,3,3X,*PROPORTION OF CULL COWS IN XCAT9,OVER LIMIT,WEST*
     5,//,5X,F5,3,3X,*PROPORTION OF BEEF COWS SLAUGHTERED,EAST*
     6,/,5X,F5,3,3X,*PROPORTION OF DAIRY COWS SLAUGHTERED,WEST*

     7,/,5X,F5,3,3X,*PROPORTION OF MALES IN UNINSPECTED CALF SLR,EAST*
     8,/,5X,F5,3,3X,*PROPORTION OF MALES IN UNINSPECTED CALF SLR,WEST*)
C
      PRINT 303,V24,V25,V26,V27,V28,V29,V32,V33,V34,V35
  303 FORMAT(* *,4X,F5,3,3X,*PROPORTION OF STEERS IN UNINSP CT SLR,EAST*
     1,/,5X,F5,3,3X,*PROPORTION OF STEERS IN UNINSP CATTLE SLR,WEST*
     2,/,5X,F5,3,3X,*PROPORTION OF COWS IN UNINSPECTED CATTLE SLR,EAST*
     3,/,5X,F5,3,3X,*PROPORTION OF COWS IN UNINSPECTED CATTLE SLR,WEST*
     4,/,5X,F5,3,3X,*PROPORTION OF BULLS IN UNINSPECTED CATTLE SLR,EAST*
     5,/,5X,F5,3,3X,*PROPORTION OF BULLS IN UNINSPECTED CATTLE SLR,WEST*
     6,//,5X,F5,3,3X,*PROPORTION OF MALES IN ZCVSTK AND ZCVFD*
     7,/,5X,F5,3,3X,*PROPORTION OF MALES IN ZCVSLR*
     8,/,5X,F5,3,3X,*PROPORTION OF MALES IN ZCTSTK AND ZCTFD*
     9,/,5X,F5,3,3X,*PROPORTION OF MALES IN ZCTSLR*)
C
      PRINT 304,V40,XDRME,XDRMW,XDRFE,XDRFW,YDRME,YDRFW,YDRFE,YDRFW
  304 FORMAT(* *,4X,F5,3,3X,*SCALE FACTOR FOR WEST-EAST TRANSFERS*
     1,//,5X,F5,3,3X,*DEATH RATE OF MALES,XCAV STREAM,EAST*
     2,/,5X,F5,3,3X,*DEATH RATE OF MALES,XCAV STREAM,WEST*
     3,/,5X,F5,3,3X,*DEATH RATE OF FEMALES,XCAV STREAM,EAST*
     4,/,5X,F5,3,3X,*DEATH RATE OF FEMALES,XCAV STREAM,WEST*
     5,//,5X,F5,3,3X,*DEATH RATE OF MALES,YCAV STREAM,EAST*
     6,/,5X,F5,3,3X,*DEATH RATE OF MALES,YCAV STREAM,WEST*
     7,/,5X,F5,3,3X,*DEATH RATE OF FEMALES,YCAV STREAM,EAST*
     8,/,5X,F5,3,3X,*DEATH RATE OF FEMALES,YCAV STREAM,WEST*)
C
      PRINT 305,DRE,DRW,V38,BRBFE,BRBFW,BRDYE,BRDYW
  305 FORMAT(* *,4X,F5,3,3X,*DEATH RATE OF ALL CATTLE 1YR AND OVER,EAST*

     1,/,5X,F5,3,3X,*DEATH RATE OF ALL CATTLE 1YR AND OVER,WEST*
     2,/,5X,F5,3,3X,*PROPORTION 1ST YEAR CALF DEATHS OCCURING XCAV STRM*
     3,//,5X,F5,3,3X,*BIRTH RATE BEEF COWS,EAST*
     4,/,5X,F5,3,3X,*BIRTH RATE BEEF COWS,WEST*
     5,/,5X,F5,3,3X,*BIRTH RATE DAIRY COWS,EAST*
     6,/,5X,F5,3,3X,*BIRTH RATE DAIRY COWS,WEST*)
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```
C
C
C
C CALCULATE CATTLE POPULATION RECONCILIATION MATRIX
C
C CALCULATE CALVES BORN THIS YEAR MATRIX
C
      SWITCH=1.0
      DO 310 I=12,26
C
C
      TOTAL1=0.0
      TOTAL2=0.0
      DO 311 J=2,4,2
      TOTAL1=TOTAL1+BIRTHE(I,J)
      TOTAL2=TOTAL2+BIRTHW(I,J)
  311 CONTINUE
      TBIRTHE(I)=TOTAL1
      TBIRTHW(I)=TOTAL2
C
      TOTAL3=0.0
      TOTAL4=0.0
      DO 312 J=1,12
      TOTAL3=TOTAL3+CAHFSE(I,J)
      TOTAL4=TOTAL4+CAHFSW(I,J)
  312 CONTINUE
C
      RATIO1=(DCOWE(I,2)+DCOWE(I,4))/(TCAHE(I,5)+TCAHE(I,11))
      RATIO2=(DCOWW(I,2)+DCOWW(I,4))/(TCAHW(I,5)+TCAHW(I,11))
C
      TOTALDE=TOTAL3*RATIO1
      TOTALDW=TOTAL4*RATIO2
      TOTALBE=TBIRTHE(I)-TOTALDE
      TOTALBW=TBIRTHW(I)-TOTALDW
C
      DBIRTHE=((DCOWE(I-1,4)+DCOWE(I,2))/2)+BRDYE
      DBIRTHW=((DCOWW(I-1,4)+DCOWW(I,2))/2)+BRDYW
      BBIRTHE=BCOWE(I-1,4)+BRBFE+BHFRE(I-1,4)*.30*BRBFE
      BBIRTHW=BCOWW(I-1,4)+BRBFW+BHFRW(I-1,4)*.75*BRBFW
C
      AA(I)=DBIRTHE-TOTALDE
      BB(I)=DBIRTHW-TOTALDW
      CC(I)=BBIRTHE-TOTALBE
      DD(I)=BBIRTHW-TOTALBW


C
      XBMCVE2(I)=BBIRTHE*.5
      XBMCVW2(I)=BBIRTHW*.5
      XBFCVE2(I)=BBIRTHE*.5
      XBFCVW2(I)=BBIRTHW*.5
      XDMCVE2(I)=DBIRTHE*.5
      XDMCVW2(I)=DBIRTHW*.5
      XDFCVE2(I)=DBIRTHE*.5
      XDFCVW2(I)=DBIRTHW*.5
C
      TOTAL5=0.0
      TOTAL6=0.0
      DO 313 J=7,12
      TOTAL5=TOTAL5+(ZCVSTK(I,J)+ZCVFD(I,J))*V40
  313 CONTINUE
      DO 314 J=4,12
      TOTAL6=TOTAL6+ZCVSLR(I,J)*V40
  314 CONTINUE
C
      XBMCVE3(I)=TOTAL5*V32+TOTAL6*V33
      XBFCVE3(I)=TOTAL5*(1.-V32)+TOTAL6*(1.-V33)
      XBMCVW8(I)=TOTAL5*V32+TOTAL6*V33
      XBFCVW8(I)=TOTAL5*(1.-V32)+TOTAL6*(1.-V33)
C
      XBMCVEP(I)=XBMCVE2(I)+XBMCVE3(I)
      XBFCVEP(I)=XBFCVE2(I)+XBFCVE3(I)
      XDMCVEP(I)=XDMCVE2(I)
      XDFCVEP(I)=XDFCVE2(I)

      XBMCVWP(I)=XBMCVW2(I)
      XBFCVWP(I)=XBFCVW2(I)
      XDMCVWP(I)=XDMCVW2(I)
      XDFCVWP(I)=XDFCVW2(I)
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C
      XBMCVE5(I)=XBMCVE2(I)*XDRME*V38
      XBMCVW5(I)=XBMCVW2(I)*XDRMW*V38
      XBFCVW5(I)=XBFCVW2(I)*XDRFW*V38
      XBFCVE5(I)=XBFCVE2(I)*XDRFE*V38
      XDMCVE5(I)=XDMCVE2(I)*XDRME*V38
      XDMCVW5(I)=XDMCVW2(I)*XDRMW*V38
      XDFCVE5(I)=XDFCVE2(I)*XDRFE*V38
      XDFCVW5(I)=XDFCVW2(I)*XDRFE*V38
C
      TOTAL1=0.0
      TOTAL2=0.0
      TOTAL3=0.0
      TOTAL4=0.0
      DO 315 J=4,12
      TOTAL1=TOTAL1+SMCAVE(I,J)
      TOTAL2=TOTAL2+SFCAVE(I,J)
      TOTAL3=TOTAL3+SMCAVW(I,J)
      TOTAL4=TOTAL4+SFCAVW(I,J)
  315 CONTINUE
C
      TOTAL5=0.0
      TOTAL6=0.0
      DO 316 J=2,4
      TOTAL5=TOTAL5+USVKEE(I)/4+USVKSE(I)/4+USRVQE(I,J)
      TOTAL6=TOTAL6+USVKEW(I)/4+USVKSW(I)/4+USRVQW(I,J)
  316 CONTINUE
C
      XBMCVE6(I)=0.0
      XBMCVW6(I)=0.0
      XBFCVE6(I)=0.0
      XBFCVW6(I)=0.0
      XDMCVE6(I)=TOTAL1+TOTAL5*V22
      XDMCVW6(I)=TOTAL3+TOTAL6*V23
      XDFCVE6(I)=TOTAL2+TOTAL5*(1.-V22)
      XDFCVW6(I)=TOTAL4+TOTAL6*(1.-V23)
C
      TOTAL7=WCAVE2(I)*.96
      TOTAL8=WCAVW2(I)*.96
      TOTAL9=WCAVE7(I)
      TOTAL10=WCAVW7(I)
C
      XBMCVE7(I)=TOTAL9*V1*V2
      XBMCVW7(I)=TOTAL10*V1*V2
      XBFCVE7(I)=TOTAL9*V1*(1.-V2)

      XBFCVW7(I)=TOTAL10*V1*(1.-V2)
      XDMCVE7(I)=TOTAL7
      XDMCVW7(I)=TOTAL8
      XDFCVE7(I)=0.0
      XDFCVW7(I)=0.0
C
      SUBXBME=XBMCVE5(I)+XBMCVE6(I)+XBMCVE7(I)
      SUBXBMW=XBMCVW5(I)+XBMCVW6(I)+XBMCVW7(I)  +XBMCVW8(I)
      SUBXBFE=XBFCVE5(I)+XBFCVE6(I)+XBFCVE7(I)
      SUBXBFW=XBFCVW5(I)+XBFCVW6(I)+XBFCVW7(I)  +XBFCVW8(I)
      SUBXDME=XDMCVE5(I)+XDMCVE6(I)+XDMCVE7(I)
      SUBXDMW=XDMCVW5(I)+XDMCVW6(I)+XDMCVW7(I)
      SUBXDFW=XDFCVW5(I)+XDFCVW6(I)+XDFCVW7(I)
      SUBXDFE=XDFCVE5(I)+XDFCVE6(I)+XDFCVE7(I)
C
      XBMCVE9(I)=XBMCVEP(I)-SUBXBME
      XBMCVW9(I)=XBMCVWP(I)-SUBXBMW
      XBFCVE9(I)=XBFCVEP(I)-SUBXBFE
      XBFCVW9(I)=XBFCVWP(I)-SUBXBFW
      XDMCVE9(I)=XDMCVEP(I)-SUBXDME
      XDMCVW9(I)=XDMCVWP(I)-SUBXDMW
      XDFCVE9(I)=XDFCVEP(I)-SUBXDFE
      XDFCVW9(I)=XDFCVWP(I)-SUBXDFW
C
      XBMCVEM(I)=XBMCVE9(I)+SUBXBME
      XBMCVWM(I)=XBMCVW9(I)+SUBXBMW
      XBFCVEM(I)=XBFCVE9(I)+SUBXBFE
      XBFCVWM(I)=XBFCVW9(I)+SUBXBFW
      XDMCVEM(I)=XDMCVE9(I)+SUBXDME
      XDMCVWM(I)=XDMCVW9(I)+SUBXDMW
      XDFCVEM(I)=XDFCVE9(I)+SUBXDFE
      XDFCVWM(I)=XDFCVW9(I)+SUBXDFW
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C
      XXCAVE2(I)=XBMCVE2(I)+XBFCVE2(I)+XDMCVE2(I)+XDFCVE2(I)
      XXCAVE3(I)=XBMCVE3(I)+XBFCVE3(I)
      XXCAVEP(I)=XBMCVEP(I)+XBFCVEP(I)+XDMCVEP(I)+XDFCVEP(I)
      XXCAVE5(I)=XBMCVE5(I)+XBFCVE5(I)+XDMCVE5(I)+XDFCVE5(I)
      XXCAVE6(I)=XBMCVE6(I)+XBFCVE6(I)+XDMCVE6(I)+XDFCVE6(I)
      XXCAVE7(I)=XBMCVE7(I)+XBFCVE7(I)+XDMCVE7(I)+XDFCVE7(I)
      XXCAVE9(I)=XBMCVE9(I)+XBFCVE9(I)+XDMCVE9(I)+XDFCVE9(I)
      XXCAVEM(I)=XBMCVEM(I)+XBFCVEM(I)+XDMCVEM(I)+XDFCVEM(I)
C
      XXCAVW2(I)=XBMCVW2(I)+XBFCVW2(I)+XDMCVW2(I)+XDFCVW2(I)
      XXCAVWP(I)=XBMCVWP(I)+XBFCVWP(I)+XDMCVWP(I)+XDFCVWP(I)
      XXCAVW5(I)=XBMCVW5(I)+XBFCVW5(I)+XDMCVW5(I)+XDFCVW5(I)
      XXCAVW6(I)=XBMCVW6(I)+XBFCVW6(I)+XDMCVW6(I)+XDFCVW6(I)
      XXCAVW7(I)=XBMCVW7(I)+XBFCVW7(I)+XDMCVW7(I)+XDFCVW7(I)
      XXCAVW8(I)=XBMCVW8(I)+XBFCVW8(I)
      XXCAVW9(I)=XBMCVW9(I)+XBFCVW9(I)+XDMCVW9(I)+XDFCVW9(I)
      XXCAVWM(I)=XBMCVWM(I)+XBFCVWM(I)+XDMCVWM(I)+XDFCVWM(I)
C CALCULATE CALVES ON HAND MATRIX
C
      IF(SWITCH.EQ.1.) GO TO 320
      YBMCVE1(I)=XBMCVE9(I-1)
      YBMCVW1(I)=XBMCVW9(I-1)
      YBFCVE1(I)=XBFCVE9(I-1)
      YBFCVW1(I)=XBFCVW9(I-1)
      YDMCVE1(I)=XDMCVE9(I-1)
      YDMCVW1(I)=XDMCVW9(I-1)
      YDFCVE1(I)=XDFCVE9(I-1)
      YDFCVW1(I)=XDFCVW9(I-1)
      GO TO 321
C
  320 YBMCVE1(I)=0.0
      YBMCVW1(I)=0.0
      YBFCVE1(I)=0.0
      YBFCVW1(I)=0.0
      YDMCVE1(I)=0.0
      YDMCVW1(I)=0.0
      YDFCVE1(I)=0.0
      YDFCVW1(I)=0.0
      SWITCH=0.0
  321 CONTINUE
C
      TOTAL1=0.0
      TOTAL2=0.0
      DO 322 J=1,6


      TOTAL1=TOTAL1+(ZCVSTK(I,J)+ZCVFD(I,J))*V40
  322 CONTINUE
      DO 323 J=1,3
      TOTAL2=TOTAL2+ZCVSLR(I,J)*V40
  323 CONTINUE
C
      YBMCVE3(I)=TOTAL1*V32+TOTAL2*V33
      YBFCVE3(I)=TOTAL1*(1.-V32)+TOTAL2*(1.-V33)
      YBMCVW8(I)=TOTAL1*V32+TOTAL2*V33
      YBFCVW8(I)=TOTAL1*(1.-V32)+TOTAL2*(1.-V33)
      YDMCVE3(I)=0.0
      YDFCVE3(I)=0.0
      YDMCVW8(I)=0.0
      YDFCVW8(I)=0.0
C
      YBMCVEP(I)=YBMCVE1(I)+YBMCVE3(I)
      YBMCVWP(I)=YBMCVW1(I)
      YBFCVEP(I)=YBFCVE1(I)+YBFCVE3(I)
      YBFCVWP(I)=YBFCVW1(I)
      YDMCVEP(I)=YDMCVE1(I)
      YDMCVWP(I)=YDMCVW1(I)
      YDFCVEP(I)=YDFCVE1(I)
      YDFCVWP(I)=YDFCVW1(I)
C
      YBMCVE5(I)=YBMCVE1(I)*YDRME*(1.-V38)
      YBMCVW5(I)=YBMCVW1(I)*YDRMW*(1.-V38)
      YBFCVE5(I)=YBFCVE1(I)*YDRFE*(1.-V38)
      YBFCVW5(I)=YBFCVW1(I)*YDRFW*(1.-V38)
      YDMCVE5(I)=YDMCVE1(I)*YDRME*(1.-V38)
      YDMCVW5(I)=YDMCVW1(I)*YDRMW*(1.-V38)
      YDFCVW5(I)=YDFCVW1(I)*YDRFW*(1.-V38)
      YDFCVE5(I)=YDFCVE1(I)*YDRFE*(1.-V38)
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C
      TOTAL3=0.0
      TOTAL4=0.0
      TOTAL5=0.0
      TOTAL6=0.0
      DO 324 J=1,3
      TOTAL3=TOTAL3+SMCAVE(I,J)
      TOTAL4=TOTAL4+SFCAVE(I,J)
      TOTAL5=TOTAL5+SMCAVW(I,J)
      TOTAL6=TOTAL6+SFCAVW(I,J)
  324 CONTINUE
C
      TOTAL7=USVKEE(I)/4+USVKSE(I)/4+USRVOE(I,1)
      TOTAL8=USVKEW(I)/4+USVKSW(I)/4+USRVOW(I,1)
C
      YBMCVE6(I)=0.0
      YBMCVW6(I)=0.0
      YBFCVE6(I)=0.0
      YBFCVW6(I)=0.0
      YDMCVE6(I)=TOTAL3+TOTAL7*V22
      YDMCVW6(I)=TOTAL5+TOTAL8*V23
      YDFCVE6(I)=TOTAL4+TOTAL7*(1.-V22)
      YDFCVW6(I)=TOTAL6+TOTAL8*(1.-V23)
C
      TOTAL9=WCAVE2(I)*.04
      TOTAL10=WCAVW2(I)*.04
      TOTAL11=WCAVE7(I)
      TOTAL12=WCAVW7(I)
C
      YBMCVE7(I)=TOTAL11*(1.-V1)*V2
      YBMCVW7(I)=TOTAL12*(1.-V1)*V2
      YBFCVE7(I)=TOTAL11*(1.-V1)*(1.-V2)
      YBFCVW7(I)=TOTAL12*(1.-V1)*(1.-V2)
      YDMCVE7(I)=TOTAL9
      YDMCVW7(I)=TOTAL10
      YDFCVE7(I)=0.0
      YDFCVW7(I)=0.0
C
      SUBYBME=YBMCVE5(I)+YBMCVE6(I)+YBMCVE7(I)
      SUBYBMW=YBMCVW5(I)+YBMCVW6(I)+YBMCVW7(I)
      SUBYBFE=YBFCVE5(I)+YBFCVE6(I)+YBFCVE7(I)
      SUBYBFW=YBFCVW5(I)+YBFCVW6(I)+YBFCVW7(I)
      SUBYDME=YDMCVE5(I)+YDMCVE6(I)+YDMCVE7(I)
      SUBYDMW=YDMCVW5(I)+YDMCVW6(I)+YDMCVW7(I)
      SUBYDFE=YDFCVE5(I)+YDFCVE6(I)+YDFCVE7(I)
      SUBYDFW=YDFCVW5(I)+YDFCVW6(I)+YDFCVW7(I)
C
      YBMCVE8(I)=YBMCVEP(I)-SUBYBME
      YBMCVW8(I)=YBMCVWP(I)-SUBYBMW
      YBFCVE8(I)=YBFCVEP(I)-SUBYBFE
      YBFCVW8(I)=YBFCVWP(I)-SUBYBFW
      YDMCVE8(I)=YDMCVEP(I)-SUBYDME
      YDMCVW8(I)=YDMCVWP(I)-SUBYDMW
      YDFCVE8(I)=YDFCVEP(I)-SUBYDFE
      YDFCVW8(I)=YDFCVWP(I)-SUBYDFW
C
      YBMCVEM(I)=YBMCVE8(I)+SUBYBME
      YBMCVWM(I)=YBMCVW8(I)+SUBYBMW
      YBFCVEM(I)=YBFCVE8(I)+SUBYBFE
      YBFCVWM(I)=YBFCVW8(I)+SUBYBFW
      YDMCVEM(I)=YDMCVE8(I)+SUBYDME
      YDMCVWM(I)=YDMCVW8(I)+SUBYDMW
      YDFCVEM(I)=YDFCVE8(I)+SUBYDFE
      YDFCVWM(I)=YDFCVW8(I)+SUBYDFW
C
      YYCAVE1(I)=YBMCVE1(I)+YBFCVE1(I)+YDMCVE1(I)+YDFCVE1(I)
      YYCAVE3(I)=YBMCVE3(I)+YBFCVE3(I)+YDMCVE3(I)+YDFCVE3(I)
      YYCAVEP(I)=YBMCVEP(I)+YBFCVEP(I)+YDMCVEP(I)+YDFCVEP(I)
      YYCAVE5(I)=YBMCVE5(I)+YBFCVE5(I)+YDMCVE5(I)+YDFCVE5(I)
      YYCAVE6(I)=YBMCVE6(I)+YBFCVE6(I)+YDMCVE6(I)+YDFCVE6(I)
      YYCAVE7(I)=YBMCVE7(I)+YBFCVE7(I)+YDMCVE7(I)+YDFCVE7(I)
      YYCAVE8(I)=YBMCVE8(I)+YBFCVE8(I)+YDMCVE8(I)+YDFCVE8(I)
      YYCAVEM(I)=YBMCVEM(I)+YBFCVEM(I)+YDMCVEM(I)+YDFCVEM(I)
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C
      YYCAVW1(I)=YBMCVW1(I)+YBFCVW1(I)+YDMCVW1(I)+YDFCVW1(I)
      YYCAVWP(I)=YBMCVWP(I)+YBFCVWP(I)+YDMCVWP(I)+YDFCVWP(I)
      YYCAVW5(I)=YBMCVW5(I)+YBFCVW5(I)+YDMCVW5(I)+YDFCVW5(I)
      YYCAVW6(I)=YBMCVW6(I)+YBFCVW6(I)+YDMCVW6(I)+YDFCVW6(I)
      YYCAVW7(I)=YBMCVW7(I)+YBFCVW7(I)+YDMCVW7(I)+YDFCVW7(I)
      YYCAVW8(I)=YBMCVW8(I)+YBFCVW8(I)+YDMCVW8(I)+YDFCVW8(I)
      YYCAVWM(I)=YBMCVWM(I)+YBFCVWM(I)+YDMCVWM(I)+YDFCVWM(I)
C
C CALCULATE BULLS AND BULL REPLACEMENTS:
C
      BULLE1(I)=BULLE(I-1,4)
      BULLW1(I)=BULLW(I-1,4)
C
      TOTAL3=USTKEE(I)+USTKSE(I)+USRTAE(I)
      TOTAL4=USTKEW(I)+USTKSW(I)+USRTAW(I)
C
      TOTAL5=VPBRDE(I)
      TOTAL6=VPBRDW(I)
C
      BULLE4(I)=TOTAL5*(1.-V5)
      BULLW4(I)=TOTAL6*(1.-V6)
      BULLE5(I)=((BULLE(I-1,4)+BULLE(I,2))/2)*DRE
      BULLW5(I)=((BULLW(I-1,4)+BULLW(I,2))/2)*DRW
C
      TOTAL7=WPBRDE(I)
      TOTAL8=WPBRDW(I)
C
      BULLE7(I)=TOTAL7*(1.-V3)
      BULLW7(I)=TOTAL8*(1.-V4)
C
      TOTAL9=0.0
      TOTAL10=0.0
      DO 325 J=1,12
      TOTAL9=TOTAL9+SBULLE(I,J)
      TOTAL10=TOTAL10+SBULLW(I,J)
  325 CONTINUE
C
      BULLE6(I)=TOTAL9+TOTAL3*V28
      BULLW6(I)=TOTAL10+TOTAL4*V29
C
      BULLE9(I)=BULLE(I,4)
      BULLW9(I)=BULLW(I,4)
      BULLEM(I)=BULLE5(I)+BULLE6(I)+BULLE7(I)+BULLE9(I)
      BULLWM(I)=BULLW5(I)+BULLW6(I)+BULLW7(I)+BULLW9(I)
      BULLE3(I)=BULLEM(I)-BULLE1(I)-BULLE4(I)
      BULLW3(I)=BULLWM(I)-BULLW1(I)-BULLW4(I)

