The dynamics of Montana beef cattle inventories
by Randal Ray Rucker

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


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Models for estimating beef cattle herd sizes in Montana are estimated using a nonlinear least squares algorithm. The use of this algorithm allows the estimation of "nonstochastic difference equations" in which the stochastic component is purged from the lagged values of the dependent variable. Models are developed to explain the levels of total herd sizes as well as the levels of breeding herds. Explanatory variables in these models include the levels of hay production, beef to corn price ratio and calf (or feeder steer) prices in preceding periods. Interpretations of the estimated distributed lag patterns and of the nonstochastic forms of the difference equations are offered. The models estimated in this thesis appear to offer an improvement over previous attempts to explain and model beef cattle herd sizes.

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Date January 2, 1981

# THE DYNAMICS OF MONTANA BEEF CATTLE INVENTORIES

by

RANDAL RAY RUCKER

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

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ABSTRACT

Models for estimating beef cattle herd sizes in Montana are estimated using a nonlinear least squares algorithm. The use of this algorithm allows the estimation of "nonstochastic difference equations" in which the stochastic component is purged from the lagged values of the dependent variable. Models are developed to explain the levels of total herd sizes as well as the levels of breeding herds. Explanatory variables in these models include the levels of hay production, beef to corn price ratio and calf (or feeder steer) prices in preceding periods. Interpretations of the estimated distributed lag patterns and of the nonstochastic forms of the difference equations are offered. The models estimated in this thesis appear to offer an improvement over previous attempts to explain and model beef cattle herd sizes.

## Chapter 1

## INTRODUCTION

### Introduction

The purpose of this thesis is to develop a model to explain and predict the level of cattle numbers in Montana. A detailed discussion of the cattle production industry will be used to help construct a theoretical model. Th model will describe the various factors that determine or influence changes in the level of cattle numbers in different time periods. The model will then be estimated empirically and the results will be analyzed in detail.

One of the primary focuses of this study will be on the dynamics of the cattle raising industry. As Nerlove suggested more than two decades ago, agricultural supply functions might be estimated most effectively with distributed lag models. Even a very cursory survey of the literature since that time indicates that his suggestion was a most useful one. Certain assumptions about the form of the lag distributions in these systems lead directly to more estimable dynamic systems, like the ones to be developed in this thesis.

It will be assumed that most of the readers have some familiarity with the field of agricultural economics and have some rudimentary notions of what cattle production entails. However, to help clarify the discussions that follow for those not particularly familiar with cattle raising, a list of terms related to the beef industry will be presented and defined. Some of the more frequently used terms in discussions of cattle raising and beef production include,[1]

<u>Cattle numbers</u> - The total inventory of cattle on farms, either in a particular state or in a country (e.g. the U.S. or Canada) as of January 1 of a given year. In this paper, cattle inventories in Montana will be the center of focus.

<u>Breeding herd</u> - The total inventory of cows and heifers one to two years old) as of January 1 of a given year. The difference between breeding herds and total cattle numbers is that steers, heifers (less than one year old) and bulls are included in the latter but not in the former.

<u>Cow herd</u> - The number of cows that have calved.

<u>Calf crop</u> - The number of calves born in a given year.

<u>Calf</u> - Generally refers to cattle less than 7 months old.

<u>Yearling</u> - Generally refers to cattle about a year old. Often the distinction between calves and yearlings is made on the basis of weights, with the division between the two classes being made at 500 lbs.

<u>Heifers</u> - Female cattle that have not yet calved. These are either kept in the herd for purposes of reproduction or sold

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[1]The definitions of several of these terms were taken directly from Rosine (p. 20).

for slaughter or feeding.

Steers - Castrated cattle. These are generally young animals sold either to feedlots for fattening or directly to slaughter-houses.

Feeder Cattle - Cattle supplied to feedlot operators by ranchers for fattening. Ranchers generally make the decision to sell to feedlots when the calves are between eight and ten months old.

Fat cattle - Cattle that have been fattened for slaughter on grain or high protein supplements.

Grass-fed (or non-fed) cattle - Cattle that have been on range and pasture before being sold for slaughter. These cattle do not pass through feedlots.

Cull cows or bulls - Old cows and bulls that are no longer considered useful for reproductive purposes and are therefore marketed for slaughter.

Cow-calf operator - Cattle producer or rancher who generally markets his cattle as calves (except for those retained in the breeding herd). Most of the cattle operations in Montana are of this type.

Cow-yearling operator - Cattle producer who markets his cattle as yearlings.

Feed-lot operator - Cattle feeder who purchases cattle from ranchers and fattens them for slaughter. Most feeder cattle in Montana are sold to feed-lot operators in the Midwest market (Nebraska, Iowa, and Kansas).

Beef - The final product of the cattle industry, i.e., all meat produced from cattle.