      BULLEP(I)=BULLE1(I)+BULLE3(I)+BULLE4(I)
      BULLWP(I)=BULLW1(I)+BULLW3(I)+BULLW4(I)
C
C CALCULATE COWS AND REPLACEMENTS


C
      DCOWE1(I)=DCOWE(I-1,4)
      DCOWW1(I)=DCOWW(I-1,4)
      BCOWE1(I)=BCOWE(I-1,4)
      BCOWW1(I)=BCOWW(I-1,4)
C
      DCOWE4(I)=TOTAL5*V5*V9
      DCOWW4(I)=TOTAL6*V6*V10
      BCOWE4(I)=TOTAL5*V5*(1.-V9)
      BCOWW4(I)=TOTAL6*V6*(1.-V10)
C
      DCOWE5(I)=(DCOWE(I-1,4)+DCOWE(I,2))/2*DRE
      DCOWW5(I)=(DCOWW(I-1,4)+DCOWW(I,2))/2*DRW
      BCOWE5(I)=BCOWE(I-1,4)*DRE
      BCOWW5(I)=BCOWW(I-1,4)*DRW
C
      TOTAL9=0.0
      TOTAL10=0.0
      DO 330 J=1,12
      TOTAL9=TOTAL9+SCOWE(I,J)
      TOTAL10=TOTAL10+SCOWW(I,J)
  330 CONTINUE
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C
      DCOWW6(I)=(DCOWW(I-1,4)+DCOWW(I,2))/2*V21
      BCOWE6(I)=BCOWE(I-1,4)*V20
      DCOWE6(I)=(TOTAL9+TOTAL3*V26)-BCOWE6(I)
      BCOWW6(I)=(TOTAL10+TOTAL4*V27)-DCOWW6(I)
C
      TOTALBE=WCATE9(I)
      TOTALBW=WCATW9(I)
      IF(TOTALBE.LE.3000) TOTALCE=TOTALBE*V15
      IF(TOTALBW.LE.8000) TOTALCW=TOTALBE*V15
      IF(TOTALBE.GT.3000) TOTALCE=2400+(TOTALBE-2400)*V16
      IF(TOTALBW.GT.3000) TOTALCW=6400+(TOTALBW-6400)*V17
C
      RATIO5=DCOWE(I,2)/(DCOWE(I,2)+BCOWE(I,2))
      RATIO6=DCOWW(I,2)/(DCOWW(I,2)+BCOWW(I,2))
C
      DCOWE7(I)= TOTAL7*V3*V7+TOTALCE*RATIO5*WODRYE(I)
      DCOWW7(I)= TOTAL8*V4*V7+TOTALCW*RATIO6*WODRYW(I)
      BCOWE7(I)= TOTAL7*V3*(1.-V7)+TOTALCE*(1.-RATIO5)
      BCOWW7(I)= TOTAL8*V4*(1.-V8)+TOTALCW*(1.-RATIO6)
C
      DCOWE9(I)=DCOWE(I,4)
      DCOWW9(I)=DCOWW(I,4)
      BCOWE9(I)=BCOWE(I,4)
      BCOWW9(I)=BCOWW(I,4)
C
      DCOWEM(I)=DCOWE5(I)+DCOWE6(I)+DCOWE7(I)+DCOWE9(I)
      DCOWWM(I)=DCOWW5(I)+DCOWW6(I)+DCOWW7(I)+DCOWW9(I)
      BCOWEM(I)=BCOWE5(I)+BCOWE6(I)+BCOWE7(I)+BCOWE9(I)
      BCOWWM(I)=BCOWW5(I)+BCOWW6(I)+BCOWW7(I)+BCOWW9(I)
C
      DCOWE3(I)=DCOWEM(I)-DCOWE1(I)-DCOWE4(I)
      DCOWW3(I)=DCOWWM(I)-DCOWW1(I)-DCOWW4(I)

      BCOWE3(I)=BCOWEM(I)-BCOWE1(I)-BCOWE4(I)
      BCOWW3(I)=BCOWWM(I)-BCOWW1(I)-BCOWW4(I)
C
      DCOWEP(I)=DCOWE1(I)+DCOWE3(I)+DCOWE4(I)
      DCOWWP(I)=DCOWW1(I)+DCOWW3(I)+DCOWW4(I)
      BCOWEP(I)=BCOWE1(I)+BCOWE3(I)+BCOWE4(I)
      BCOWWP(I)=BCOWW1(I)+BCOWW3(I)+BCOWW4(I)
C
C CALCULATE DAIRY HEIFER AND DAIRY HEIFER SLAUGHTER
C
      DHFPE1(I)=DHFRE(I-1,4)
      DHFPW1(I)=DHFRW(I-1,4)
      DHFPE3(I)=YDFCVE8(I)
      DHFPW3(I)=YDFCVW8(I)
      DHFPEP(I)=DHFRE1(I)+DHFRE3(I)
      DHFPWP(I)=DHFRW1(I)+DHFRW3(I)
C
      DHFPE5(I)=((DHFRE(I-1,4)+DHFRE(I,2))/2)*DRE
      DHFPW5(I)=((DHFRW(I-1,4)+DHFRW(I,2))/2)*DRW
      DHFPE8(I)=DCOWE3(I)
      DHFPW8(I)=DCOWW3(I)
      DHFPE9(I)=DHFRE(I,4)
      DHFPW9(I)=DHFRW(I,4)
C
      DHFPE6(I)=DHFREP(I)-DHFRE5(I)-DHFRE8(I)-DHFRE9(I)
      DHFPW6(I)=DHFRWP(I)-DHFRW5(I)-DHFRW8(I)-DHFRW9(I)
      DHFPEM(I)=DHFRE5(I)+DHFRE6(I)+DHFRE8(I)+DHFRE9(I)
      DHFPWM(I)=DHFRW5(I)+DHFRW6(I)+DHFRW8(I)+DHFRW9(I)
C
C CALCULATE BEEF HEIFERS AND BEEF HEIFER SLAUGHTER
C
      BHFPFE1(I)=BHFRE(I-1,4)
      BHFPFW1(I)=BHFRW(I-1,4)
C
      BHFPRE6(I)=0.0
      BHFPRW6(I)=0.0
      BHFPRE8(I)=BCOWE3(I)
      BHFPRW8(I)=BCOWW3(I)
C
      TOTAL9=0.0
      TOTAL10=0.0
      DO 335 J=1,12
      TOTAL9=TOTAL9+SHFRE(I,J)
      TOTAL10=TOTAL10+SHFRW(I,J)
  335 CONTINUE
```

```
C
      TOTAL11=0.0
      TOTAL12=0.0
      DO 337 J=1,12
      TOTAL11=TOTAL11+SSTPE(I,J)
      TOTAL12=TOTAL12+SSTRW(I,J)
  337 CONTINUE
C
      BHFPFE6(I)=TOTAL9+TOTAL3*(1.-V26-V28)*(1.-V24)  -DHFRE6(I)
      BHFRFW6(I)=TCTAL10+TOTAL4*(1.-V27-V29)*(1.-V25)  -DHFRW6(I)
      BHFPFE4(I)=VCTHRE(I)*(1.-V12)
      BHFRFW4(I)=VOTHRW(I)*(1.-V12)
      BHFPFE7(I)=(TOTALBE-TOTALCE)*(1.-V14)
      BHFRFW7(I)=(TOTALBW-TOTALCW)*(1.-V14)
C
      BHFPRE3(I)=BHFRPE8(I)*(1.+DRE)
      BHFFRW3(I)=BHFRRW8(I)*(1.+DRW)
      BHFPRE5(I)=BHFRRE3(I)-BHFRRE8(I)
      BHFPRW5(I)=BHFRRW3(I)-BHFRRW8(I)
C
      TOTAL9=0.0
      TOTAL10=0.0
      DO 336 J=1,12
      TOTAL9=TOTAL9+ZCTSLR(I,J)*V40
      TOTAL10=TOTAL10+(ZCTSTK(I,J)+ZCTFD(I,J))*V40
  336 CONTINUE
C
      BHFPFE3(I)=YBFCVE8(I)-BHFRRE3(I)+TOTAL9*(1.-V35)+TOTAL10*(1.-V34)
      BHFPFW3(I)=YBFCVW8(I)-BHFRRW3(I)
      BHFPFEP(I)=BHFRFE1(I)+BHFRFE3(I)+BHFRFE4(I)
      BHFFFWP(I)=BHFRFW1(I)+BHFRFW3(I)+BHFRFW4(I)
C
      BHFPFW8(I)=TCTAL9*(1.-V35)+TOTAL10*(1.-V34)
      BHFFREP(I)=BHFRPE3(I)
      BHFFRWP(I)=BHFRRW3(I)
      BHFFFE5(I)=((BHFRE(I-1,4)+BHFRE(I,2))/2)*DRE
      BHFPFW5(I)=((BHFRW(I-1,4)+BHFRW(I,2))/2)*DRW
      BHFPFE9(I)=BHFRE(I,4)
      BHFPFW9(I)=BHFRW(I,4)
C
      BHFPREM(I)=BHFRRE5(I)+BHFRRE8(I)
      BHFRRWM(I)=BHFRPW5(I)+BHFRRW8(I)
      BHFPFEM(I)=BHFRFE5(I)+BHFRFE6(I)+BHFRFE7(I)+BHFRFE9(I)
      BHFFFWM(I)=BHFRFW5(I)+BHFRFW6(I)+BHFRFW7(I)+BHFRFW9(I)+BHFRFW8(I)
C
C CALCULATE STEERS AND STEER SLAUGHTER
C
      STRSE1(I)=STRSE(I-1,4)
      STRSW1(I)=STRSW(I-1,4)
      STRSE9(I)=STRSE(I,4)
      STRSW9(I)=STRSW(I,4)
C
      STRSE3(I)=YDHCVE8(I)+YBMCVE8(I)-BULLE3(I)+TOTAL9*V35+TOTAL10*V34
      STRSW3(I)=YDHCVW8(I)+YBMCVW8(I)-BULLW3(I)
      STRSE4(I)=VOTHRE(I)*V12
      STRSW4(I)=VOTHRW(I)*V12


C
      STRSEP(I)=STRSE1(I)+STRSE3(I)+STRSE4(I)
      STRSWP(I)=STRSW1(I)+STRSW3(I)+STRSW4(I)
      STRSE5(I)=(STPSE(I-1,4)+STRSE(I,2))/2*DRE
      STRSW5(I)=(STRSW(I-1,4)+STRSW(I,2))/2*DRW
C
      STRSE6(I)=TOTAL11+TOTAL3*(1.-V26-V28)*V24
      STRSW6(I)=TOTAL12+TOTAL4*(1.-V27-V29)*V25
      STRSE7(I)=(TCTALBE-TOTALCE)*V14
      STRSW7(I)=(TOTALBW-TOTALCW)*V14
      STRSW8(I)=TOTAL9*V35+TOTAL10*V34
      STRSEM(I)=STRSE5(I)+STRSE6(I)+STRSE7(I)+STRSE9(I)
      STRSWM(I)=STRSW5(I)+STRSW6(I)+STRSW7(I)+STRSW9(I)+STRSW8(I)
C
C SUM COWS,BULLS,HEIFERS AND STEERS
C
      BEGINVE(I)=BULLE1(I)+DCOWE1(I)+DHFRE1(I)+BCOWE1(I)+BHFRFE1(I)+
```

```
-
      1STRSE1(I)
       TRANINE(I)=BULLE3(I)+DCOWE3(I)+DHFRE3(I)+BCOWE3(I)+BHFRRE3(I)+
      1BHFRFE3(I)+STRSE3(I)
       TIMPTE(I)=BULLE4(I)+DCOWE4(I)+BCOWE4(I)+BHFRFE4(I)+STRSE4(I)
       SOURCE(I)=BULLEP(I)+DCOWEP(I)+DHFREP(I)+BCOWEP(I)+BHFRREP(I)+
      1BHFRFEP(I)+STRSEP(I)
C
       TDIFDE(I)=BULLE5(I)+DCOWE5(I)+DHFRE5(I)+BCOWE5(I)+BHFRRE5(I)+
      1BHFRFE5(I)+STRSE5(I)
       TSLPE(I)=BULLE6(I)+DCOWE6(I)+DHFRE6(I)+BCOWE6(I)+BHFRFE6(I)+
      1STRSE6(I)
       TEXPTE(I)=BULLE7(I)+DCOWE7(I)+BCOWE7(I)+BHFRFE7(I)+STRSE7(I)
       TRNOUTE(I)=DHFRE8(I)+BHFRRE8(I)
       ENDINVE(I)=BULLE9(I)+DCOWE9(I)+DHFRE9(I)+BCOWE9(I)+BHFRFE9(I)+
      1STRSE9(I)
       TDSPNE(I)=BULLEM(I)+DCOWEM(I)+DHFREM(I)+BCOWEM(I)+BHFRREM(I)+
      1BHFRFEM(I)+STRSEM(I)

       BEGINVW(I)=BULLW1(I)+DCOWW1(I)+DHFRW1(I)+BCOWW1(I)+BHFRFW1(I)+
      1STRSW1(I)
       TRANINW(I)=BULLW3(I)+DCOWW3(I)+DHFRW3(I)+BCOWW3(I)+BHFRRW3(I)+
      1BHFRFW3(I)+STRSW3(I)
       TIMPTW(I)=BULLW4(I)+DCOWW4(I)+BCOWW4(I)+BHFRFW4(I)+STRSW4(I)
       SOURCW(I)=BULLWP(I)+DCOWWP(I)+DHFRWP(I)+BCOWWP(I)+BHFRRWP(I)+
      1BHFRFWP(I)+STRSWP(I)
C
       TDIFDW(I)=BULLW5(I)+DCOWW5(I)+DHFRW5(I)+BCOWW5(I)+BHFRRW5(I)+
      1BHFRFW5(I)+STRSW5(I)
       TSLPW(I)=BULLW6(I)+DCOWW6(I)+DHFRW6(I)+BCOWW6(I)+BHFRFW6(I)+
      1STRSW6(I)
       TEXPTW(I)=BULLW7(I)+DCOWW7(I)+BCOWW7(I)+BHFRFW7(I)+STRSW7(I)
       TRNOUTW(I)=DHFRW8(I)+BHFRRW8(I)
       ENDINVW(I)=BULLW9(I)+DCOWW9(I)+DHFRW9(I)+BCOWW9(I)+BHFRFW9(I)+
      1STRSW9(I)
       TDSPNW(I)=BULLWM(I)+DCOWWM(I)+DHFRWM(I)+BCOWWM(I)+BHFRRWM(I)+
      1BHFRFWM(I)+STRSWM(I)
C
C
  310 CONTINUE
C
C PRINT THE LIVESTOCK RECONCILIATION MATRIX,WEST
C
       DO 338 I=12,26
C
       J=1946+I
       PRINT 370,J
  370 FORMAT(*1*,*LIVESTOCK POPULATION-STOCK AND FLOW-RECONCILIATION MAT
      1RIX FOR THE YEAR *,I6,2X,*WEST*)
C
       PRINT 371
  371 FORMAT(*-*,17X,*BEGINING*,6X,*BORN*,2X,*TRANSFER*,4X,*IMPORT*,5X,*
      1TOTAL*,5X,*DIED*,2X,*SLAUGHTER*,4X,*EXPORT*,2X,*TRANSFER*,4X,*ENDI
      2NG*,5X,*TOTAL*,/,17X,*INVENTORY*,18X,*IN*,13X,*SOURCES*,37X,*OUT*,
      33X,*INVENTORY*,2X,*DPSITION*,4X,*ERROR*)
C
       PRINT 372,BULLW1(I),BULLW3(I),BULLW4(I),BULLWP(I),BULLW5(I),BULLW6
      1(I),BULLW7(I),BULLW9(I),BULLWM(I)
  372 FORMAT(*-*,*BULLS*,10X,F10.0,10X,6F10.0,10X,2F10.0)
C
       PRINT 373,DCOWW1(I),DCOWW3(I),DCOWW4(I),DCOWWP(I),DCOWW5(I),DCOWW6
      1(I),DCOWW7(I),DCOWW9(I),DCOWWM(I)

  373 FORMAT(*0*,*DAIRY COWS*,5X,F10.0,10X,6F10.0,10X,2F10.0)
C
       PRINT 374,DHFRW1(I),DHFRW3(I),DHFRWP(I),DHFRW5(I),DHFRW6(I),DHFRW8
      1(I),DHFRW9(I),DHFRWM(I)
  374 FORMAT(*0*,*DAIRY HEIFERS*,2X,F10.0,10X,F10.0,10X,3F10.0,10X,3F10.
      10)
C
       PRINT 375,BCOWW1(I),BCOWW3(I),BCOWW4(I),BCOWWP(I),BCOWW5(I),BCOWW6
      1(I),BCOWW7(I),BCOWW9(I),BCOWWM(I)
  375 FORMAT(*0*,*BEEF COWS*,6X,F10.0,10X,6F10.0,10X,2F10.0)
C
       PRINT 376,BHFRRW3(I),BHFRRWP(I),BHFRRW5(I),BHFRRW6(I),BHFRRW8(I),
      1BHFRRWM(I)
  376 FORMAT(*0*,*BF HFR REPLACE*,21X,F10.0,10X,3F10.0,10X,F10.0,10X,
      1F10.0)
```

```
C
      A=BHFRFWP(I)-BHFRFWM(I)
      B=STRSWP(I)-STRSWM(I)
      C=SOURCW(I)-TDSPNW(I)
      D=XXCAVW9(I)-CALVW(I,4)
      E=XXCAVW2(I)-TBIRTHW(I)
C
      PRINT 377,BHFRFW1(I),BHFRFW3(I),BHFRFW4(I),BHFRFWP(I),BHFRFW5(I),
     1BHFRFW6(I),BHFRFW7(I),BHFRFW9(I),BHFRFWM(I),A
  377 FORMAT(*0*,*BF HFR FEEDING*,1X,F10.0,10X,6F10.0,10X,3F10.0)
C
      PRINT 378,STRSW1(I),STRSW3(I),STRSW4(I),STRSWP(I),STRSW5(I),STRSW6
     1(I),STRSW7(I),STRSW9(I),STRSWM(I),B
  378 FORMAT(*0*,*STEERS*,9X,F10.0,10X,6F10.0,10X,3F10.0)
C
      PRINT 379,BEGINVW(I),TRANINW(I),TIMPTW(I),SOURCW(I),TDIEDW(I),
     1TSLRW(I),TEXPTW(I),TRNOUTW(I),ENDINVW(I),TDSPNW(I),C
  379 FORMAT(*0*,3X,*TOTAL CATTLE*,F10.0,10X,10F10.0)
C
      PRINT 380,XBMCVW2(I),             XBMCVWP(I),XBMCVW5(I),XBMCVW6(I),
     1XBMCVW7(I),XBMCVW8(I),XBMCVW9(I),XBMCVWM(I),BB(I)
  380 FORMAT(*-*,*ML BF CALVES*,13X, F10.0,20X,8F10.0)
C
      PRINT 381,XBFCVW2(I),             XBFCVWP(I),XBFCVW5(I),XBFCVW6(I),
     1XBFCVW7(I),XBFCVW8(I),XBFCVW9(I),XBFCVWM(I),DD(I)
  381 FORMAT(*0*,*FM BF CALVES*,13X, F10.0,20X,8F10.0)
C
      PRINT 382,XDMCVW2(I),XDMCVWP(I),XDMCVW5(I),XDMCVW6(I),XDMCVW7(I),
     1XDMCVW9(I),XDMCVWM(I)
  382 FORMAT(*0*,*ML DY CALVES*,13X,F10.0,20X,4F10.0,10X,2F10.0)
C
      PRINT 383,XDFCVW2(I),XDFCVWP(I),XDFCVW5(I),XDFCVW6(I),XDFCVW7(I),
     1XDFCVW9(I),XDMCVWM(I),E
  383 FORMAT(*0*,*FM DY CALVES*,13X,F10.0,20X,4F10.0,10X,3F10.0)
C
      PRINT 384,XXCAVW2(I),XXCAVWP(I),XXCAVW5(I),XXCAVW6(I),XXCAVW7(I),
     1XXCAVW8(I),XXCAVW9(I),XXCAVWM(I),D
  384 FORMAT(*0*,4X,*SUBTOTAL*,13X,F10.0,20X,8F10.0)
C
      PRINT 385,YBMCVW1(I),             YBMCVWP(I),YBMCVW5(I),
     1YBMCVW7(I),YBMCVW8(I),YBMCVWM(I)
  385 FORMAT(*-*,*ML BF CALVES*,3X,F10.0,30X,2F10.0,10X,2F10.0,10X,F10.)
C
      PRINT 386,YBFCVW1(I),             YBFCVWP(I),YBFCVW5(I),

     1YBFCVW7(I),YBFCVW8(I),YBFCVWM(I)
  386 FORMAT(*0*,*FM BF CALVES*,3X,F10.0,30X,2F10.0,10X,2F10.0,10X,F10.)
C
      PRINT 387,YDMCVW1(I),YDMCVWP(I),YDMCVW5(I),YDMCVW6(I),YDMCVW7(I),
     1YDMCVW8(I),YDMCVWM(I)
  387 FORMAT(*0*,*ML DY CALVES*,3X,F10.0,30X,5F10.0,10X,F10.0)
C
      PRINT 388,YDFCVW1(I),YDFCVWP(I),YDFCVW5(I),YDFCVW6(I),YDFCVW7(I),
     1YDFCVW8(I),YDFCVWM(I)
  388 FORMAT(*0*,*FM DY CALVES*,3X,F10.0,30X,5F10.0,10X, F10.0)
C
      PRINT 389,YYCAVW1(I),             YYCAVWP(I),YYCAVW5(I),YYCAVW6(I),
     1YYCAVW7(I),YYCAVW8(I),YYCAVWM(I)
  389 FORMAT(*0*,4X,*SUBTOTAL*,3X,F10.0,30X,5F10.0,10X,F10.0)
C
      TOTALP=XXCAVWP(I)+YYCAVWP(I)
      TOTAL5=XXCAVW5(I)+YYCAVW5(I)
      TOTAL6=XXCAVW6(I)+YYCAVW6(I)
      TOTAL7=XXCAVW7(I)+YYCAVW7(I)


      TOTALM=XXCAVWM(I)+YYCAVWM(I)
C
      PRINT 390,YYCAVW1(I),XXCAVW2(I),        TOTALP,TOTAL5,TOTAL6,TOTAL7
     1,YYCAVW8(I),XXCAVW9(I),TOTALM
  390 FORMAT(*-*,3X,*TOTAL CALVES*,2F10.0,20X,7F10.0)
  330 CONTINUE
```

```
C
C PRINT THE LIVESTOCK RECONCILIATION MATRIX,EAST
C
      DO 339 I=12,26
      J=1946+I
      PRINT 340,J
  340 FORMAT(*1*,*LIVESTOCK POPULATION-STOCK AND FLOW-RECONCILIATION MAT
     1RIX FOR THE YEAR *,I6,2X,*EAST*)
C
      PRINT 341
  341 FORMAT(*-*,17X,*BEGINING*,6X,*BORN*,2X,*TRANSFER*,4X,*IMPORT*,5X,*
     1TOTAL*,5X,*DIED*,2X,*SLAUGHTER*,4X,*EXPORT*,2X,*TRANSFER*,4X,*ENDI
     2NG*,5X,*TOTAL*,/,17X,*INVENTORY*,18X,*IN*,13X,*SOURCES*,37X,*OUT*,
     33X,*INVENTORY*,2X,*DPSITION*,4X,*ERROR*)
C
      PRINT 342,BULLE1(I),BULLE3(I),BULLE4(I),BULLEP(I),BULLE5(I),BULLE6
     1(I),BULLE7(I),BULLE9(I),BULLEM(I)
  342 FORMAT(*-*,*BULLS*,10X,F10.0,10X,6F10.0,10X,2F10.0)
C
      PRINT 343,DCOWE1(I),DCOWE3(I),DCOWE4(I),DCOWEP(I),DCOWE5(I),DCOWE6
     1(I),DCOWE7(I),DCOWE9(I),DCOWEM(I)
  343 FORMAT(*0*,*DAIRY COWS*,5X,F10.0,10X,6F10.0,10X,2F10.0)
C
      PRINT 344,DHFRE1(I),DHFRE3(I),DHFREP(I),DHFRE5(I),DHFRE6(I),DHFRE8
     1(I),DHFRE9(I),DHFREM(I)
  344 FORMAT(*0*,*DAIRY HEIFERS*,2X,F10.0,10X,F10.0,10X,3F10.0,10X,3F10.
     10)
C
      PRINT 345,BCOWE1(I),BCOWE3(I),BCOWE4(I),BCOWEP(I),BCOWE5(I),BCOWE6
     1(I),BCOWE7(I),BCOWE9(I),BCOWEM(I)
  345 FORMAT(*0*,*BEEF COWS*,6X,F10.0,10X,6F10.0,10X,2F10.0)
C
      PRINT 346,BHFRRE3(I),BHFRREP(I),BHFRRE5(I),BHFRRE6(I),BHFRRE8(I),
     1BHFRREM(I)

  346 FORMAT(*0*,*BF HFR REPLACE*,21X,F10.0,10X,3F10.0,10X,F10.0,10X,
     1F10.0)
C
      A=BHFRFEP(I)-BHFRFEM(I)
      B=STRSEP(I)-STRSEM(I)
      C=SOURCE(I)-TDSPNE(I)
      D=XXCAVE9(I)-CALVE(I,4)
      E=XXCAVE2(I)-TBIRTHE(I)
C
      PRINT 347,BHFRFE1(I),BHFRFE3(I),BHFRFE4(I),BHFRFEP(I),BHFRFE5(I),
     1BHFRFE6(I),BHFRFE7(I),BHFRFE9(I),BHFRFEM(I),A
  347 FORMAT(*0*,*BF HFR FEEDING*,1X,F10.0,10X,6F10.0,10X,3F10.0)
C
      PRINT 348,STRSE1(I),STRSE3(I),STRSE4(I),STRSEP(I),STRSE5(I),STRSE6
     1(I),STRSE7(I),STRSE9(I),STRSEM(I),B
  348 FORMAT(*0*,*STEERS*,9X,F10.0,10X,6F10.0,10X,3F10.0)
C
      PRINT 349,BEGINVE(I),TRANINE(I),TIMPTE(I),SOURCE(I),TDIEDE(I),
     1TSLFE(I),TEXPTE(I),TRNOUTF(I),ENDINVE(I),TDSPNE(I),C
  349 FORMAT(*0*,3X,*TOTAL CATTLE*,F10.0,10X,10F10.0)
C
      PRINT 350,XBMCVE2(I),XBMCVE3(I),XBMCVEP(I),XBMCVE5(I),XBMCVE6(I),
     1XBMCVE7(I),XBMCVE9(I),XBMCVEM(I),AA(I)
  350 FORMAT(*-*,*ML BF CALVES*,13X,2F10.0,10X,4F10.0,10X,3F10.0)
C
      PRINT 351,XBFCVE2(I),XBFCVE3(I),XBFCVEP(I),XBFCVE5(I),XBFCVE6(I),
     1XBFCVE7(I),XBFCVE9(I),XBFCVEM(I),CC(I)
  351 FORMAT(*0*,*FM BF CALVES*,13X,2F10.0,10X,4F10.0,10X,3F10.0)
C
      PRINT 352,XDMCVE2(I),XDMCVEP(I),XDMCVE5(I),XDMCVE6(I),XDMCVE7(I),
     1XDMCVE9(I),XDMCVEM(I)
  352 FORMAT(*0*,*ML DY CALVES*,13X,F10.0,20X,4F10.0,10X,2F10.0)
C
      PRINT 353,XDFCVE2(I),XDFCVEP(I),XDFCVE5(I),XDFCVE6(I),XDFCVE7(I),
     1XDFCVE9(I),XDMCVEM(I),E
  353 FORMAT(*0*,*ML DY CALVES*,13X,F10.0,20X,4F10.0,10X,3F10.0)
C
      PRINT 354,XXCAVE2(I),XXCAVE3(I),XXCAVEP(I),XXCAVE5(I),XXCAVE6(I),
```

```
      1XXCAVE7(I),XXCAVE9(I),XXCAVEM(I),D
  354 FORMAT(*0*,4X,*SUBTOTAL*,13X,2F10.0.10X,4F10.0,10X,3F10.0)
C
       PRINT 355,YBMCVE1(I),YBMCVE3(I),YBMCVEP(I),YBMCVE5(I),YBMCVE6(I),
      1YBMCVE7(I),YBMCVE8(I),YBMCVEM(I)
  355 FORMAT(*-*,*ML BF CALVES*,3X,F10.0,10X,F10,0,10X,5F10.0,10X,F10.0)
C
       PRINT 356,YBFCVE1(I),YBFCVE3(I),YBFCVEP(I),YBFCVE5(I),YBFCVE6(I),
      1YBFCVE7(I),YBFCVE8(I),YBFCVEM(I)
  356 FORMAT(*0*,*FM BF CALVES*,3X,F10.0,10X,F10,0,10X,5F10.0,10X,F10.0)
      1,10X,F10.0)
C
       PRINT 357,YDMCVE1(I),YDMCVEP(I),YDMCVE5(I),YDMCVE6(I),YDMCVE7(I),
      1YDMCVE8(I),YDMCVEM(I)
  357 FORMAT(*0*,*ML DY CALVES*,3X,F10;0,30X,5F10.0,10X,F10,0)
C
       PRINT 358,YDFCVE1(I),YDFCVEP(I),YDFCVE5(I),YDFCVE6(I),YDFCVE7(I),
      1YDFCVE8(I),YDFCVEM(I)
  358 FORMAT(*0*,*FM DY CALVES*,3X,F10,0,30X,5F10.0,10X, F10.0)
C
       PRINT 359,YYCAVE1(I),YYCAVE3(I),YYCAVEP(I),YYCAVE5(I),YYCAVE6(I),
      1YYCAVE7(I),YYCAVE8(I),YYCAVEM(I)
  359 FORMAT(*0*,4X,*SUBTOTAL*,3X,F10.0,10X,F10.0,10X,5F10.0.10X,F10.0)
C
       TOTAL3=XXCAVE3(I)+YYCAVE3(I)
       TOTALP=XXCAVEP(I)+YYCAVEP(I)
       TOTAL5=XXCAVE5(I)+YYCAVE5(I)
       TOTAL6=XXCAVE6(I)+YYCAVE6(I)
       TOTAL7=XXCAVE7(I)+YYCAVE7(I)
       TOTALM=XXCAVEM(I)+YYCAVEM(I)
C
       PRINT 360,YYCAVE1(I),XXCAVE2(I),TOTAL3,TOTALP,TOTAL5,TOTAL6,TOTAL7
      1,YYCAVE8(I),XXCAVE9(I),TOTALM
  360 FORMAT(*-*,3X,*TOTAL CALVES*,3F10.0,10X,7F10,0)
  339 CONTINUE
       END
```

APPENDIX E

PROGRAM CATSIM2 WEST

Appendix E provides a listing of program CATSIM2 West. While there are five other versions of CATSIM, they are basically similar; CATSIM and its variants are described in Chapter V.

The dimension statements for all subscripted variables and the read statements for the published statistical data base are the first statements encountered in the model.[1] The statements that read the revised program MATRIX output are next encountered.[2] The variable names for these data are listed immediately below.

RDCWSLE, RDCWSLW	SLAUGHTER, Dairy Cows, East, West
RBCWSLE, RBCWSLW	SLAUGHTER, Beef Cows, East, West
RDHFRRE, RDHFRRW	REPLACEMENTS, Dairy Heifers, East, West
RBHFRRE, RBHFRRW	REPLACEMENTS, Beef Heifers, East, West
RCSLRME, RCLSRMW	SLAUGHTER, Male Calves, East, West
RCSLRFE, RCSLRFW	SLAUGHTER, Female Calves, East, West
RBLSLRE, RBLSLRW	SLAUGHTER, Bulls, East, West
RBLRPLE, RBLRPLW	REPLACEMENT, Bulls, East, West.

---

[1]The core storage required to compile and execute CATSIM in its present form is about 130 K. A minor rewrite is planned to combine CATSIM1, CATSIM2, and CATSIM3 while concurrently reducing the core storage requirement to 65 K.

[2]These identical statements read the output of the behavioral models in CATSIM3. In fact, the only difference between CATSIM2 and CATSIM3 is the data read by these statements.

Statements 245 to 329 describe and initialize the parameters for CATSIM. The initialization of a wide set of distributions occupy statements 330 to 480; all of these are described in Chapter V, if only in a generic fashion.

The next major part of the program initializes beginning values including the intermediate values in the delay subroutines. This part of the program was difficult to program and would be equally difficult to describe. The tact ultimately taken was to attempt to simulate approximate beginning values then operate the model for several cycles; the values generated by the model tend to converge on correct values in most instances. The main problem involves initializing intermediate values for the continuous (distributed) delays.

The main element of the program is the execution phase. This phase is described in terms of exact block diagrams (Figures 18 to 26) in Chapter V. CATSIM employs several subroutines; these are described in Appendix B.

The output of CATSIM2 West is the disaggregate Population and Steer and Heifer SLAUGHTER data listed in Appendices F and G, respectively. These output variables are listed below for the Western Dairy Herd.

PCMDW1, PCFDW1	Population Calves, one to three months, Male, Female
PCMDW2, PCFDW2	Population Calves, four to six months, Male, Female
PCMDW3, PCFDW3	Population Calves, seven to twelve months, Stream A, Male, Female
PCMDW4, PCFDW4	Population Cattle, seven months onward, Stream B, Male, Female

PCMDW5, PCFDW5	Population Cattle, twelve months onward, Stream A, Male, Female
PHFRDW	Population Replacement Heifers, one to two years
PCOWDW	Population Cows over two years
PBULL	Population Bulls (Dairy plus Beef)
SLRMDW	SLAUGHTER, Steers
SLRFDW	SLAUGHTER, Heifers.

A similar set of variables is used to describe the Western Beef Herd except that the letter B replaces the D in the variable name.

A third set of variables sums the above two sets and disaggregates the published statistical data series in order to make a comparison of the simulated (albeit reaggregated) with the published data. These may be determined from the logic of the program so will not be listed here.

```
      PROGRAM CATSIM2(INPUT,OUTPUT,TAPE1)
C
      REAL INGRAT,NETWHC,NETWBL,NETWDC
      REAL JCMBW5,JCFBW5,KCMBW4,KCFBW4,LCMBW4,LCFBW4
      REAL JCMDW5,JCFDW5,KCMDW4,KCFDW4,LCMDW4,LCFDW4
C
C DIMENSION THE MATRIX OF INTERMEDIATE AND OUTPUT VARIABLE VALUES
C
      COMMON     TNMBW1(1),TNFBW1(1),TNWBC(3),TNMBW2(1),TNFBW2(1),TNMBW
     13(2),TNFBW3(2),CTMBW4(10),CTFBW4(10),CTMBW5(10),CTFBW5(10),
     2 TNWBHR(4),CYMBCW(4),CYFBCW(4),CYCTFW(4),CYCTBW(4),VALBW(13),
     3CTRWBH(10),Q1(4),Q2(4),Q3(4),Q4(4),Q5(4),Q6(4),Q7(4)
C
      COMMON     TNMDW1(1),TNFDW1(1),TNWDC(3),TNMDW2(1),TNFDW2(1),TNMDW
     13(2),TNFDW3(2),CTMDW4(10),CTFDW4(10),CTMDW5(10),CTFDW5(10),TNWDHR
     2(4),CYMDCW(4),CYFDCW(4),CYCTDW(4),VALDW(13),ABRWDC(50),ABRWDH(50),
     3CTRWDH(10),ADDDCW(4),ADDBCW(4),ADDBLW(4)
C
      COMMON PCMBW1(26,4),PCMDW1(26,4),PCFBW1(26,4),PCFDW1(26,4),PCMBW2
     1(26,4),PCMDW2(26,4),PCFBW2(26,4),PCFDW2(26,4),PCMBW3(26,4),PCMDW3
     2(26,4),PCFBW3(26,4),PCFDW3(26,4),PCMBW4(26,4),PCMDW4(26,4),PCFBW4
     3(26,4),PCFDW4(26,4),PCMBW5(26,4),PCMDW5(26,4),PCFBW5(26,4),PCFDW5
     4(26,4),PHFRBW(26,4),PHFRDW(26,4),PCOWBW(26,4),PCOWDW(26,4),
     5        PBULLW(26,4),ASBMW(26,4),ASDMW(26,4),ASBFW(26,4),ASDFW(26,
     64),SLRMBW(26,4),SLRMDW(26,4),SLRFBW(26,4),SLRFDW(26,4),TSLRMW(26,
     74),TSLRFW(26,4)
C
C DIMENSION THE MATRIX OF PUBLISHED STATISTICAL DATA
C
      COMMON     BCOWE(27,4),BCOWW(27,4),BCOWT(27,4),BHFRE(27,4),BHFRW(27
     1,4),BHFRT(27,4),DCOWE(27,4),DCOWW(27,4),DCOWT(27,4),DHFRE(27,4),
     2DHFRW(27,4),DHFRT(27,4),STRSE(27,4),STRSW(27,4),STRST(27,4),CALVE(
     327,4),CALVW(27,4),CALVT(27,4),BULLE(27,4),BULLW(27,4),BULLT(27,4),
     4BIRTHE(27,4),BIRTHW(27,4),BIRTHT(27,4), SCAVE(27,12),SCAVW(27,12),
     5SMCAVE(27,12),SFCAVE(27,12),SMCAVW(27,12),SFCAVW(27,12),
     6SCOWE(27,12),SCOWW(27,12),SBULLE(27,12),SBULLW(27,12),SHFRE(27,12
     7),SSTRE(27,12),SSTRW(27,12),SCATE(27,12),SCATW(27,12),SHFRW(27,12)
     8,ZCTSLR(27,12),ZCTFD(27,12),ZCTSTK(27,12),ZCTTOT(27,12),ZCVSLR(27,
     912),ZCVFD(27,12),ZCVSTK(27,12),ZCVTOT(27,12)
C
      COMMON VPBROW(27),VPBROE(27),VOTHRW(27),VOTHRE(27),WPDRYW(27),
     1WPDRYE(27),WPDBFW(27),WPDBFE(27),WODRYW(27),WODRYE(27),WCAVW2(27),
     2WCAVE2(27),WCAVW7(27),WCAVE7(27),WCATW9(27),WCATE9(27),WPBROE(27),
     3WPBROW(27),WDRYW2(27),WDRYE2(27),WDRYW9(27),WDRYE9(27),
     2USTKFE(27),USTKSE(27),USPTOE(27,4),USPTAE(27),USTKFW(27),USTKSW(
     327),USPTOW(27,4),USPTAW(27),USVKFE(27),USVKSE(27),USRVOE(27,4),
     4USRVAE(27),USVKEW(27),USVKSW(27),USRVOW(27,4),USRVAW(27)
C
      COMMON        YPDRYE(27,12),YPDRYW(27,12),YPBFE(27,12),YPBFW(27,12),
     1YOTHRE(27,12),YOTHRW(27,12),XCAVE2(27,12),XCAVW2(27,12),XCAVW7(27
     2,12),XCAVE7(27,12),XCATE9(27,12),XCATW9(27,12),XPDRYE(27,12),XPBF
     3E(27,12),XPBFW(27,12),XPDRYW(27,12),XOTDYE(27,12),XOTDYW(27,12),
     4FARME(27,12),FARMW(27,12),TCAHE(27,12),TCAHW(27,12),CAHMKE(27,12),
     5CAHMKW(27,12),CAHCVE(27,12),CAHCVW(27,12),CAHFSE(27,12),CAHFSW(27,
     612),CWBCHE(27,12),CWBCHW(27,12)
C
C DIMENSION THE MATRIX OF CALF SLAUGHTER,COW AND BULL CULL AND REPLACEMENT DATA
C
      COMMON RDCWSLE(26,4),RDCWSLW(26,4),RBCWSLE(26,4),RBCWSLW(26,4),
     1RDHFRRE(26,4),RDHFRRW(26,4),RBHFRRE(26,4),RBHFRRW(26,4),RCSLRME
     2(26,4),RCSLRMW(26,4),RCSLRFE(26,4),RCSLRFW(26,4),RBLSLRE(26,4),
     3RBLSLRW(26,4),RBLRPLE(26,4),RBLRPLW(26,4)
C
C READ JUNE 1 AND DEC 1 POPULATION DATA
C
      SWITCH=1.0
      DO 2 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 3
      L=2
      READ(1,4)        CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
    4 FORMAT(11X,12F9.0)
    3 L=4
      READ(1,4)        CALVE(K,L),CALVW(K,L),CALVT(K,L),STRSE(K,L),STRSW(K,
     1L),STRST(K,L),BHFRE(K,L),BHFRW(K,L),BHFRT(K,L),BCOWE(K,L),BCOWW(K,
     2L),BCOWT(K,L)
      SWITCH=0.0

      SWITCH=1.0
      DO 7 K=1,27
      IF(SWITCH.EQ.1.0)GO TO 9
      L=2
      READ(1,8)        DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,
     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
    8 FORMAT(11X,9F9.0)
    9 L=4
      READ(1,8)        DHFRE(K,L),DHFRW(K,L),DHFRT(K,L),DCOWE(K,L),DCOWW(K,
     1L),DCOWT(K,L),BULLE(K,L),BULLW(K,L),BULLT(K,L)
      SWITCH=0.0
    7 CONTINUE
C
C READ JUNE 1 AND DEC 1 CALF BIRTH DATA
C
      DO 13 K=2,27
      L=2
      READ(1,14)       BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   14 FORMAT(11X,3F10.0)
      L=4
      READ(1,14)       BIRTHE(K,L),BIRTHW(K,L),BIRTHT(K,L)
   13 CONTINUE
```

```
C

C
C READ INSPECTED SLAUGHTER DATA
C
      DO 11 I=3,12
      DO 12 J=1,12
      READ(1,15) SCAVE(I,J),SCAVW(I,J),SCATE(I,J),SCATW(I,J),SBULLE(I,J),
     1SBULLW(I,J)
   15 FORMAT(9X,2F10.0,10X,2F10.0,10X,2F10.0)
   12 CONTINUE
   11 CONTINUE
C
      DO 18 K=12,26
      DO 19 L=1,12
      READ(1,21) SMCAVE(K,L),SMCAVW(K,L),SFCAVE(K,L),SFCAVW(K,L)
   21 FORMAT(11X,2F10.0,10X,2F10.0)
   19 CONTINUE
   18 CONTINUE
C
      DO 24 K=12,26
      DO 25 L=1,12
      READ(1,27)      SSTRE(K,L),SSTRW(K,L),SHFRE(K,L),SHFRW(K,L),SCOWE(
     1K,L),SCOWW(K,L),SBULLE(K,L),SBULLW(K,L)
   27 FORMAT(11X,8F10.0)
   25 CONTINUE
   24 CONTINUE
C
C READ WEST-EAST CATTLE-CALF MOVEMENT DATA
C
      DO 31 K=2,25
      DO 32 L=1,12
      READ(1,34)      ZCTSLR(K,L),ZCTFD(K,L),ZCTSTK(K,L),ZCTTOT(K,L),ZCV
     1SLR(K,L),ZCVFD(K,L),ZCVSTK(K,L),ZCVTOT(K,L)
   34 FORMAT(11X,8F12.0)
   32 CONTINUE
   31 CONTINUE
C
C READ DAIRY CORRESPONDENTS STUDY DATA
C
      DO 38 I=10,27
      DO 39 J=1,12
      READ(1,42)      FARME(I,J),TCAHE(I,J),CAHMKE(I,J),CAHCVE(I,J),CAH
     1FSE(I,J),CWBCHE(I,J)
   42 FORMAT(11X,F15.0,5F20.0)
   39 CONTINUE
   38 CONTINUE
C
      DO 45 I=10,27
      DO 46 J=1,12
      READ(1,42)      FARMW(I,J),TCAHW(I,J),CAHMKW(I,J),CAHCVW(I,J),CAH
     1FSW(I,J),CWBCHW(I,J)
   46 CONTINUE
   45 CONTINUE
C
C READ UNINSPECTED SLAUGHTER DATA

C
      DO 53 I=10,26
      DO 54 J=1,4
      IF(J.EQ.4.0)GO TO 58
      READ(1,55)      USRTQE(I,J),USRTQW(I,J)
   55 FORMAT(17X,40X,2F10.1)
      GO TO 54
   58 READ(1,59)      USTKEE(I),USTKEW(I),USTKSE(I),USTKSW(I),USRTQE(I,J)
     1,USRTQW(I,J),USRTAE(I),USRTAW(I)
   59 FORMAT(17X,8F10.1)
   54 CONTINUE
   53 CONTINUE
C
      DO 82 I=10,26
      DO 88 J=1,4
      IF(J.EQ.4.0)GO TO 92
      READ(1,55)      USRVQE(I,J),USRVQW(I,J)
      GO TO 88
   92 READ(1,59)      USVKEE(I),USVKEW(I),USVKSE(I),USVKSW(I),USRVQE(I,J)
     1,USRVQW(I,J),USRVAE(I),USRVAW(I)
   88 CONTINUE
   82 CONTINUE
C
C READ ANNUAL IMPORT DATA
C
      DO 72 I=2,26
      READ(1,73) VPBROW(I),VPBROE(I),VOTHRW(I),VOTHRE(I)
   73 FORMAT(6X,2F15.0,15X,2F15.0)
   72 CONTINUE
C
C READ MONTHLY IMPORT DATA
C
      DO 77 I=23,26
      DO 78 J=1,12
      READ(1,76)      YPORYE(I,J),YPORYW(I,J),YPBFE(I,J),YPBFW(I,J),YOTH
     2RE(I,J),YOTHRW(I,J)
   76 FORMAT(9X,6F12.0)
   78 CONTINUE
   77 CONTINUE
```

```
C
C READ ANNUAL EXPORT DATA
C
      DO 67 I=2,19
      READ(1,61) WPORYE(I),WPOBFE(I),WPBRDE(I),WPORYW(I),WPOBFW(I),
     1WPBROW(I)
   61 FORMAT(5X,6F15.0)
   67 CONTINUE
C
      DO 60 I=20,26
      READ(1,61) WPORYW(I),WPOBFW(I),WPBROW(I),WPORYE(I),WPOBFE(I),
     1WPBRDE(I)
   60 CONTINUE
C
      DO 62 I=2,26
      READ(1,63) WDORYW(I),WDORYE(I),WCAVW2(I),WCAVE2(I),WCAVW7(I),
     1WCAVE7(I),WCATW9(I),WCATE9(I)
   63 FORMAT(5X,8F15.0)
   62 CONTINUE
C
C READ MONTHLY EXPORT DATA
C
      DO 64 I=23,26
      DO 65 J=1,12
      READ(1,66)       XCAVE2(I,J),XCAVW2(I,J),XCAVE7(I,J),XCAVW7(I,J),XC
     1ATE9(I,J),XCATW9(I,J),XOTDYE(I,J),XOTDYW(I,J),XPORYE(I,J),XPORYW
     2(I,J),XPBFE(I,J),XPBFW(I,J)
   66 FORMAT(8X,12F9.0)
   65 CONTINUE
   64 CONTINUE
C
C READ CALF SLAUGHTER,COW AND BULL CULL AND
C REPLACEMENT DATA (AS GENERATED BY PROGRAM MATRIX)
C
      DO 93 I=12,26
      DO 94 J=1,4
      READ 95,RDCWSLE(I,J),RDCWSLW(I,J),RBCWSLE(I,J),RBCWSLW(I,J),
     1RDHFRRE(I,J),RDHFRRW(I,J),RBHFRRE(I,J),RBHFRRW(I,J),RCSLRME(I,J),
     2RCSLRMW(I,J),RCSLRFE(I,J),RCSLRFW(I,J),RBLSLRE(I,J),RBLSLRW(I,J),
     3RBLRPLE(I,J),RBLRPLW(I,J)
   95 FORMAT(8F10.0,/,4F10.0,/,4F10.0)
C
   94 CONTINUE
   93 CONTINUE
C
C PROGRAM CATSIM2
C
C PARAMETER DESCRIPTIONS
C
C      BRWBC    BIRTH RATE OF WESTERN BEEF COWS FROM SECOND CALF ONWARD
C      BRWDC    BIRTH RATE OF WESTERN DAIRY COWS FROM SECOND CALF ONWARD
C
C      BRWBH    BIRTH RATE OF 1ST CALF WESTERN BEEF HEIFERS
C      BRWDH    BIRTH RATE OF 1ST CALF WESTERN DAIRY HEIFERS
C
C      DRMBCW   DEATH RATE OF WESTERN BEEF MALE CALVES
C      DRMDCW   DEATH RATE OF WESTERN DAIRY MALE CALVES
C
C      DRFBCW   DEATH RATE OF WESTERN BEEF FEMALE CALVES
C      DRFDCW   DEATH RATE OF WESTERN DAIRY FEMALE CALVES
C
C      DRCATF   DEATH RATE OF CATTLE IN FEEDLOTS
C
C      DRCAT    DEATH RATE OF CATTLE OVER 1 YR.,NOT IN FEED LOT
C      V1       PROPORTION OF BEEF IN SMCAVW(I,J)
C      V2       PROPORTION OF BEEF IN SFCAVW(I,J)
C      V3       PROPORTION OF FEMALES IN UNINSPECTED CALF SLAUGHTER
C      V11      PROPORTION OF COWS IN UNINSPECTED CATTLE SLAUGHTER
C      V35      PROPORTION OF BULLS IN UNINSPECTED CATTLE SLAUGHTER
C      V36      PROPORTION OF STEERS IN UNINSPECTED CATTLE SLAUGHTER
C
C      V5       PROPORTION OF MALES IN ZCVSTK(I,J),ZCVSLR(I,J),ZCVFD(I,J)
C      V12      PROPORTION OF MALES IN ZCTFD(I,J) AND ZCTSTK(I,J)
C      V15      PROPORTION OF MALES IN ZCTSLR(I,J)
C      V9       SCALE FACTOR FOR WEST-EAST CATTLE SHIPMENTS
C
C      V4       PROPORTION OF MALES IN XCAVW7(I,J)
C      V6       PROPORTION OF 6 MOS. OLD CALVES IN XCAV7(I,J)
C      V13      PROPORTION OF CULL COWS IN XCAT9W(I,J),UNDER A CRITICAL LIMIT
C      V131     PROPORTION OF CULL COWS IN XCAT9W(I,J),OVER  A CRITICAL LIMIT
C      V14      PROPORTION OF MALES IN XCAT9W(I,J)
C      V16      PROPORTION OF MALES IN YOTHRW(I,J)
C
C      V25      PROPORTION OF DAIRY IN VPBRD(I)
C      V26      PROPORTION OF DAIRY IN WPBRD(I)
C
C      V18      PROPORTION OF FEMALES IN WPBRD(I)
C      V19      PROPORTION OF FEMALES IN VPBRD(I)
C
C      V7       PROPORTION OF BEEF MALES TO RATION B
C      V27      PROPORTION OF DAIRY MALES TO RATION B
C      V8       PROPORTION OF BEEF FEMALES TO RATION B
C      V28      PROPORTION OF DAIRY FEMALES TO RATION B
C
C      V31      PROPORTION OF THE BEEF  COW HERD BEING REPLACED
C      V21      PROPORTION OF THE DAIRY COW HERD BEING REPLACED
C      V22      PROPORTION OF THE BULL HERD BEING REPLACED
```

```
C INITIALIZE PARAMETER VALUES
C
      V1=.10
      V2=.25
      V3=.50
      V4=.50
      V5=.80
      V6=.90
      V7=.60
      V8=.20
      V9=1.07
      V11=.25
      V12=.80
      V13=.80
      V131=.05
      V14=.35
      V15=.95
      V16=.70
      V18=.85

      V19=.90
      V20=.80
      V21=.150
      V22=.307
      V25=.20
      V26=.926
      V27=.70
      V29=0.0
      V31=.100
      V35=.660
      V36=.207
C
      BPWBC=.94
      BPWDC=.76
      BPWBH=.94
      BPWDH=.94
      DT=.25
C
C QUARTERLY DEATH DISTRIBUTION(AT ANNUAL RATES)
C
      CYMBCW(1)=.049
      CYMBCW(2)=.049
      CYMBCW(3)=.022
      CYMBCW(4)=.022
      CYMDCW(1)=.048
      CYMDCW(2)=.049
      CYMDCW(3)=.022
      CYMDCW(4)=.022
      CYFBCW(1)=.048
      CYFBCW(2)=.049
      CYFBCW(3)=.022
      CYFBCW(4)=.022
      CYFDCW(1)=.049
      CYFDCW(2)=.048
      CYFDCW(3)=.022
      CYFDCW(4)=.022
      CYCTFW(1)=.014
      CYCTFW(2)=.014
      CYCTFW(3)=.012
      CYCTFW(4)=.012
      CYCTBW(1)=.015
      CYCTBW(2)=.016
      CYCTBW(3)=.012
      CYCTBW(4)=.012
      CYCTDW(1)=.016
      CYCTDW(2)=.016
      CYCTDW(3)=.012
      CYCTDW(4)=.012
C
C MONTHLY CALVING DISTRIBUTION
C
      VALBW(1)=.01
      VALBW(2)=.04
      VALBW(3)=.11
      VALBW(4)=.25
      VALBW(5)=.39
      VALBW(6)=.11
      VALBW(7)=.04
      VALBW(8)=.01
      VALBW(9)=.01
      VALBW(10)=.01
      VALBW(11)=.01
      VALBW(12)=.01
      VALBW(13)=.01
      VALDW(1)=.039
      VALDW(2)=.033
      VALDW(3)=.069
      VALDW(4)=.112
      VALDW(5)=.093
      VALDW(6)=.065
      VALDW(7)=.054
      VALDW(8)=.069
      VALDW(9)=.077
      VALDW(10)=.097
      VALDW(11)=.076
      VALDW(12)=.074
      VALDW(13)=.038
C
```

```
C QUARTERLY EXPORT-IMPORT DISTRIBUTION
C
      Q1(1)=.21
      Q1(2)=.32
      Q1(3)=.18
      Q1(4)=.29
      Q2(1)=.18
      Q2(2)=.28
      Q2(3)=.24
      Q2(4)=.30
      Q3(1)=.15
      Q3(2)=.32
      Q3(3)=.30
      Q3(4)=.22
      Q4(1)=.31
      Q4(2)=.26
      Q4(3)=.03
      Q4(4)=.40
      Q5(1)=.20
      Q5(2)=.52
      Q5(3)=.18
      Q5(4)=.10
      Q6(1)=.04
      Q6(2)=.04
      Q6(3)=.08
      Q6(4)=.84
      Q7(1)=.31
      Q7(2)=.22
      Q7(3)=.18
      Q7(4)=.29
C
C PARAMETER VALUES FOR ALL CONTINUOUS
C AND DISCRETE DELAY SUBROUTINES
C
      NCOUNT=0
      NOCY=1
      NCY=1
      SUMIN=0
      IOT=10
C
      LTBTH=3
      LTDTH=4
      LTHFR=4
      LTMBW1=1
      LTMDW1=1
      LTFBW1=1
      LTFDW1=1
      LTMBW2=1
      LTMDW2=1
      LTFBW2=1
      LTFDW2=1
      LTMBW3=2
      LTMDW3=2
      LTFBW3=2
      LTFDW3=2
C
      NK=0
      KWBH=3
      KWDH=3
      KMBW4=4
      KMDW4=4
      KFBW4=4
      KFDW4=4
      KMBW5=4
      KMDW5=4
      KFBW5=4
      KFDW5=4
C
      DELWDH=.85
      DEPWDH=.35
      V40=DELWDH/.75
      V41=.00
C
      DLMDW4=.99
      DLFBW4=.83
      DLMBW4=.93
      DLFDW4=.83
      DPMBW4=.99
      DPFBW4=.93
      DPMDW4=.99
      DPFDW4=.93
      DLMBW5=.75
      DLFBW5=.75
      DLMDW5=.75
      DLFDW5=.75
      DPMBW5=.75
      DPFBW5=.75
      DPMDW5=.75
      DPFDW5=.75
C
      PRINT 350
  350 FORMAT('1','THE VARIABLE AND PARAMETER SETTINGS FOR THIS RUN')
C
      PRINT 345, BRWBC,BRWBH,BRWDC,BRWDH,V1,V2,V3,V11
  345 FORMAT('-',4X,F5.3,3X,'BIRTH RATE OF WESTERN BEEF COWS'
     1,/,5X,F5.3,3X,'BIRTH RATE OF WESTERN BEEF HEIFERS'
     2,//,5X,F5.3,3X,'BIRTH RATE OF WESTERN DAIRY COWS'
     3,/,5X,F5.3,3X,'BIRTH RATE OF WESTERN DAIRY HEIFERS'
     4,//,5X,F5.3,3X,'PROPORTION OF BEEF IN SMCAVH(I,J)'
     5,/,5X,F5.3,3X,'PROPORTION OF BEEF IN SFCAVH(I,J)'
     6,/,5X,F5.3,3X,'PROPORTION OF FEMALE IN UNINSPECTED CALF SLAUGHTER'
     7,/,5X,F5.3,3X,'PROPORTION OF COWS IN UNINSPECTED CATTLE SLR')
```

```
C
      PRINT 346,V35,V36,V5,V12,V17,V4,V6,V13,V131,V14,V16
  346 FORMAT(' ',4X,F5.3,3X,'PROPORTION OF BULLS IN UNINSP CATTLE SLR'
     1,/,5X,F5.3,3X,'PROPORTION OF STEERS IN UNINSPECTED CATTLE SLR'
     1,//,5X,F5.3,3X,'PROPORTION OF MALES IN ZCVSTK,ZCVFD AND ZCVSLR'
     2,/,5X,F5.3,3X,'PROPORTION OF MALES IN ZCTFD AND ZCTSTK'
     3,/,5X,F5.3,3X,'PROPORTION OF MALES IN ZCTSLR'
     4,//,5X,F5.3,3X,'PROPORTION OF MALES IN XCAVW7(I,J)'
     5,/,5X,F5.3,3X,'PROPORTION OF 6MOS. OLD CALVES IN XCAVW7(I,J)'
     7,/,5X,F5.3,3X,'PROPORTION OF COWS IN XCAT9W(I,J),OVER  CRITICAL L'
     8,/,5X,F5.3,3X,'PROPORTION OF MALES IN XCAT9W(I,J)'
     9,/,5X,F5.3,3X,'PROPORTION OR MALES IN YOTHRW(I,J)')
C
      PRINT 347,V25,V26,V18,V19,V7,V27,V8,V28
  347 FORMAT('0',4X,F5.3,3X,'PROPORTION OF DAIRY IN VPBRO(I)'
     1,/,5X,F5.3,3X,'PROPORTION OF DAIRY IN VPBRO(I)'
     2,/,5X,F5.3,3X,'PROPORTION OF FEMALES IN WPBRO(I)'
     3,/,5X,F5.3,3X,'PROPORTION OF FEMALES IN VPBRO(I)'
     4,//,5X,F5.3,3X,'PROPORTION OF WESTERN BEEF STEERS TO RATION 8'
     5,/,5X,F5.3,3X,'PROPORTION OF WESTERN BEEF FEMALES TO RATION 3'
     6,/,5X,F5.3,3X,'PROPORTION OF DAIRY MALES TO RATION 3'
     7,/, 5X,F5.3,3X,'PROPORTION OF DAIRY FEMALES TO RATION 8')
C
      PRINT 351,V31,V21,V22
  351 FORMAT('0',4X,F5.3,3X,'PROPORTN OF DAIRY COW HERD BEING REPLACED'
     1,/,5X,F5.3,3X,'PROPORTION OF BEEF COW HERD BEING REPLACED'
     2,/,5X,F5.3,3X,'PROPORTION OF THE BULL HERD BEING REPLACED,WEST')
C
C CALCULATE BEGINNING POPULATION FIGURES
C
      L=6
      JJ=12
      ORMBCW=CYMBCW(1)
      ORFBCW=CYFBCW(1)
      ORMDCW=CYMDCW(1)
      ORFDCW=CYFDCW(1)
      ORCATF=CYCTFW(1)
      ORCATW=CYCT9W(1)
C
      TOTAL9=0.0
C
      DO 314 J=7,9
      TOTAL9=TOTAL9+ZCVSTK(JJ-1,J)+ZCVSTK(JJ-1,J+3)+ZCVFD(JJ-1,J)+
     1ZCVFD(JJ-1,J+3)
  314 CONTINUE
C
C
      PCMBW1(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(10,13,VAL3W)*.5
      PCFBW1(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(10,13,VAL3W)*.5
      PCMDW1(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(10,13,VALDW)*.5
      PCFDW1(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(10,13,VALDW)*.5
C
      PCMBW2(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(7, 10,VAL3W)*.5
      PCFBW2(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(7, 10,VAL3W)*.5
C
      PCMDW2(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(7, 10,VALDW)*.5*.55
      PCFDW2(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(7, 10,VALDW)*.5*.60
C
      PCMBW3(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(1, 7, VAL3W)*.5*(1.-V7)
     1-TOTAL9*(1.-V7) *V5*V9
      PCFBW3(JJ-1,4)=BCOWW(JJ-1,4)*BRWBC*INGRAT(1, 7, VAL3W)*.5*(1.-V8)
     1*.95
      PCMDW3(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(1, 7, VALDW)*.5*.15
      PCFDW3(JJ-1,4)=DCOWW(JJ-1,4)*BRWDC*INGRAT(1, 7, VALDW)*.5*.75
C
      PCMBW4(JJ-1,4)=STRSW(JJ-1,4)*V7 *1.25
      PCMDW4(JJ-1,4)=STRSW(JJ-1,4)*V27*.35
      PCFBW4(JJ-1,4)=BHFRW(JJ-1,4)*V8*1.5
      PCFDW4(JJ-1,4)=0.0
C
      PCMBW5(JJ-1,4)=STRSW(JJ-1,4)*(1.-V7)*.15
      PCMDW5(JJ-1,4)=STRSW(JJ-1,4)*(1.-V27)*.20
      PHFRBW(JJ-1,4)=BCOWW(JJ-1,4)*V31
      PHFRDW(JJ-1,4)=DCOWW(JJ-1,4)*V21
      PCFBW5(JJ-1,4)=(BHFRW(JJ-1,4)-PCFBW4(JJ-1,4)*.5-PHFRBW(JJ-1,4))
     1*1.75
      PCFDW5(JJ-1,4)=DHFRW(JJ-1,4)-PHFRDW(JJ-1,4)
C
      PBULLW(JJ-1,4)=BULLW(JJ-1,4)
      PCOWBW(JJ-1,4)=BCOWW(JJ-1,4)
      PCOWDW(JJ-1,4)=DCOWW(JJ-1,4)
C
      ROTAL1=PCOWBW(JJ-1,4)
      ROTAL2=PCOWDW(JJ-1,4)
      ROTAL3=PBULLW(JJ-1,4)
C
      RATIO1=PCOWBW(JJ-1,4)/(PCOWBW(JJ-1,4)+PCOWDW(JJ-1,4))
C
      MM=JJ+45
      PRINT 370
  370 FORMAT('1','BEGINNING POPULATION FIGURES')
      PRINT 371,MM,L,PCMBW1(JJ-1,4),PCFBW1(JJ-1,4),PCMBW2(JJ-1,4),PCFBW2
     1(JJ-1,4),PCMBW3(JJ-1,4),PCFBW3(JJ-1,4),PCMBW4(JJ-1,4),PCFBW4(JJ-1,
     24),PCMBW5(JJ-1,4),PCFBW5(JJ-1,4),PHFRBW(JJ-1,4),PCOWBW(JJ-1,4),
     3PBULLW(JJ-1,4),PCMDW1(JJ-1,4),PCFDW1(JJ-1,4),PCMDW2(JJ-1,4),PCFDW2
     4(JJ-1,4),PCMDW3(JJ-1,4),PCFDW3(JJ-1,4),PCMDW4(JJ-1,4),PCFDW4(JJ-1,
     54),PCMDW5(JJ-1,4),PCFDW5(JJ-1,4),PHFRDW(JJ-1,4),PCOWDW(JJ-1,4)
  371 FORMAT('-',I2,I4,13F8.0,/,7X,12F8.0)
```

```
C
C CALCULATE VALUES IN DELAYS AND BEGINNING FLOW VALUES FOR INTEGRATERS
C
C LOAD TRAIN FOR WESTERN CALF BIRTHS
C
      TNWBC(1)=(BCOWW(JJ-1,2)+BCOWW(JJ-1,4))/2*INGRAT(4,7,VALBW)*4*BRWBC
      TNWDC(1)=(DCOWW(JJ-1,2)+DCOWW(JJ-1,4))/2*INGRAT(4,7,VALDW)*4*BRWDC
     1*.5
      TNWBC(2)=(BCOWW(JJ-1,2)+BCOWW(JJ-1,4))/2*INGRAT(7,10, VALBW)*4
     1*BRWBC
      TNWDC(2)=(DCOWW(JJ-1,2)+DCOWW(JJ-1,4))/2*INGRAT(7,10, VALDW)*4
     1*BRWDC*.5
      TNWBC(3)=(BCOWW(JJ-1,4)+BCOWW(JJ  ,2))/2*INGRAT(10,13,VALBW)*4
     1*BRWBC
      TNWDC(3)=(DCOWW(JJ-1,4)+DCOWW(JJ  ,2))/2*INGRAT(10,13,VALDW)*4
     1*BRWDC*.5
C
      PRINT 352
  352 FORMAT(*-*,*TRAIN FOR WESTERN CALF BIRTHS*)
       PRINT 353,TNWBC(1),TNWBC(2),TNWBC(3),TNWDC(1),TNWDC(2),TNWDC(3)
  353 FORMAT(*0*,6F10.0)
C
C LOAD TRAIN FOR CALVES(1-3)
C
      TCALVE1=((BCOWW(JJ-2,4)+BCOWW(JJ-1,2))/2)*INGRAT( 1,4, VALBW)*4
     1*BRWBC
      TCALVE3=((DCOWW(JJ-2,4)+DCOWW(JJ-1,2))/2)*INGRAT( 1,4, VALDW)*4
     1*BRWDC
      TCALVE2=((BCOWW(JJ-2,4)+BCOWW(JJ-1,2))/2)*INGRAT(10,13,VALBW)*4
     1*BRWBC
      TCALVE4=((DCOWW(JJ-2,4)+DCOWW(JJ-1,2))/2)*INGRAT(10,13,VALDW)*4
     1*BRWDC
      ACMBW1=TCALVE1*.5*(1.-DRMBCW*DT)
      ACFBW1=TCALVE1*.5*(1.-DRFBCW*DT)
      ACMDW1=TCALVE3*.5*(1.-DRMDCW*DT)

      ACFDW1=TCALVE3*.5*(1.-DRFDCW*DT)
      BCMBW1=TCALVE2*.5*(1.-DRMBCW*DT)
      BCFBW1=TCALVE2*.5*(1.-DRMBCW*DT)
      BCMDW1=TCALVE4*.5*(1.-DRMDCW*DT)
      BCFDW1=TCALVE4*.5*(1.-DRFDCW*DT)
      TNMBW1(1)=ACMBW1
      TNFBW1(1)=ACFBW1
      TNMDW1(1)=ACMDW1
      TNFDW1(1)=ACFDW1
C
      PRINT 354
  354 FORMAT(*-*,*TRAIN FOR WESTERN CALVES 1-3*)
      PRINT 355,ACMBW1,ACFBW1,ACMDW1,ACFDW1,BCMBW1,BCFBW1,BCMDW1,BCFDW1
  355 FORMAT(*0*,4F10.0/4F10.0)
C
C LOAD TRAIN FOR WESTERN CALVES(4-6)
C
      TOTAL1=0.0
      TOTAL2=0.0
      I=JJ
      L=1
      DO 311 J=1,3
      TOTAL1=TOTAL1+SMCAVW(I,J)+(USVKEW(I)/12+USVKSW(I)/12+USRVQW(I,L)
     1/3)*(1.-V1)
      TOTAL2=TOTAL2+SFCAVW(I,J)+(USVKEW(I)/12+USVKSW(I)/12+USRVQW(I,L)
     1/3)*V1
  311 CONTINUE
C
      TOTAL3=0.0
      TOTAL4=0.0
      I=JJ-1
      K=JJ
      L=4
      DO 312 J=10,12
      TOTAL3=TOTAL3+SMCAVW(K,J)+(USVKEW(I)/12+USVKSW(I)/12+USRVQW(I,L)
     1/3)*(1.-V3)
      TOTAL4=TOTAL4+SFCAVW(K,J)+(USVKEW(I)/12+USVKSW(I)/12+USRVQW(I,L)
     1/3)*V3
  312 CONTINUE
C
      CCMBW2=(BCMBW1-TOTAL1*V1*4)*(1.-DRMBCW*DT)
      CCMDW2=(BCMDW1-TOTAL1*(1.-V1)*4)*(1.-DRMDCW*DT)
      CCFBW2=(BCMBW1-TOTAL2*V2*4)*(1.-DRFBCW*DT)
      CCFDW2=(BCFDW1-TOTAL2*(1.-V2)*4)*(1.-DRFDCW*DT)
C
      TCALVE3=((BCOWW(JJ-1,2)+BCOWW(JJ-2,4))/2)*INGRAT( 7,10,VALBW)*4
     1*BRWBC
      TCALVE4=((DCOWW(JJ-1,2)+DCOWW(JJ-2,4))/2)*INGRAT( 7,10,VALDW)*4
     1*BRWDC
      DCMBW2=(TCALVE3*.5*(1.-DRMBCW*DT)-TOTAL3*V1*4)*(1.-DRMBCW*DT)
      DCMDW2=(TCALVE4*.5*(1.-DRMDCW*DT)-TOTAL3*(1.-V1)*4)*(1.-DRMDCW*DT)
      DCFBW2=(TCALVE3*.5*(1.-DRFBCW*DT)-TOTAL4*V2*4)*(1.-DRFBCW*DT)
      DCFDW2=(TCALVE4*.5*(1.-DRFDCW*DT)-TOTAL4*(1.-V2)*4)*(1.-DRFDCW*DT)
C
      TNMBW2(1)=CCMBW2
      TNFBW2(1)=CCFBW2
      TNMDW2(1)=CCMDW2
      TNFDW2(1)=CCFDW2
C
      PRINT 356
  356 FORMAT(*-*,*TRAIN FOR WESTERN CALVES 4-6*)
      PRINT 357,CCMBW2,CCFBW2,CCMDW2,CCFDW2,DCMBW2,DCFBW2,DCMDW2,DCFDW2
  357 FORMAT(*0*,4F10.0/4F10.0)
```

```
C
C CALCULATE VALUES FOR CALVES 7-12
C
      FCMBW3=PCMBW3(JJ-1,4)/(2*DT)
      FCMDW3=PCMDW3(JJ-1,4)/(2*DT)
      FCFBW3=PCFBW3(JJ-1,4)/(2*DT)
      FCFDW3=PCFDW3(JJ-1,4)/(2*DT)
C
      TNMBW3(1)=FCMBW3
      TNMDW3(1)=FCMDW3
      TNFBW3(1)=FCFBW3
      TNFDW3(1)=FCFDW3
C
      TNMBW3(2)=FCMBW3
      TNMDW3(2)=FCMDW3

      TNFBW3(2)=FCFBW3
      TNFDW3(2)=FCFDW3
C
      GCMBW3=PCMBW3(JJ-1,4)/(2*DT)
      GCMDW3=PCMDW3(JJ-1,4)/(2*DT)
      GCFBW3=PCFBW3(JJ-1,4)/(2*DT)
      GCFDW3=PCFDW3(JJ-1,4)/(2*DT)
C
C CALCULATE THE BEGINNING VALUES FOR CATTLE ON RATION B
C
      KCMBW4=PCMBW4(JJ-1,4)/DLMBW4
      KCMDW4=PCMDW4(JJ-1,4)/DLMDW4
      KCFBW4=PCFBW4(JJ-1,4)/DLFBW4
      KCFDW4=PCFDW4(JJ-1,4)/DLFDW4
C
      LCMDW4=PCMDW4(JJ-1,4)/DLMDW4
      LCMBW4=PCMBW4(JJ-1,4)/DLMBW4
      LCFBW4=PCFBW4(JJ-1,4)/DLFBW4
      LCFDW4=PCFDW4(JJ-1,4)/DLFDW4
C
C CALCULATE THE BEGINNING VALUES FOR CATTLE ON RATION A
C
      HCMBW5=PCMBW5(JJ-1,4)/DLMBW5
      HCMDW5=PCMDW5(JJ-1,4)/DLMDW5
      HCFBW5=PCFBW5(JJ-1,4)/DLFBW5
      HCFDW5=PCFDW5(JJ-1,4)/DLFDW5
C
      JCMBW5=PCMBW5(JJ-1,4)/DLMBW5
      JCMDW5=PCMDW5(JJ-1,4)/DLMDW5
      JCFBW5=PCFBW5(JJ-1,4)/DLFBW5
      JCFDW5=PCFDW5(JJ-1,4)/DLFDW5
C
      ABULLW=RBLRBLW(JJ,1)*4
      IF(ABULLW.LT.0.0) ABULLW=0.9
C
C CALCULATE BEGINNING HEIFER VALUES
C
      BHFRBW=RBHFRBW(JJ+1,1)*4
      BHFRDW=RDHFRDW(JJ+1,1)*4
      CHFRBW=RBHFRBW(JJ,1)*4
      CHFRDW=RDHFRDW(JJ,1)*4
C
      TNWBHR(4)=BHFRBW
      TNWDHR(4)=DHFRDW
      TNWBHR(3)=RBHFRBW(JJ,4)*4
      TNWDHR(3)=RDHFRDW(JJ,4)*4
      TNWBHR(2)=RBHFRBW(JJ,3)*4
      TNWDHR(2)=RDHFRDW(JJ,3)*4
      TNWBHR(1)=RBHFRBW(JJ,2)*4
      TNWDHR(1)=RDHFRDW(JJ,2)*4
C
      PRINT 354
  364 FORMAT('-','TRAIN FOR WESTERN HEIFERS')
      PRINT 365,BHFRBW,TNWBHR,CHFRBW,BHFRDW,TNWDHR,CHFRDW
  365 FORMAT('0',6F10.0,/,6F10.0)
C
C LOAD BEGINNING VALUES FOR COWS AND BULLS
C
      TOTALB=WCATW9(JJ) *Q7(1)
      TOTAL2=WPBRDW(JJ)*Q2(1)*(1.-V26)
      TOTAL3=VRBRDW(JJ)*Q1(1)*(1.-V25)
      TOTAL5=VRBRDW(JJ)*Q1(1)*V25
      TOTAL6=WPBRDW(JJ)*Q2(1)*V26
      TOTAL7=WDDRYW(JJ)*Q3(1)
C
      IF(TOTALB.LE.2000) TOTALC=TOTALB*V13
      IF(TOTALB.GT.2000) TOTALC=1600+(TOTALB-1600)*V131
C
      SCOWDW=RDCWSLW(JJ,1)*4
      SCOWBW=RBCWSLW(JJ,1)*4
      XCOWBW=TOTAL2*V13*4+TOTALC*RATIO1*4
      XCOWDW=TOTAL6*V13*4+TOTALC*(1.-RATIO1)*4+TOTAL7*4
      YCOWBW=TOTAL3*V19*4
      YCOWDW=TOTAL5*V19*4
      DCOWBW=PCOWBW(JJ-1,4)*DRCATW
      DCOWDW=PCOWDW(JJ-1,4)*DRCATW
C
      SWBULL=RBLSLRW(JJ,1)*4
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      XBULLW=TOTAL2*(1.-V19)*4+TOTAL6*(1.-V18)*4
      YBULLW=TOTAL3*(1.-V19)*4+TOTAL5*(1.-V19)*4
      DBULLW=PBULLW(JJ-1,4)*DRCATW
C
      NETWBC=CHFRBW+YCOWBW-XCOWBW-SCOWBW-DCOWBW
      NETWDC=CHFRDW+YCOWDW-XCOWDW-SCOWDW-DCOWDW
      NETWBL=ABULLW+YBULLW-XBULLW-SWBULL-DBULLW
C
      PRINT 366
  366 FORMAT('-','BEGINNING VALUES FOR WESTERN COWS AND BULLS')
      PRINT 367,NETWBC,NETWDC,NETWBL
  367 FORMAT('0',2F10.0/ F10.0)
C
C LOAD THE CROUTR FOR FEEDLOT(RATION A AND B)
C
      DO 334 I=1,KMBW5
      CTMBW5(I)=(PCMBW5(JJ-1,4)/DLMBW5)/IDT
      CTMDW5(I)=(PCMDW5(JJ-1,4)/DLMDW5)/IDT
  334 CONTINUE
C
      DO 335 I=1,KFBW5
      CTFBW5(I)=(PCFBW5(JJ-1,4)/DLFBW5)/IDT
      CTFDW5(I)=(PCFDW5(JJ-1,4)/DLFDW5)/IDT
  335 CONTINUE
C
      DO 336 I=1,KMBW4
      CTMBW4(I)=(PCMBW4(JJ-1,4)/DLMBW4)/IDT
      CTMDW4(I)=(PCMDW4(JJ-1,4)/DLMDW4)/IDT
  336 CONTINUE
C
      DO 337 I=1,KFBW4
      CTFBW4(I)=(PCFBW4(JJ-1,4)/DLFBW4)/IDT
      CTFDW4(I)=(PCFDW4(JJ-1,4)/DLFDW4)/IDT
  337 CONTINUE
C
      PRINT 360
  360 FORMAT('-','TRAIN FOR WESTERN CATTLE,RATION A')
      PRINT 361,HCMBW5,CTMBW5,JCMBW5,HCFBW5,CTFBW5,JCFBW5,HCMDW5,CTMDW5,
     1JCMDW5,HCFDW5,CTFDW5,JCFDW5
  361 FORMAT('0',12F10.0,/,12F10.0,/,12F10.0,/,12F10.0)
C
      PRINT 362
  362 FORMAT('-','TRAIN FOR WESTERN CATTLE,RATION B')
      PRINT 363,KCMBW4,CTMBW4,LCMBW4,KCFBW4,CTFBW4,LCFBW4,KCMDW4,CTMDW4,
     1LCMDW4,KCFDW4,CTFDW4,LCFDW4
  363 FORMAT('0',12F10.0,/,12F10.0,/,12F10.0,/,12F10.0)
C
C LOAD CROUTR FOR HEIFER FRESHENINGS
C
      DO 338 I=1,KWDH
      CTRWDH(I)=(((TNWDHR(1)+TNWDHR(2)+TNWDHR(3)+TNWDHR(4))/4    *BRWDH)
     1/IDT
  338 CONTINUE
C
      PRINT 368
  368 FORMAT('-','TRAIN FOR WESTERN HEIFER FRESHENINGS')
      PRINT 369,CTRWDH
  369 FORMAT('0',10F10.0)
C
C
C PRINT INITIAL RATES,TRAIN AND CROUTR VALUES
C
      PRINT 372
  372 FORMAT('1',    'YR',3X,'QUART',2X,'PCMBW1',2X,'PCFBW1',2X,'PCMBW2'
     1,2X,'PCFBW2',2X,'PCMBW3',2X,'PCFBW3',2X,'PCMBW4',2X,'PCFBW4'
     2,2X,'PCMBW5',2X,'PCFBW5',2X,'PHFRBW',2X,'PCOWBW',2X,'PBULBW',/,
     313X,'PCMDW1',2X,'PCFDW1',2X,'PCMDW2',2X,'PCFDW2',2X,'PCMDW3',1X,'
     4PCFDW3',2X,'PCMDW4',2X,'PCFDW4',2X,'PCMDW5',2X,'PCFDW5',2X,'PHFRDW
     5',2X,'PCOWDW',2X,'PBULDW',4X,'SLR STR',1X,'SLR HFR',/,
     610X,'TOTAL CALVES',2X,'ACTUAL CALVES',2X,'TOTAL STEERS',2X,
     7'ACTUAL STEERS',2X,'TOTAL HEIFERS',2X,'ACTUAL HEIFERS',2X,
     8'ACT COWS',2X,'ACT BULLS',1X,'A SLR ST',1X,'A SLR HF')
C
C EXECUTION PHASE
C
      ERRORS=0.0
      ERRORH=0.0
      ERRORT=0.0
C
      COUNTR=0.0
      LOW=1
      LHIGH=4
      DO 349 JJ=12,26
      I=JJ
      DO 348 L=1,4
      COUNTR=COUNTR+3.0
      M=L+1
      IF(L.EQ.4)M=1
      IF(L.EQ.4)COUNTR=0.0
      IF(L.EQ.4)I=I+1
C
      IF(JJ.GT.17) V4=.00
      IF(JJ.GT.19) V36=.00
      IF(JJ.GT.20) V3=1.00
```

```
C
C CYCLE DEATH RATES
C
      CALL CBOX(CYMBCW,LTOTH,NCY,NK)
      CALL CBOX(CYFBCW,LTOTH,NCY,NK)
      CALL CBOX(CYCTFW,LTOTH,NCY,NK)
      CALL CBOX(CYCTBW,LTOTH,NCY,NK)
      CALL CBOX(CYMOCW,LTOTH,NCY,NK)
      CALL CBOX(CYFOCW,LTOTH,NCY,NK)
      CALL CBOX(CYCTOW,LTOTH,NCY,NK)
C
      DRMBCW=CYMBCW(1)
      DRMOCW=CYMOCW(1)
      DRFBCW=CYFBCW(1)
      DRFOCW=CYFOCW(1)
      DRCATF=CYCTFW(1)
      DRCATW=CYCTBW(1)
C
C CALCULATION OF COWS
C
      PCOWBW(JJ,L)=ROTAL1+DT*NETWBC
      PCOWOW(JJ,L)=ROTAL2+DT*NETWOC
      ROTAL1=PCOWBW(JJ,L)
      ROTAL2=PCOWOW(JJ,L)
C
C
      RATIO1=PCOWBW(JJ,L)/(PCOWBW(JJ,L)+PCOWOW(JJ,L))
      TOTALB=WCATWB(I)*Q7(M)
      TOTAL2=WPBROW(I) *Q2(M)*(1.-V26)
      TOTAL3=VPBROW(I) *Q1(M)*(1.-V25)
      TOTAL4=WPBROW(I) *Q2(M)*V26
      TOTAL5=VPBROW(I) *Q1(M)*V25
      TOTAL7=WODRYW(I)*Q7(M)
C
      IF(I .LT.23)GO TO 408
      TOTALB=0.0
      TOTAL2=0.0
      TOTAL3=0.0
      TOTAL4=0.0
      TOTAL5=0.0
      TOTAL7=0.0
      DO 609 K=1,3
      J=COUNTR+K
      TOTALB=TOTALB+XCATW9(I,J)
      TOTAL2=TOTAL2+XPBFW(I,J)
      TOTAL3=TOTAL3+YPBFW(I,J)
      TOTAL4=TOTAL4+XPDRYW(I,J)
      TOTAL5=TOTAL5+YPDRYW(I,J)
      TOTAL7=TOTAL7+XOTDYW(I,J)
  609 CONTINUE
  408 CONTINUE
C
      IF(TOTALB.LE.2000) TOTALC=TOTALB*V13
      IF(TOTALB.GT.2000) TOTALC=1600+(TOTALB-1600)*V131
C
      YCOWBW=TOTAL3*V19*4
      YCOWOW=TOTAL5*V19*4
      XCOWBW=TOTAL2*V18*4+TOTALC*RATIO1*4
      XCOWOW=TOTAL4*V19*4+TOTALC*(1.-RATIO1)*4+TOTAL7*4
C
      XSCOWBW=SCOWBW
      SCOWBW=RBCWSLW(I,M)*4

      SCOWOW=ROCWSLW(I,M)*4
      DCOWBW=PCOWBW(JJ,L)*DRCATW
      DCOWOW=PCOWOW(JJ,L)*DRCATW
C
C
C CALCULATION OF BULLS
C
      PBULLW(JJ,L)=ROTAL3+DT*NETWBL
      ROTAL3=PBULLW(JJ,L)
C
      SWBULL=RBLSLPW(I,M)*4
      XBULLW=TOTAL2*(1.-V18)*4+TOTAL4*(1.-V18)*4
      YBULLW=TOTAL3*(1.-V18)*4+TOTAL5*(1.-V18)*4
      DBULLW=PBULLW(JJ,L)*DRCATW
C
C CALCULATION OF HEIFERS(BRED AND FOR BREEDING)
C
      TOTAL5=0.0
      TOTAL6=0.0
      DO 612 K=1,LTHER
      TOTAL5=TOTAL5+TNWBHR(K)
      TOTAL6=TOTAL6+TNWOHR(K)
  612 CONTINUE
  PHFRBW(JJ,L)=TOTAL5 *DT
      PHFROW(JJ,L)=TOTAL6 *DT
C
      IF(I.EQ.26) N=I
      IF(I.LT.26) N=I+1
      AHFRBW=RBHFRPW(N,M)/(1.-DRCATW)*4
      AHFROW=ROHFRPW(N,M)/(1.-DRCATW)*4
      ABULLW=RBLRPLW(I,M)*4
C
      XHFRBW=CHFRBW
      XHFROW=CHFROW
      BHFRBW=AHFRBW*(1.-DRCATW)
      BHFROW=AHFROW*(1.-DRCATW)
      CALL BOXC(BHFRBW,CHFRBW,TNWBHR,NCOUNT,NOCY,LTHER,SUMIN)
      CALL BOXC(BHFROW,CHFROW,TNWOHR,NCOUNT,NOCY,LTHER,SUMIN)
C
      NETWBL=ABULLW*0.970+YBULLW-XBULLW-SWBULL-DBULLW
      NETWBC=CHFRBW+YCOWBW-XCOWBW-SCOWBW-DCOWBW
      NETWOC=CHFROW*1.000+YCOWOW-XCOWOW-SCOWOW-DCOWOW
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```
C
C CALCULATION OF CALVES(1-3)
C
      PCMBW1(JJ,L)=ACMBW1*DT
      PCMDW1(JJ,L)=ACMDW1*DT
      PCFBW1(JJ,L)=ACFBW1*DT
      PCFDW1(JJ,L)=ACFDW1*DT
C
      IF(LHIGH.LT.16)GO TO 303
      LOW=1
      LHIGH=4
  303 BROWBC=(PCOWBW(JJ,L)-XHFRBW*DT*V41*4)*BRWBC*INGRAT(LOW,LHIGH,
     1VALBW)*4
      BROWDC=(PCOWDW(JJ,L)-XHFRDW*DT*V40*4)*BRWDC*INGRAT(LOW,LHIGH,
     1VALDW)*4
      BROWBH=XHFRBW*DT*BRWBH*4
      BROWDH=XHFRDW*DT*BRWDH*4
C
      LOW=LHIGH
      LHIGH=LHIGH+3
C
      CALL BOXC(BROWBC,BTHWBC,TNWBC,NCOUNT,NOCY,LTBTH,SUMIN)
      CALL BOXC(BROWDC,BTHWDC,TNWDC,NCOUNT,NOCY,LTBTH,SUMIN)
      CALL VDELDT(BROWDH,BTHWDH,CTRWDH,DFLWDH,DEPWDH,IDT,DT,KWDH)
C
      BTHWB=BTHWBC+BROWBH
      BTHWD=BTHWDC+BTHWDH
      BMBCW=BTHWB*.5
      BMDCW=BTHWD*.5
      BFBCW=BTHWB*.5
      BFDCW=BTHWD*.5
      DMBCW1=BMBCW*DPMBCW*DT
      DFBCW1=BFBCW*DPFBCW*DT
      DMDCW1=BMDCW*DPMDCW*DT
      DFDCW1=BFDCW*DRFDCW*DT
      ACMBW1=BMBCW-DMBCW1

      ACMDW1=BMDCW-DMDCW1
      ACFBW1=BFBCW-DFBCW1
      ACFDW1=BFDCW-DFDCW1
C
      CALL BOXC(ACMBW1,BCMBW1,TNMBW1,NCOUNT,NOCY,LTMBW1,SUMIN)
      CALL BOXC(ACMDW1,BCMDW1,TNMDW1,NCOUNT,NOCY,LTMDW1,SUMIN)
      CALL BOXC(ACFBW1,BCFBW1,TNFBW1,NCOUNT,NOCY,LTFBW1,SUMIN)
      CALL BOXC(ACFDW1,BCFDW1,TNFDW1,NCOUNT,NOCY,LTFDW1,SUMIN)
C
C CALCULATION OF CALVES(4-6)
C
      PCMBW2(JJ,L)=CCMBW2*DT
      PCMDW2(JJ,L)=CCMDW2*DT
      PCFBW2(JJ,L)=CCFBW2*DT
      PCFDW2(JJ,L)=CCFDW2*DT
C
      SMBCW2=PCSLRMW(I,M)*V1*4
      SMDCW2=RCSLRMW(I,M)*(1.-V1)*4
      SFBCW2=PCSLRFW(I,M)*V2*4
      SFDCW2=RCSLRFW(I,M)*(1.-V2)*4
      DMBCW2=(BCMBW1-SMBCW2)*DPMBCW*DT
      DMDCW2=(BCMDW1-SMDCW2)*DPMDCW*DT
      DFBCW2=(BCFBW1-SFBCW2)*DPFBCW*DT
      DFDCW2=(BCFDW1-SFDCW2)*DRFDCW*DT
      CCMBW2=BCMBW1-SMBCW2-DMBCW2
      CCMDW2=BCMDW1-SMDCW2-DMDCW2
      CCFBW2=BCFBW1-SFBCW2-DFBCW2
      CCFDW2=BCFDW1-SFDCW2-DFDCW2
C
      CALL BOXC(CCMBW2,DCMBW2,TNMBW2,NCOUNT,NOCY,LTMBW2,SUMIN)
      CALL BOXC(CCMDW2,DCMDW2,TNMDW2,NCOUNT,NOCY,LTMDW2,SUMIN)
      CALL BOXC(CCFBW2,DCFBW2,TNFBW2,NCOUNT,NOCY,LTFBW2,SUMIN)
      CALL BOXC(CCFDW2,DCFDW2,TNFDW2,NCOUNT,NOCY,LTFDW2,SUMIN)
C
C CALCULATION OF CALVES(7-12) ON RATION A
C
      TOTAL7=0.0
      TOTAL8=0.0
      TOTAL9=0.0
      TOTAL10=0.0
      DO 613 K=1,LTMBW3
      TOTAL7=TOTAL7+TNMBW3(K)
      TOTAL8=TOTAL8+TNMDW3(K)
      TOTAL9=TOTAL9+TNFBW3(K)
      TOTAL10=TOTAL10+TNFDW3(K)
  613 CONTINUE
C
      PCMBW3(JJ,L)=TOTAL7*DT
      PCMDW3(JJ,L)=TOTAL8*DT
      PCFBW3(JJ,L)=TOTAL9*DT
      PCFDW3(JJ,L)=TOTAL10*DT
C
      TOTAL4=0.0
      DO 406 K=1,3
      J=COUNTP+K
      TOTAL4=TOTAL4+ZCVSTK(I,J)+ZCVFD(I,J)
  406 CONTINUE
C
      TOTAL3=WCAVW7(I) *D6(M)
C
      IF(I .LT.23)GO TO 604
      TOTAL3=0.0
      DO 605 K=1,3
      J=COUNTP+K
      TOTAL3=TOTAL3+XCAVW7(I,J)
  605 CONTINUE
  604 CONTINUE
C
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      XMBCW3=TOTAL3*V4*V6*4
      XFBCW3=TOTAL3*(1.-V4)*V6*4
      ZMBCW3=TOTAL4*V5*V9*4
      ZFBCW3=TOTAL4*(1.-V5)*V9*4
      XMDCW3=0.0
      XFDCW3=0.0
      ZMDCW3=0.0
      ZFDCW3=0.0
C
      ECMBW4=(DCMBW2-XMBCW3-ZMBCW3)*V7

      ECMDW4=(DCMDW2-XMDCW3-ZMDCW3)*V27
      ECFBW4=(DCFBW2-XFBCW3-ZFBCW3)*V8
      ECFDW4=(DCFDW2-XFDCW3-ZFDCW3)*V28
      DMBCW3=(DCMBW2-ECMBW4-XMBCW3-ZMBCW3)*DPMBCW  *2*DT
      DMDCW3=(DCMDW2-ECMDW4-XMDCW3-ZMDCW3)*DPMDCW  *2*DT
      DFBCW3=(DCFBW2-ECFBW4-XFBCW3-ZFBCW3)*DPFBCW  *2*DT
      DFDCW3=(DCFDW2-ECFDW4-XFDCW3-ZFDCW3)*DPFDCW  *2*DT
      FCMBW3=DCMBW2-ECMBW4-XMBCW3-ZMBCW3-DMBCW3
      FCMDW3=DCMDW2-ECMDW4-XMDCW3-ZMDCW3-DMDCW3
      FCFBW3=DCFBW2-ECFBW4-XFBCW3-ZFBCW3-DFBCW3
      FCFDW3=DCFDW2-ECFDW4-XFDCW3-ZFDCW3-DFDCW3
C
      CALL  BOXC(FCMBW3,GCMBW3,TNMBW3,NCOUNT,NOCY,LTMBW3,SUMIN)
      CALL  BOXC(FCMDW3,GCMDW3,TNMDW3,NCOUNT,NOCY,LTMDW3,SUMIN)
      CALL  BOXC(FCFBW3,GCFBW3,TNFBW3,NCOUNT,NOCY,LTFBW3,SUMIN)
      CALL  BOXC(FCFDW3,GCFDW3,TNFDW3,NCOUNT,NOCY,LTFDW3,SUMIN)
C
C CALCULATION OF FEEDER CATTLE,RATION B
C
      TOTAL11=0.0
      TOTAL12=0.0
      TOTAL13=0.0
      TOTAL14=0.0
      DO 614 K=1,KMBW4
      TOTAL11=TOTAL11+CTMBW4(K)*IDT
      TOTAL12=TOTAL12+CTMDW4(K)*IDT
      TOTAL13=TOTAL13+CTFBW4(K)*IDT
      TOTAL14=TOTAL14+CTFDW4(K)*IDT
  614 CONTINUE
      PCMBW4(JJ,L)=TOTAL11*DT*DLMBW4
      PCMDW4(JJ,L)=TOTAL12*DT*DLMDW4
      PCFBW4(JJ,L)=TOTAL13*DT*DLFBW4
      PCFDW4(JJ,L)=TOTAL14*DT*DLFDW4
C
      KCMBW4=ECMBW4*(1.-DRCATF*DLMBW4)
      KCMDW4=ECMDW4*(1.-DRCATF*DLMDW4)
      KCFBW4=ECFBW4*(1.-DRCATF*DLFBW4)
      KCFDW4=ECFDW4*(1.-DRCATF*DLFDW4)
C
      CALL  VDELDT(KCFBW4,LCFBW4,CTFBW4,DLFBW4,DPFBW4,IDT,DT,KFBW4)
      CALL  VDELDT(KCFDW4,LCFDW4,CTFDW4,DLFDW4,DPFDW4,IDT,DT,KFDW4)
      CALL  VDELDT(KCMBW4,LCMBW4,CTMBW4,DLMBW4,DPMBW4,IDT,DT,KMBW4)
      CALL  VDELDT(KCMDW4,LCMDW4,CTMDW4,DLMDW4,DPMDW4,IDT,DT,KMDW4)
C
C CALCULATION OF FEEDER CATTLE,RATION A
C
      TOTAL1=0.0
      TOTAL2=0.0
      TOTAL3=0.0
      TOTAL4=0.0
      DO 611 K=1,KMBW5
      TOTAL1=TOTAL1+CTMBW5(K)*IDT
      TOTAL2=TOTAL2+CTMDW5(K)*IDT
      TOTAL3=TOTAL3+CTFBW5(K)*IDT
      TOTAL4=TOTAL4+CTFDW5(K)*IDT
  611 CONTINUE
      PCMBW5(JJ,L)=TOTAL1*DT*DLMBW5
      PCMDW5(JJ,L)=TOTAL2 *DT*DLMDW5
      PCFBW5(JJ,L)=TOTAL3 *DT*DLFBW5
      PCFDW5(JJ,L)=TOTAL4 *DT*DLFDW5
C
      TOTAL5=0.0
      DO 407 K=1,3
      J=COUNT2 +K
      TOTAL5=TOTAL5+ZCTFD(I,J)+ZCTSTK(I,J)
  407 CONTINUE
C
      TOTAL6=WCAVW7(I) *D7(M)
C
      IF(I .LT.23)GO TO 606
      TOTAL6=0.0
      DO 607 K=1,3
      J=COUNT2+K
      TOTAL6=TOTAL6+XCAVW7(I,J)
  607 CONTINUE
  606 CONTINUE
C
      XMBCW5=TOTAL6*(1.-V6)*V4*4
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      XFBCW5=TOTAL6*(1.-V6)*(1.-V4)*4
      ZMBCW5=TOTAL5*V12*V9*4
      ZFBCW5=TOTAL5*(1.-V12)*V9*4
      XMDCW5=0.0
      XFDCW5=0.0
      ZMDCW5=0.0
      ZFDCW5=0.0
C
      ABULBW=ABULLW*RATIO1
      ABULDW=ABULLW*(1.-RATIO1)
C
      DMBCW5=(GCMBW3-XMBCW5-ZMBCW5-ABULBW)*DRCATF  *DLMBW5
      DMDCW5=(GCMDW3-XMDCW5-ZMDCW5-ABULDW)*DRCATF  *DLMDW5
      DFBCW5=(GCFBW3-XFBCW5-ZMBCW5-AHFRBW)*DRCATF  *DLFBW5
      DFDCW5=(GCFDW3-XFDCW5-ZFDCW5-AHFRDW)*DRCATF  *DLFDW5
      HCMBW5=GCMBW3-XMBCW5-ZMBCW5-DMBCW5-ABULBW
      HCMDW5=GCMDW3-XMDCW5-ZMDCW5-DMDCW5-ABULDW
      HCFBW5=GCFBW3-XFBCW5-ZFBCW5-DFBCW5-AHFRBW
      HCFDW5=GCFDW3-XFDCW5-ZFDCW5-DFDCW5-AHFRDW
C
      CALL  VDELDT(HCMBW5,JCMBW5,CTMBW5,DLMBW5,DPMBW5,IDT,DT,KMBW5)
      CALL  VDELDT(HCMDW5,JCMDW5,CTMDW5,DLMDW5,DPMDW5,IDT,DT,KMDW5)
      CALL  VDELDT(HCFBW5,JCFBW5,CTFBW5,DLFBW5,DPFBW5,IDT,DT,KFBW5)
      CALL  VDELDT(HCFDW5,JCFDW5,CTFDW5,DLFDW5,DPFDW5,IDT,DT,KFDW5)
C
C
C CALCULATION OF SLAUGHTER CATTLE
C
      ASBMW(JJ,L)=(JCMBW5+LCMBW4)*DT
      ASDMW(JJ,L)=(JCMDW5+LCMDW4)*DT
      ASBFW(JJ,L)=(JCFBW5+LCFBW4)*DT
      ASDFW(JJ,L)=(JCFDW5+LCFDW4)*DT
C
      TOTAL9=0.0
      DO 405 K=1,3
      J=COUNTP+K
      TOTAL9=TOTAL9+ZCTSLR(I,J)
  405 CONTINUE
C
      TOTAL1=VOTHRW(I) *D4(M)
      TOTAL8=TOTAL8-TOTALC
C
      IF(I .LT.23)GO TO 602
      TOTAL1=0.0
      DO 603 K=1,3
      J=COUNTP+K
      TOTAL1=TOTAL1+VOTHRW(I,J)
  603 CONTINUE
  602 CONTINUE
C
      XSMBW6=TOTAL8*V14
      XSFBW6=TOTAL8*(1.-V14)
      ZSMBW6=TOTAL9*V15*V9
      ZSFBW6=TOTAL9*(1.-V15)*V9
      YSMBW6=TOTAL1*V16
      YSFBW6=TOTAL1*(1.-V16)
      XSMDW6=0.0
      XSFDW6=0.0
      ZSMDW6=0.0
      ZSFDW6=0.0
      YSMDW6=0.0
      YSFDW6=0.0
C
      TOTAL=USTKEW(JJ)/4+USTKSW(JJ)/4+USRTQW(JJ,L)
C
      SLRMDW(JJ,L)=ASDMW(JJ,L)
      SLRMBW(JJ,L)=ASBMW(JJ,L)-XSMBW6-ZSMBW6+YSMBW6-TOTAL *V36
      SLRFBW(JJ,L)=ASBFW(JJ,L)-XSFBW6-ZSFBW6+YSFBW6-TOTAL*(1.-V11-V35
     1-V36)
      SLRFDW(JJ,L)=ASDFW(JJ,L)
C
      TSLRMW(JJ,L)=SLRMBW(JJ,L)+SLRMDW(JJ,L)
      TSLRFW(JJ,L)=SLRFBW(JJ,L)+SLRFDW(JJ,L)
C
C PRINT OUTPUT OF SIMULATION AND LIVESTOCK STOCK FIGURES
C
      IF(L.EQ.4)I=JJ
      IF(L.EQ.1) COUNTP=0.0

      IF(L.EQ.2)COUNTP=3.0
      IF(L.EQ.3) COUNTP=6.0
      IF(L.EQ.4)COUNTP=9.0
C
      TOTAL1= PCMBW1(JJ,L)+PCFBW1(JJ,L)+PCMBW2(JJ,L)+PCFBW2(JJ,L)
     1+PCMBW3(JJ,L)+PCFBW3(JJ,L)+PCMBW4(JJ,L)*(1.-(DLMBW4-.5)/DLMBW4)
     2+PCFBW4(JJ,L)*(1.-(DLFBW4-.5)/DLFBW4)
C
      TOTAL2=PCMBW5(JJ,L)+PCMBW4(JJ,L)*(DLMBW4-.5)/DLMBW4
      TOTAL3=PCFBW5(JJ,L)+PCFBW4(JJ,L)*(DLFBW4-.5)/DLFBW4+PHFRBW(JJ,L)
C
      TOTAL4=PCMDW1(JJ,L)+PCFDW1(JJ,L)+PCMDW2(JJ,L)+PCFDW2(JJ,L)
     1+PCMDW3(JJ,L)+PCFDW3(JJ,L)+PCMDW4(JJ,L)*(1.-(DLMDW4-.5)/DLMDW4)
     2+PCFDW4(JJ,L)*(1.-(DLFDW4-.5)/DLFDW4)
C
      TOTAL5=PCMDW5(JJ,L)+PCMDW4(JJ,L)*(DLMDW4-.5)/DLMDW4
      TOTAL6=PCFDW5(JJ,L)+PCFDW4(JJ,L)*(DLFDW4-.5)/DLFDW4+PHFRDW(JJ,L)
C
      TOTAL7=TOTAL1+TOTAL4
      TOTAL8=TOTAL2+TOTAL5
      TOTAL9=TOTAL3+TOTAL6
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C
      TSTEEP=0.0
      THEIFR=0.0
      DO 382 K=1,3
      J=COUNTR+K
      TSTEFR=TSTEER+SSTRW(I,J)
      THEIFR=THEIFR+SHFRW(I,J)
  382 CONTINUE
C
      IF(L.EQ.1) COUNTR=3.0
      IF(L.EQ.2)COUNTR=6.0
      IF(L.EQ.3) COUNTR=9.0
      IF(L.EQ.4)COUNTR=0.0
C
      IF(L.EQ.2.OR.L.EQ.4)GO TO 374
      MM=JJ+46
      PRINT 373,MM,L,PCMBW1(JJ,L),PCFBW1(JJ,L),PCMBW2(JJ,L),PCFBW2(JJ,L)
     1,PCMBW3(JJ,L),PCFBW3(JJ,L),PCMBW4(JJ,L),PCFBW4(JJ,L),PCMBW5(JJ,L),
     2PCFBW5(JJ,L),PHFRBW(JJ,L),PCOWBW(JJ,L),PBULLW(JJ,L),SLRMBW(JJ,L),
     3SLRFBW(JJ,L)
  373 FORMAT('0',I2,I4,4X,13F8.0,2F10.0)
C
      PRINT 380,       PCMDW1(JJ,L),PCFDW1(JJ,L),PCMDW2(JJ,L),PCFDW2(JJ,L)
     1,PCMDW3(JJ,L),PCFDW3(JJ,L),PCMDW4(JJ,L),PCFDW4(JJ,L),PCMDW5(JJ,L),
     2PCFDW5(JJ,L),PHFRDW(JJ,L),PCOWDW(JJ,L),               SLRMDW(JJ,L),
     3SLRFDW(JJ,L)
  380 FORMAT(' ',10X,12F8.0,8X,2F10.0)
C
      PRINT 377,TOTAL1,TOTAL2,TOTAL3,TOTAL4,TOTAL5,TOTAL6,TSLRMW(I,L),
     1TSLRFW(I,L),TOTAL7,TOTAL8,TOTAL9,TSTEER,THEIFR
  377 FORMAT('0',5X,F15.0,15X,F15.0,15X,F15.0,/,6X,F15.0,15X,F15.0,15X,
     1F15.0,34X,2F10.0/6X,F15.0,15X,F15.0,15X,F15.0,34X,2F10.0)
      GO TO 376
C
  374 ACALVES=RATIO1*CALVW(I,L)
      ASTERS=RATIO1*STRSW(I,L)
      BCALVES=(1.-RATIO1)*CALVW(I,L)
      BSTERS=(1.-RATIO1)*STRSW(I,L)
      CCALVE =ACALVES+BCALVES
      CSTERS=ASTERS+BSTERS
C
      MM=JJ+45
      PRINT 373,MM,L,PCMBW1(JJ,L),PCFBW1(JJ,L),PCMBW2(JJ,L),PCFBW2(JJ,L)
     1,PCMBW3(JJ,L),PCFBW3(JJ,L),PCMBW4(JJ,L),PCFBW4(JJ,L),PCMBW5(JJ,L),
     2PCFBW5(JJ,L),PHFRBW(JJ,L),PCOWBW(JJ,L),PBULLW(JJ,L),SLRMBW(JJ,L),
     3SLRFBW(JJ,L)
C
      PRINT 380,       PCMDW1(JJ,L),PCFDW1(JJ,L),PCMDW2(JJ,L),PCFDW2(JJ,L)
     1,PCMDW3(JJ,L),PCFDW3(JJ,L),PCMDW4(JJ,L),PCFDW4(JJ,L),PCMDW5(JJ,L),
     2PCFDW5(JJ,L),PHFRDW(JJ,L),PCOWDW(JJ,L),               SLRMDW(JJ,L),
     3SLRFDW(JJ,L)
C
      PRINT 381,TOTAL1,ACALVES,TOTAL2,ASTERS,TOTAL3,BHFRW(I,L),BCOWW
     1(I,L),          TOTAL4,BCALVES,TOTAL5,BSTERS,TOTAL6,DHFRW(I,L),DCOWW
     2(I,L),          TSLRMW(I,L),TSLRFW(I,L),TOTAL7,CCALVE,TOTAL8,CSTERS,
     3TOTAL9,          BULLW(I,L),TSTEER,THEIFR
  381 FORMAT('0',5X,6F15.0, F11.0,/,6X,6F15.0, F11.0, 8X,2F10.0,/,6X,


     15F15.0,24X,F10.0,2F10.0)
C
  376 CONTINUE
  348 CONTINUE
  349 CONTINUE
      END


C
C SUBROUTINE BOXC
C
      SUBROUTINE BOXC(RINR,BOUTR,TRAIN,NCOUNT,NOCY,LT,SUMIN)
      DIMENSION TRAIN(10)
      NCOUNT=NCOUNT+1
      SUMIN=SUMIN+RINR
      IF(NCOUNT.NE.NOCY)GO TO 1
      BOUTR=TRAIN(1)/FLOAT(NOCY)
      DO 3 I=2,LT
    3 TRAIN(I-1)=TRAIN(I)
      TRAIN(LT)=SUMIN
      SUMIN=0.0
      NCOUNT=0
    1 RETURN
      END
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C
C SUBROUTINE CBOX
C
      SUBROUTINE CBOX(CYCLE,LT,NCY,NK)
      DIMENSION CYCLE(5)
      NK=NK+1
      IF(NCY.GT.NK)GO TO 1
      TEMP=CYCLE(1)
      DO 2 I=2,LT
    2 CYCLE(I-1)=CYCLE(I)
      CYCLE(LT)=TEMP
      NK=0
    1 RETURN
      END
```

```
C
C SUBROUTINE VDELDT
C
      SUBROUTINE VDELDT(RINR,ROUTR,CROUTR,DEL,DELP,IDT,DT,K)
      DIMENSION CROUTR(10)
      XIDT=FLOAT(IDT)
      DEL1=(DEL*IDT)/(FLOAT(K)*DT)
      DELD=(DEL-DELP)/(DT*K)
      DELP=DEL
      ROUTR=0.0
      DO 2 J=1,IDT
      RIN=RINR/XIDT
      DO 1 I=1,K
      ABC=CROUTR(I)
      CROUTR(I)=ABC+(RIN-ABC*(1.+DELD))/DEL1
    1 RIN=ABC
    2 ROUTR=ROUTR+CROUTR(K)
      RETURN
      END
```

```
C
C FUNCTION INGRAT
C
      REAL FUNCTION INGRAT(IBEG,IEND,VAL)
      DIMENSION VAL(15),DEP(10)
      KK=(IEND-IBEG)+1
      K=0
      DO 1 I=1,KK
      DEP(I)=VAL(IBEG+K)
      K=K+1
    1 CONTINUE
      AREA=0.0
      KKK=IEND-IBEG
      DO 4 I=1,KKK
      AREA=AREA+(DEP(I)+DEP(I+1))/2
    4 CONTINUE
      INGRAT=AREA
    2 CONTINUE
      END
```

APPENDIX F

DISAGGREGATE QUARTERLY CATTLE AND CALF POPULATION--
1958-1972, ESTIMATED BY PROGRAM CATSIM2

Appendices F and G display the output of CATSIM2 for the parameter settings given in Chapter V. These are not necessarily the correct settings; the correct setting is undoubtedly a function of a wide range of factors not considered at this stage of development. Indeed, the structure of CATSIM may be in substantial error and itself a function of both exogenous and endogenous factors.

These appendices are included to demonstrate the sorts of output possible from a model such as CATSIM2. The obvious anomalies in the output underline the fact that additional work must be done. The reasonableness of most of these results support the contention that this work is worth pursuing.

APPENDIX F. DISAGGREGATE QUARTERLY CATTLE AND CALF POPULATION--1958-1972, ESTIMATED BY PROGRAM CATSIM2
DAIRY CATTLE, EAST

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1958	1	215204	217619	133250	170153	39566	237394	133525	0	66095	78167	368915	2209330	115196
	2	151395	200842	44568	145269	97814	284767	162599	0	37342	76771	356628	2208122	138485
	3	192772	201250	72656	160489	104478	309740	146632	0	35948	83648	338760	2202398	117805
	4	236238	251145	109319	168545	69561	302394	140825	0	81201	130636	328804	2149318	101607
1959	1	155461	198127	155499	219257	107131	323223	152365	0	74336	117676	350671	2157002	107282
	2	121525	166425	16151	128578	155072	377519	189843	0	60576	120670	367846	2156973	133054
	3	145193	166355	39017	132054	100639	340183	155469	0	87030	138679	380838	2145634	115843
	4	193155	238759	79600	139005	32737	257766	126921	0	131723	199244	389435	2113916	103586
1960	1	152337	195268	110062	175663	69767	266270	121219	0	98567	155166	391101	2141924	108719
	2	118046	163989	17692	129986	111066	307116	138824	0	58958	117295	397074	2162695	133036
	3	143695	165570	34959	129596	74951	330003	114291	0	68304	101894	404199	2155436	114776
	4	193219	209260	75736	136339	31243	256727	96607	0	95747	131254	410330	2124027	101671
1961	1	154736	176574	109733	174738	65096	261237	101158	0	70470	106974	403796	2151786	106682
	2	113270	160558	12723	119157	109611	303611	127295	0	38077	98424	397726	2173995	1 2137
	3	145559	165704	40095	127969	71810	288390	105732	0	51831	87726	392393	2182184	116449
	4	192117	209784	72943	134788	31343	244408	93823	0	83401	127302	387904	2147919	103944
1962	1	156713	180612	110173	177540	65508	258115	99005	0	61523	96076	391139	2164612	107404
	2	112952	161423	6431	122175	107233	304832	126382	0	37357	76454	394237	2171163	129702
	3	142169	165453	24524	124116	65334	294110	102164	0	52716	78939	392602	2156016	110961
	4	193315	207978	64425	131672	18369	243561	82940	0	85666	124636	391195	2102370	97430
1963	1	161265	133479	111008	174981	52280	251263	85010	0	60270	83697	409737	2115556	102585
	2	114338	160939	12555	120707	102734	299293	115427	0	27694	50741	427060	2125094	127675
	3	141412	163904	27361	122581	72456	290160	97901	0	40977	52751	431499	2110644	110908
	4	193266	205678	69017	132205	23686	240612	83195	0	77588	133017	432621	2065909	97703
1964	1	153765	177169	114214	172212	56067	250265	88479	0	58511	70960	428920	2100127	101325
	2	102518	154138	7562	109393	105714	297111	120385	0	31162	45449	424773	2123684	122661
	3	135906	161638	15749	115114	71371	276269	99399	0	44718	34725	446697	2113920	107636
	4	193955	203547	56238	124912	13833	222037	77742	0	80472	73077	464771	2066332	95675
1965	1	137174	167818	84212	159854	42278	235761	76807	0	57819	51928	447763	2099599	99636
	2	99509	151200	-21099	99251	82247	277931	95235	0	23989	39192	432740	2113454	121454
	3	131334	159505	-10300	102604	36794	254176	63648	0	32909	46218	407753	2101385	102871
	4	192704	203251	49363	120211	-18632	199634	35736	0	57770	90161	388346	2049259	90556
1966	1	131127	169992	82624	157124	22209	218801	40581	0	28448	73966	367074	2049509	92644
	2	74637	154514	-12900	103643	76706	270679	69435	0	-6964	61345	347241	2052872	111968
	3	125945	157774	2159	120927	40730	255856	52077	0	8279	59685	347063	2047137	98295
	4	172642	135562	55439	124569	-6373	222100	37475	0	41800	94410	348305	2006260	86223
1967	1	139293	172161	85627	155752	33746	241176	49098	0	22405	71714	357299	2007784	89907
	2	79382	150997	-7314	107576	82608	273593	79171	0	-3955	65453	365634	2002264	110074
	3	127215	156982	5443	113633	45803	258406	62211	0	15047	57975	375797	1997689	96549
	4	173160	193875	60134	126139	-1110	224710	46322	0	48540	85894	384542	1962009	86480

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1968	1	129904	171049	87433	154455	38444	241428	57487	0	29967	59923	394239	1966076	89270
	2	57850	151760	-3853	112395	85415	273859	85964	0	3638	48688	403248	1959940	107249
	3	112132	150342	-16525	119413	48914	261907	68498	0	21623	49381	399226	1961437	94769
	4	161724	198560	41334	119733	-12092	229258	39811	0	52962	82692	395765	1931435	84438
1969	1	115774	163837	72548	146774	14399	234929	46563	0	34195	59593	399505	1941786	86663
	2	54670	149222	-2137	107920	66690	260081	63032	0	-2992	46402	402930	1933899	103814
	3	121485	147878	-10785	119136	41216	249984	50808	0	7175	55336	386295	1917935	90064
	4	164085	184962	53540	117731	-7668	224559	30992	0	34828	93318	371920	1977495	79971
1970	1	126624	162533	85103	150207	24953	232731	42894	0	22102	79191	352694	1878289	78874
	2	49958	145674	17784	111071	81190	261508	74078	0	-6125	74923	334911	1954934	91499
	3	114519	147778	-12966	119531	60390	256452	71197	0	10776	67900	345360	1912907	79915
	4	164367	193853	56300	124119	2859	228066	47101	0	43065	95527	354437	1759137	70747
1971	1	119890	155262	89657	150767	25275	239356	55333	0	37057	62619	378729	1737947	71779
	2	71115	137042	14445	107727	85473	268298	83894	0	3509	43257	401239	1696175	86936
	3	105463	142322	9711	112519	61075	253691	75754	0	19551	41478	409940	1659709	72506
	4	149967	174005	48647	119880	14334	217823	60405	0	52278	72899	415329	1621781	61640
1972	1	107787	147308	80155	144560	34250	228294	62950	0	42502	45193	415329	1643149	62876
	2	49577	129280	10310	102321	75427	258094	84223	0	17522	26991	415329	1639359	78161
	3	96063	129309	-298	109005	53057	242296	71744	0	28044	27395	415329	1631309	64224
	4	129286	160430	34270	108499	5941	208012	50963	0	54214	58955	415329	1596954	52219

BEEF CATTLE EAST

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
1958	1	31663	31663	13220	17211	46534	61005	233669	78937	42060	26096	67266	383750	115196
	2	73090	81776	12611	23535	27515	42326	182042	61593	55042	31891	70597	373252	138485
	3	27404	29214	67900	76965	8498	28127	132650	47676	72960	29152	74450	385311	117805
	4	31640	33161	19203	25542	35853	75866	173166	61002	83416	18950	73095	398034	101607
1959	1	33192	39993	22603	23444	37858	77333	150658	55191	70346	20989	70675	381038	107282
	2	77562	80974	21254	33147	13689	38308	131005	49621	79839	54260	64625	392294	133054
	3	23924	30726	69042	75812	17217	45411	117327	46067	89371	41140	67092	396016	115843
	4	33690	35119	21565	27619	43292	85679	177743	63584	102279	30710	72733	404937	103586
1960	1	37293	39175	24311	31298	41165	80425	164941	59311	91304	34934	74099	392506	108719
	2	77395	80756	20991	32809	16106	41746	146933	53552	98721	59561	82510	382307	133036
	3	27006	29833	67810	76601	15918	45498	122237	47959	92495	46675	76929	401636	114776
	4	35705	37152	19395	25528	46829	87539	195545	66093	90045	36619	70923	416380	101671
1961	1	40591	42433	26258	33150	47533	83037	181442	60736	75149	36784	71738	411610	106682
	2	79067	91248	24531	35790	17743	42594	163153	55262	90976	61245	73999	419737	132137
	3	31113	32919	69023	77278	21145	50951	145749	51128	96488	48235	75150	432166	116449
	4	33861	35420	22959	29305	60592	97312	242199	71948	96060	39209	76161	439589	103944

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1962	1	39733	41641	24606	31801	61582	93441	234069	67961	84446	39941	77593	435000	107404
	2	85953	89437	22767	34889	24676	47869	211829	61156	95502	62977	81173	444911	128702
	3	33659	35569	75765	84898	22920	50881	177788	54455	90317	53487	75979	457714	110961
	4	35633	37276	24923	31722	59412	99596	256696	75219	83430	44945	70698	465328	97430
1963	1	42189	43914	26703	33439	57590	96324	231750	69994	69461	42075	72502	461419	102585
	2	91912	95141	25381	36657	20627	47432	201133	62279	87757	63762	77236	474209	127675
	3	35537	38717	81812	90455	20681	50879	165265	55074	84763	53427	77431	490998	110908
	4	35232	36789	28625	35082	65824	107134	271007	79449	82802	43915	79499	481947	97703
1964	1	42274	43834	26932	32904	69067	107177	258228	75707	75549	35443	89312	479470	101325
	2	99968	101918	25727	35994	24165	50565	225960	66647	103090	57250	98870	496658	122661
	3	45422	42211	88845	97116	22031	50440	186475	57741	110014	47463	107377	497952	107636
	4	36160	37739	31331	37997	83130	119610	331929	87483	114131	37603	113825	493223	95675
1965	1	43652	45761	24829	32701	90660	124364	326995	85054	108939	39030	105966	490334	99636
	2	107346	110722	25725	37818	29186	55125	279734	73819	139563	92092	90917	506765	121454
	3	45654	47041	95720	104917	21670	51549	221991	62799	133273	72542	88126	496202	102871
	4	43320	41952	35697	42514	74584	119964	326583	89902	131794	58736	85660	479947	90556
1966	1	47235	49267	28959	36593	81364	125474	310418	87083	117979	55692	82775	465336	92644
	2	135699	139629	30940	41530	30627	60523	269236	76943	137844	89553	86064	465526	111968
	3	39599	41653	98105	105399	25053	58144	222523	67048	132620	77881	86636	469199	98295
	4	39904	40199	31613	37234	95337	134192	384847	99365	133885	64148	87136	465227	86223
1967	1	44720	46530	28900	35554	101928	134945	372620	93886	116988	58578	90004	462323	89907
	2	96737	99826	29080	39995	37096	60914	332272	82431	155825	95359	97173	477605	110074
	3	39090	40690	88038	95884	35702	62139	282496	71351	170227	97542	81865	493909	96549
	4	33240	39599	31499	37146	99939	131299	424973	99139	166716	93249	66308	499493	86490
1968	1	44650	46395	28487	35003	100487	129495	394486	92635	143235	77233	73282	497477	89270
	2	103931	103788	29535	39553	31596	57240	328978	79387	170714	90136	90716	519244	107249
	3	43587	45172	92207	99716	29039	57314	264688	67913	161261	80869	96330	515538	94769
	4	33737	35241	35550	41611	105976	136543	433594	100361	145197	70631	101872	505678	84438
1969	1	43962	42650	23640	30426	113236	140898	417685	97021	119434	59828	99181	511515	86663
	2	113212	115559	27424	36144	39021	61542	362457	83404	154872	87638	92454	552082	103814
	3	52901	54275	105350	111791	27503	52934	279926	68389	136507	69859	107157	554257	90064
	4	35699	38112	45135	50717	100213	137409	436032	102436	116473	48027	121738	549416	78971
1970	1	44696	46367	27702	34051	111226	150558	413186	101120	91318	35335	124856	551953	78874
	2	119322	121489	32235	40310	33155	64712	341144	86220	130137	66619	132727	584309	91499
	3	52688	54077	111704	119005	24597	54594	268159	71776	125888	75828	112198	600086	79915
	4	46352	47346	45999	51241	103280	143822	430297	106590	107575	71492	91294	603401	70747

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1971	1	54265	55834	37417	43346	111626	153697	411146	104973	87214	55084	95029	613528	71779
	2	127534	129721	42059	50090	35308	69945	347698	91068	127618	76091	104390	652968	86936
	3	59978	60465	120054	126366	29448	65681	279176	78479	119359	78343	104893	646155	72506
	4	41228	42516	52504	57726	111025	156824	457983	115951	99241	74400	105200	631713	61640
1972	1	50710	52234	33177	38966	121318	166494	445302	114146	86513	62087	105200	639031	62876
	2	143793	145779	39414	46805	40267	73882	379508	97569	138771	89669	105200	687630	78161
	3	65514	67559	137602	142692	29204	62126	299564	81015	137054	93684	105200	680701	64224
	4	43039	44238	60446	65065	117668	166964	491207	122971	117595	85240	105200	664970	52219
DAIRY CATTLE WEST														
1958	1	94669	94669	54514	65829	23380	116961	123579	0	30264	46490	146039	821576	107172
	2	74486	74486	40184	61979	27652	122699	129990	0	24599	55114	142436	822356	118889
	3	71251	71251	26373	47715	27884	125546	126229	0	26795	52197	147417	819619	109017
	4	95843	85943	34902	46830	19747	108487	112348	0	33961	59911	151703	803958	99121
1959	1	79674	78674	56913	69666	18044	92897	105079	0	32883	59339	158113	801513	103804
	2	73744	73744	43237	61184	26883	113700	115298	0	22374	46765	164058	900383	118286
	3	59008	69008	39197	50746	29493	128535	117573	0	21733	30318	163220	803497	112038
	4	94612	94612	35495	38147	24458	110699	116343	0	29598	46288	162490	795426	107325
1960	1	79023	78023	57040	61944	22023	87419	111531	0	31541	46596	167069	800016	109709
	2	73413	73413	45060	55572	27094	97689	121604	0	27053	37621	171323	805401	120104
	3	55729	66729	35559	46992	30071	115418	123620	0	26288	20169	167666	907607	114042
	4	93077	83077	37262	33580	23920	101426	118138	0	32683	35035	164519	798778	108533
1961	1	75489	76489	58872	63415	21461	79240	113170	0	33612	49138	149691	807583	110668
	2	72560	72560	45417	55161	29148	94667	123752	0	26887	53253	133996	916950	122561
	3	59341	69341	38190	45043	30713	116447	125573	0	26305	41702	121624	814644	114324
	4	84823	84923	38181	33302	24806	99103	121461	0	33301	62835	110997	801919	108090
1962	1	75991	75981	59912	62219	22510	77051	116561	0	34391	64715	114816	794687	111174
	2	72005	72005	49222	56250	28722	93229	127111	0	28492	55695	118373	789054	124202
	3	69170	69170	43830	47903	32146	116357	130708	0	28148	34586	123683	775744	116763
	4	83940	83940	41036	33654	27609	103007	129530	0	35257	50190	128252	753852	108302
1963	1	77592	77892	63191	67040	25020	80222	125264	0	36716	59364	125047	752962	112235
	2	71117	71117	55229	61939	30518	98277	136220	0	31498	59445	122069	753046	128307
	3	65919	66919	46017	50315	34898	126688	141779	0	30430	44968	116723	747001	124336
	4	91720	81720	41497	37315	30039	111020	139699	0	36894	67884	112123	731845	119995
1964	1	71300	71300	63005	65430	25804	86182	133138	0	39319	82305	108091	728899	125350
	2	65763	66763	41446	47117	30598	100280	141461	0	33955	82050	104345	727023	142841
	3	63046	63046	38081	42045	30745	110459	135479	0	31724	69516	98366	716391	140954
	4	77347	77347	30724	23696	23596	88181	127049	0	36966	88183	93221	695561	138319

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1965	1	69943	69943	49769	47303	20295	64709	114188	0	35384	89951	83871	692914	142585
	2	64660	64660	42192	42779	23568	69295	116495	0	28871	85002	75195	689118	159129
	3	61200	61200	32945	36315	27091	88476	115800	0	25413	58287	74016	673583	154372
	4	74504	74504	24891	14120	22293	78224	109484	0	29210	61337	73011	651892	147666
1966	1	66486	66486	49749	45365	17063	49696	97910	0	30858	66533	70710	639143	147843
	2	60788	60788	41261	41407	21855	58057	104790	0	26628	66437	68572	628119	158782
	3	57544	57544	37822	36125	26809	85227	107358	0	24511	36543	70091	615864	148646
	4	69295	69295	26436	17131	23464	76679	107466	0	33572	43081	71379	596956	135877
1967	1	62782	62782	49042	46718	18962	52447	98946	0	31755	50888	74027	584752	140013
	2	56876	56876	41490	40130	22100	62316	106102	0	28174	54011	76497	574154	155784
	3	51561	51561	32789	25387	26670	85286	108731	0	25501	30714	77622	566340	147085
	4	62668	62668	25492	9956	22039	64796	104979	0	30357	40934	78598	552015	138572
1968	1	57611	57611	43799	38704	17190	34824	95624	0	31782	47737	79954	544142	141296
	2	52542	52542	39117	34796	20286	47492	99550	0	27566	39958	81233	537269	153617
	3	46890	46890	31707	24075	24430	72189	101497	0	25609	3697	89577	531321	140371
	4	57654	57654	24736	16694	21013	58223	98493	0	29953	4996	96757	520048	126853
1969	1	53023	53023	40371	38223	16650	40093	90376	0	30529	12256	100992	515276	130706
	2	48877	48877	38355	37432	19239	53590	94008	0	25747	11133	104907	510350	145706
	3	44166	44166	34092	32035	23376	74326	96876	0	23397	2771	94598	515155	135982
	4	54380	54380	28856	26934	21495	68703	96835	0	26925	18816	85728	511347	126828
1970	1	50571	50571	43191	43469	18564	57970	92608	0	28131	27079	86427	510946	131801
	2	47566	47566	39582	40873	21095	68712	98186	0	25029	28289	87077	510739	148967
	3	41563	41563	37196	35839	24390	82848	101508	0	24364	38670	72694	504392	141915
	4	51904	51904	30353	28857	22777	75867	102637	0	28477	64190	60318	492117	134700
1971	1	49276	49276	42205	41264	19920	63618	98193	0	29323	55693	67850	493706	142436
	2	45675	45675	41064	40559	21245	68448	101695	0	25888	40544	74848	495585	165536
	3	43533	43533	36518	35699	24541	80387	104724	0	24448	42313	77174	476171	161808
	4	53077	53077	32212	32438	23019	75419	104363	0	27274	60515	79175	453449	158017
1972	1	45691	45691	43597	43754	20267	66575	100450	0	29030	51486	79175	464745	162832
	2	41585	41585	37243	37448	22197	73373	104359	0	26361	37455	79175	475692	182293
	3	44338	44338	32992	33074	23815	79740	104207	0	26192	43633	79175	460492	172902
	4	53882	53882	33586	33771	20809	69746	100893	0	29786	64767	79175	440543	164869

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs	Bulls over 1 yr.
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
BEEF CATTLE WEST														
1958	1	161951	161951	13168	9010	225595	409955	378300	124380	30264	100744	276995	1550358	107172
	2	445088	446088	155079	152684	114827	206578	286025	87452	96955	118390	287129	1633665	118889
	3	84932	84932	439335	434848	57433	111563	278658	80940	166538	247313	275559	1619375	109017
	4	37169	37169	80470	76455	158425	336233	354360	110067	90045	151396	263999	1595902	99121
1959	1	197177	197177	33563	31614	132311	282977	323627	97575	79549	127893	260669	1617555	103804
	2	463138	463139	190978	189295	40012	78279	258691	72762	114626	157354	253090	1720468	118286
	3	83982	83982	456797	453066	79033	163920	281110	80336	74175	110840	270263	1701062	112038
	4	32320	32320	85806	79327	203943	437230	412036	130186	4077	27160	287446	1675101	107325
1960	1	200183	200183	28981	24714	166371	354079	381989	117134	30413	55098	306304	1684926	109709
	2	484993	484993	194222	190610	39295	75557	303080	85733	122579	146672	349408	1776772	120104
	3	98366	98366	478164	473650	81763	162496	318615	88603	107715	145494	329399	1773313	114042
	4	40489	40489	84647	76953	215998	466533	447749	140942	48974	81417	307370	1764393	108533
1961	1	215141	215141	37425	33781	170172	374252	402585	123728	67242	104403	300036	1793783	110668
	2	507598	507598	209209	205756	37150	74206	317373	90720	147981	217699	283470	1921954	122561
	3	107729	107729	501320	495055	82065	170920	325774	92675	106074	145447	325535	1886677	114324
	4	32825	32825	103827	95582	182896	424560	403124	131989	39938	26141	367600	1850110	108090
1962	1	219067	219067	29776	25236	140931	340040	363112	117826	56524	55300	369819	1865437	111174
	2	543700	543700	213566	210165	33007	77551	274460	84438	122136	139145	374891	1974989	124202
	3	102915	102915	537624	532809	76871	165459	296271	89344	105513	97133	380753	1974307	116763
	4	51473	51473	99265	96637	202239	456385	410081	137393	49369	-12322	386615	1964083	108302
1963	1	244848	244848	48662	45558	162112	369355	382237	123758	74580	19958	407912	1985264	112235
	2	558843	558843	239495	236904	48207	98322	311163	94065	145809	93836	456592	2105417	128307
	3	106680	106680	553024	548965	103310	212880	350338	103611	124924	61443	463127	2121804	124336
	4	55350	55350	103310	95349	242864	548615	493168	164581	69403	-20016	469662	2134975	119995
1964	1	261203	261203	52715	49582	186867	438011	449763	146636	93545	39482	476436	2179542	125350
	2	602589	602589	254546	250293	49697	105063	364140	110384	178131	161029	491918	2333209	142841
	3	129786	129786	596129	591159	112598	225143	396105	115644	133487	121874	486779	2349598	140954
	4	60221	60221	125519	116071	271010	577470	556347	176622	56095	23476	481640	2344773	138319
1965	1	286487	286487	56537	49793	211230	460986	504699	155300	75454	75709	466783	2367537	142595
	2	666368	666368	280359	274275	54024	101138	406919	114499	183922	230205	432824	2529265	159129
	3	140534	140534	659219	653374	123747	221298	440137	118268	155561	181496	427499	2509809	154372
	4	60703	60703	135764	124180	320032	476950	646930	151961	72454	51325	422174	2444775	147666
1966	1	306198	306198	57323	50559	257005	366521	591822	135430	99713	105027	410591	2411261	147843
	2	712410	712410	299809	294430	59753	112881	473484	100384	245009	175064	384117	2517930	158782
	3	129361	129361	705977	700392	129699	242965	496050	115154	213769	158139	363334	2496312	149646
	4	59732	59732	125228	115284	321702	565562	676820	169676	115589	64775	342551	2431997	135877

APPENDIX F--Continued

Year	Quarter	Calves 1-3 mos. Male	Calves 1-3 mos. Female	Calves 4-6 mos. Male	Calves 4-6 mos. Female	Stream A Calves 7-12 mos. Male	Stream A Calves 7-12 mos. Female	Stream B Cattle over 7 mos. Male	Stream B Cattle over 7 mos. Female	Stream A Cattle over 12 mos. Male	Stream A Cattle over 12 mos. Female	Replace Heifers 1-2 yrs.	Cows over 2 yrs.	Bulls over 1 yr.
		(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)	(year)
1967	1	339068	339068	56857	51767	243368	430917	595443	151385	136343	148204	343952	2415414	140013
	2	734810	734810	303078	299060	45238	110812	460085	112544	251845	277278	347154	2514469	155784
	3	118050	118050	698292	690542	116865	253496	470928	124467	173971	225590	352128	2462544	147085
	4	53991	50891	114534	103627	308798	660475	645499	196990	71095	105961	357102	2399229	138572
1968	1	300927	300927	48267	42543	234073	509451	565588	172093	99992	169860	363839	2359992	141296
	2	734492	734492	295339	289941	44824	98513	441891	125545	228535	358239	379139	2444930	153617
	3	119752	119752	698335	691225	121063	245953	462134	130537	184521	279178	389511	2393393	140371
	4	52433	52433	115666	108116	303033	656938	626326	199445	101807	126152	399853	2326519	126853
1969	1	296435	296435	50827	45557	220732	512648	545258	173663	130415	168162	407152	2316773	130706
	2	689637	689637	291319	287893	35733	101371	416453	126552	242316	339029	423766	2427518	145706
	3	123911	123911	583236	679325	118170	252196	446563	132650	207687	274912	422199	2419781	135982
	4	55979	55979	121456	117467	304394	718588	618154	215050	127222	135670	420632	2421275	126828
1970	1	295934	295934	54137	51888	229658	579536	551514	190266	156406	150061	455491	2449228	131801
	2	687019	687019	291130	289253	52770	124027	440211	141715	265252	298006	535138	2590490	148967
	3	131291	131291	662116	679419	125890	264030	466326	143066	218968	264001	521631	2591420	141915
	4	56512	56512	129349	126413	304140	722990	635358	222045	141173	158304	508124	2593392	134700
1971	1	310573	310573	54825	52495	233553	590310	568770	196102	161676	189929	493194	2649257	142436
	2	745100	745100	306000	304139	57287	132261	454206	145716	261490	366042	459033	2859611	165536
	3	167789	167789	740012	737760	135617	276368	487726	148507	221638	290614	492990	2934602	161808
	4	53027	53027	165635	163115	329695	774555	679281	235964	146132	135728	526767	2799322	158017
1972	1	323093	323093	51408	49495	263499	657325	624966	214630	167626	173313	526767	2819356	162832
	2	810930	810930	323279	321591	64389	155300	492716	158893	275785	332390	526767	2999184	182293
	3	159096	159096	805530	803709	137418	296044	524118	160073	240876	343484	526767	2996577	172902
	4	69741	69741	156059	153785	359462	808830	738852	248546	156216	168559	526767	2992575	164869

APPENDIX 6

DISAGGREGATE QUARTERLY INSPECTED STEER AND HEIFER SLAUGHTER--1961-1972, ESTIMATED BY PROGRAM CATSIM2

Year	Quarter	WEST						EAST					
		Steers			Heifers			Steers			Heifers		
		Beef	Dairy	Total	Beef	Dairy	Total	Beef	Dairy	Total	Beef	Dairy	Total
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1961	1	86325	40804	127130	41664	13207	54870	61126	53576	114702	10768	46060	56828
	2	84253	39960	124213	55479	16838	72317	76560	45707	122207	14620	40156	54776
	3	99133	39716	138849	54892	16480	71371	54373	45693	100066	12895	37054	49949
	4	86518	40943	127460	36778	17193	53971	53794	50372	104166	8835	42441	51276
1962	1	88339	41795	130134	27013	20616	47629	58586	48598	107184	9276	42735	52011
	2	88639	41210	129849	36713	20355	57068	67786	43350	111136	13150	35992	49142
	3	89492	41268	130760	37744	15916	53660	57701	45121	102822	12015	33101	45116
	4	86511	42972	129483	24479	14019	38498	49181	49947	99129	8555	39781	48336
1963	1	92092	44411	136503	17268	17452	34720	56873	46397	103270	10739	39160	49899
	2	101054	44287	145341	27163	19728	46891	63349	38327	101676	14356	28740	43096
	3	104152	44593	148745	30454	18139	48593	58074	38859	96933	13746	23336	37082
	4	109022	46293	155315	25062	18620	43682	55922	45122	101044	11825	30363	42188
1964	1	119025	47565	166590	28750	24088	52838	67331	44495	111825	12291	32197	44488
	2	115651	47031	162682	47354	27368	74723	86458	39240	125698	14149	24468	38617
	3	117564	45940	163504	58519	26004	84523	86283	41037	127320	12180	18102	30283
	4	93690	45186	138876	25848	26054	51903	85384	46601	131985	9069	21526	30595
1965	1	112735	43709	156444	31800	29097	60897	91511	43621	135132	9483	23146	32629
	2	125125	40676	165801	56052	29270	85321	106294	34632	140925	17917	19300	37218
	3	128042	38337	166378	61952	24709	86661	96113	31670	127784	18485	18732	37217
	4	129008	37658	166666	45856	20246	66102	86167	31757	117924	17310	26696	44006
1966	1	152595	37089	189684	29929	20725	50654	96852	24559	121410	21064	30849	51913
	2	162682	35601	198283	41349	21822	63172	115284	14943	130228	27986	27830	55816
	3	150165	34853	185017	41816	18053	59869	124755	15296	140051	27552	25532	53084
	4	164383	35833	200216	44804	13669	58474	109070	21224	130295	26052	30318	56370
1967	1	174042	36816	210858	56926	14946	71872	121128	20431	141559	30879	31716	62595
	2	171016	36178	207194	80077	17117	97194	141520	16030	157550	34840	28319	63159
	3	170017	35647	205664	90467	14881	105348	137151	19270	156421	37794	25740	63533
	4	126146	36136	162281	65067	12188	77255	145864	26052	171916	35766	28567	64333

APPENDIX G--Continued

Year	Quarter	WEST						EAST					
		Steers			Heifers			Steers			Heifers		
		Beef	Dairy	Total	Beef	Dairy	Total	Beef	Dairy	Total	Beef	Dairy	Total
		(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)	(head)
1968	1	149320	36339	185658	69038	14036	83074	132527	25313	157841	34173	27850	62022
	2	153941	35061	189002	95690	14481	110171	145794	20795	166589	33272	22880	56152
	3	150082	34015	184097	104974	8429	113404	140323	23579	163902	31315	20939	52254
	4	145363	34315	179678	79096	1951	81048	122460	29072	151532	27265	25910	53175
1969	1	156865	34459	191323	71758	2107	73365	124222	25570	149791	27500	26872	54372
	2	160527	33137	193664	93368	3688	97056	144269	16411	160680	32372	22450	54822
	3	147364	32041	179405	104047	2828	106875	142789	14857	157646	28758	21888	50646
	4	160182	32464	192646	87202	3423	90626	106213	19031	125243	18929	29119	48048
1970	1	166901	33227	200127	80662	7067	87729	113469	18036	131505	19194	32959	52154
	2	151025	33037	184062	92216	9373	101589	151332	13870	165202	25632	31423	57055
	3	186263	33036	219299	111662	11276	122938	136051	17429	153479	34934	29575	64508
	4	193856	34137	227993	102351	16313	118665	109318	25404	134721	33867	32352	66218
1971	1	195993	35110	231103	101022	19789	120811	105954	26238	132192	30652	30165	60830
	2	165638	34690	200328	114373	16949	131321	141340	21327	162667	31630	22557	54187
	3	183924	34199	218124	128240	14081	142321	117380	23281	140661	31978	18538	50516
	4	183349	34722	218071	101299	16323	117622	98394	30533	128927	29954	22321	52274
1972	1	205376	35397	240773	95882	18472	114355	110999	31465	142463	34404	21941	56345
	2	182165	35219	217384	117173	15651	132824	144895	26984	171879	34009	15635	49644
	3	211136	34957	246093	141079	13677	154756	127837	27530	155367	38706	12421	51127
	4	215279	35285	250564	121114	17104	138218	85165	31780	116945	29804	16633	46437

BIBLIOGRAPHY

BIBLIOGRAPHY

Agriculture Canada. Livestock Market Review. Ottawa: Queen's Printer, various issues.

________. Livestock and Meat Trade Report. Ottawa: Queen's Printer, various issues.

Allen, R. G. D. Macro-Economic Theory--A Mathematical Treatment. New York: St. Martin's Press, 1968.

Blaug, M. Economic Theory in Retrospect. Homewood, Ill.: Richard D. Irwin, Inc., 1968.

Boswell, A. M. "The Changing Economic Profile of Canada's Beef and Veal Trade." Canadian Farm Economics 8(5):1-14, October 1973.

________ and G. A. MacEchern. "Determinants of Change in the North American Feeder Cattle Economy." Canadian Journal of Agricultural Economics 15(1):53-65, 1967.

Branson, W. H. Macro-Economic Theory and Policy. New York: Harper and Row, 1972.

Canadian Agriculture in the 70's. Report of the Federal Task Force on Agriculture. Ottawa: Queen's Printer, 1969.

Canada: Growth Potential in the Grain and Livestock Sector. Foreign Agricultural Report No. 77, Economics Research Service, U.S. Department of Agriculture, 1972.

Durbin, J. "Testing for Serial Correlation in Least Squares Regression, When Some of the Regressions Are Lagged Dependent Variables." Econometrica 38:410-421, 1970.

Ferber, R., and P. J. Verdoorn. Research Methods in Economics and Business. New York: The MacMillan Company, 1962.

Forrester, J. W. Industrial Dynamics. Cambridge: The Massachusetts Institute of Technology Press, 1961.

Forster, D. L. "The Effects of Selected Water Pollution Control Rates on the Simulation Behavior of Beef Feedlots." Unpublished Ph.D. dissertation, Michigan State University, 1974.

Freebain, J. W. "Some Adaptive Control Models for the Analysis of Economic Policy: United States Beef Trade Policy." Unpublished Ph.D. dissertation, University of California, 1972.

Hayenga, M. L., T. J. Manetsch and A. N. Halter. "Computer Simulation as a Planning Tool in Developing Economics." American Journal of Agricultural Economics 50(5):1755-1759, December 1968.

Henderson, J. M., and R. E. Quant. Micro-Economic Theory--A Mathematical Approach. New York: McGraw-Hill Book Company, 1971.

Johnson, G. L., et al. A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria. East Lansing: Michigan State University, 1971.

________. Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985. East Lansing: Michigan State University, 1972.

Johnson, G. L., and C. L. Quance. The Overproduction Trap in U.S. Agriculture. Baltimore: The John Hopkins Press, 1972.

Johnson, G. L., and L. K. Zerby. What Economists Do About Values. East Lansing: Michigan State University, 1973.

Johnson, J. Econometric Methods. New York: McGraw-Hill Book Company, 1973.

Jorgenson, D. W. "Econometric Studies of Investment Behavior: A Survey." Journal of Economic Literature 9:1111-1147, December 1971.

Kerr, T. C. Determinants of Regional Livestock Supply in Canada. Agricultural Economics Research Council of Canada, Publication No. 15, Ottawa, 1968.

Kmenta, J. Elements of Econometrics. New York: The MacMillan Company, 1971.

Kulshreshtha, S. N., A. G. Wilson, and D. N. Brown. An Econometric Analysis of the Canadian Cattle-Calves Economy. Department of Agricultural Economics, University of Saskatchewan, 1971.

Lee, B. "Reconciliation of Canadian Cattle Statistics, 1971-1972 and 1972-1973." A mimeographed paper, Economics Branch, Agriculture Canada, Ottawa, 1974.

________. "Simulation of Population in Several Sub-Categories of the Canadian Cattle Herd (a project outline). A mimeographed paper, Economics Branch, Agriculture Canada, Ottawa, 1973.

Llewellyn, R. W. FORDYN: An Industrial Dynamics Simulator. Raleigh: Univeristy of North Carolina, 1965.

Lockhart, W. J. "Structural Changes in Cattle Enterprize of the Prairie Provinces." Canadian Farm Economics 3(2):17-21, June 1968.

Lohoar, J. S. "Prospects for Increasing Beef Supplies in Canada." Canadian Farm Economics 4(1):1-8, April 1969.

Lok, M. K. "A Dynamic Model of Canada's Slaughter and Feeder Cattle Trade with the United States." Unpublished MSc dissertation, University of Guelph, 1970.

Manetsch, T. J., and G. L. Park. System Analysis and Simulation with Application to Economic and Social Systems. East Lansing: Michigan State University, 1973.

Marshall, R. G. An Assessment of Current and Prospective Trade Patterns, Supply and Demand Situations for Cattle and Beef, Hogs and Pork, with Reference to Canada's Position in the North American Market. Department of Agricultural Economics, University of Guelph, 1968.

________. "The Size of the Livestock Industry in Canada, 1980. Canadian Journal of Agricultural Economics 17(3):90-103, November 1969.

________. Variations in Canadian Cattle Inventories and Marketing. Department of Agricultural Economics, Ontario Agricultural College, Guelph, 1964.

________ and H. B. Huff. A National Research Program for the Marketing of Canadian Cattle and Beef. A restricted distribution publication, School of Agricultural Economics and Extension Education, University of Guelph, 1970.

MacAuley, G. L. . . . . Unpublished Ph.D. dissertation, University of Guelph, 1975 (forthcoming).

McCallum, B. T. "Competitive Price Adjustments--An Imperical Study." American Economics Review 44:56-65, March 1974.

Mills, C. "WSGA Market Information Service (CANFAX)." Proceedings of the CAES Workshop: Banff, 1970.

Petit, M. "Econometric Analysis of the Feed Grain, Livestock Economy." Unpublished Ph.D. dissertation, Michigan State University, 1964.

Petrie, T. "Analysis of Seasonal Cyclical and Trend Variations in the Prices and Output of the Cattle and Hogs in Canada." Unpublished Ph.D. dissertation, University of Saskatchewan, 1971.

Posada, Alvaro. "A Simulation Analysis of Policy for the Northern Columbia Beef Cattle Industry." Unpublished Ph.D. dissertation, Michigan State University, 1974.

Rutherford, L. "Dairy Beef in Ontario." Proceedings at the CAES Workshop: Banff, 1970.

Slen, S. B., and M. A. Cameron. "Prospects and Potential in Canadian Beef Production." Canadian Journal of Agricultural Economics 17:80-89, 1969.

Situation and Outlook Reports. Various issues, Economics Branch, Canada Agriculture, Ottawa.

Statistics Canada, Dairy Review. Ottawa: Queen's Printer, various issues.

________. Livestock and Animal Product Statistics. Ottawa: Queen's Printer, various issues.

________. Report on Livestock Survey s Cattle, Sheep, Horses. Ottawa: Queen's Printer, various issues.

________. Quarterly Bulletin of Agricultural Statistics. Ottawa: Queen's Printer, various issues.

________. Trade of Canada. Ottawa: Queen's Printer, various issues.

Sumner, Dan. "An Empirical Examination Concerning Investment and Disinvestment in Durable Assets: Econometric Analysis of the U.S. Milk Cow Herd." A Plan B paper, Department of Agricultural Economics, Michigan State University, 1973.

Talpaz, Hovav. "Simulation Decomposition and Control of a Multi-Frequency Dynamic System: The United States Hog Production Cycle." Unpublished Ph.D. dissertation, Michigan State University, 1973.

The Interregional Structure of the American Beef Industry in 1975 and 1980. Publication No. B-708. Stillwater: Oklahoma State University, 1973.

Teigen, L. D. "Costs, Loss and Forecasting Error: An Evaluation of Models for Beef Prices." Unpublished Ph.D. dissertation, Michigan State University, 1973.

Theil, H. *Principles of Econometrics*. New York: John Wiley and Sons, Inc., 1971.

Van Horne, J. C. *Financial Management and Policy*. 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958.

Yang, W. Y. *Death Rates of Farm Animals*. Economics Branch, Canada Department of Agriculture, 1969.

Yankowsky, Z. "The Intermediate and Long Term Outlook for Canadian Beef." *Proceedings of the CAES Workshop: Banff*, 1970.