## Statement of the Problem and Structure of the Industry

The estimation of beef cattle inventories is, by itself, a stimulating problem, particularly from an academic point of view. Cattle producers' decisions regarding desired herd sizes emanate from their expectations of future prices of cattle and calves, but these expectations are not observable. To the economist interested in developing an empirical model for cattle numbers, specification of a proxy for these expectations is a problem of considerable importance. Another problem stems from the fact that planned changes in herd sizes do not correspond perfectly with actual changes. If it is assumed that herd size in a given year is determined in part by herd sizes in previous years, then it may be that ranchers base their desired herd size for this year on what would have been the average herd size last year if it were not for certain random disturbances, rather than on actual herd size. This problem and the methods to account for it in an empirical model have received little attention in the literature.[2] An attempt to deal with this problem will be made in this thesis.

From a nonacademic point of view, estimation of beef cattle inventories is of interest for at least two reasons. First, cattle prices as well as cattle numbers seem to follow a cyclical pattern with some modicum of regularity. For many purposes, cyclical or seasonal fluctuations around the trend in the level of a variable can be ignored. For example, if the problem being addressed is to predict long term growth rates in the level of national income, then the problem of predicting cyclical fluctuations around the trend is not of interest. But for other problems, the prediction of these cyclical movements is of vital importance. For individual cattle operators, the trend level in cattle prices is of little relevance to them if they do not have the financial resources to survive the trough of the current cycle. Prediction of turning points in the levels of variables over time is one of the most difficult tasks faced by econometricians and is thus of

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[2]This problem appears to have been recognized first by Griliches (1960, p. 291). Recently, work related to this problem has been done by Burt (1978, 1980) and LaFrance. Methods of handling this problem have been discussed primarily in the context of estimating crop responses. In the present problem, livestock responses are being estimated. The intrepretation of the nature and causes of the differences between the expected level (or systematic component) and the actual level may prove to be somewhat different for a livestock response model than for an acreage or yield response model. This problem will be discussed in detail in later chapters.

interest from an academic standpoint. But from a practical or policy-oriented point of view, the problem is also of great importance. If the turning points (and possibly the amplitudes) of these cycles can be predicted with some accuracy, then it may be possible for ranchers to alter their actions in ways that will enable them to survive the low points in the cycles or for policy makers to intervene with actions that ease the burden on cattle producers during hard times.

The development of a model to estimate Montana cattle numbers would seem at first glance to be an endeavor of limited value to anyone other than Montana policy makers. But it is hoped that after the Montana model is developed it will be useful, without major alterations, for estimating and predicting cattle numbers in other states and possibly on the national level. It might be expected that the structure of the cattle industry in Montana would be less complex than the structure of the industry on a national level because of more homogeneous conditions and a relatively small dairy industry. An additional simplification for a state model is that cattle prices can be treated as exogenous with little risk of joint dependence in the relationship between inventories and prices. Often, valuable insights to a problem can be gained by solving more simplified versions of the problem first. A logical approach to the problem of estimating a national model for beef cattle inventories might thus be to estimate a model on a state level and then use the knowledge obtained to help in constructing the more complicated national model.

Beef cattle inventories are important determinants of the number of cattle that enter feedlots and are slaughtered. The number of cattle slaughtered is in turn the primary determinant of the supply of beef on retail meat counters. The ultimate usefulness of beef cattle inventory models on the state and national levels therefore lies in the role they play in obtaining estimates of retail beef supply. This is the second nonacademic reason for developing a model of Montana cattle herd sizes.

It has long been recognized that hog prices and numbers follow a cyclical path over time. There have been numerous attempts to develop models that effectively account for this type of variation and accurately predict upcoming phases of these cycles. As was mentioned above, cattle prices and numbers also appear to follow a cyclical pattern. Yet there has been considerably less attention directed towards the development of models to explain and predict cattle numbers.[3] It is not clear why these cattle cycles have been neglected relative to the hog cycles. One possible explanation is that because the cattle cycles have longer periods, more data would be required to develop a model that

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[3]The studies that have been done on this topic include Maki (1962 and 1963), Tryfos, Martin and Haack, and Arzac and Wilkinson. In most of these studies, the equations for estimating cattle numbers are parts of larger systems for estimating livestock or meat supplies. In these articles, the authors spend little time interpreting the results of their cattle number equations. These articles and the results they contain are analysed in detail in the next chapter of this thesis.

effectively deals with these cyclical movements.[4] The longer time series increases the hazards of structural change during the sample period.

On a national level, the United States cattle industry is currently going through the final phases of the seventh cycle of this century.[5] These cycles have typically lasted about ten to twelve years. The average cycle has had an expansionary phase of about six or seven years and a contractionary phase of three to four years. However, these cycles have not by any means been uniform in these traits. The second cycle of the century, for example, lasted from 1912 to 1928 and had expansionary and contractionary phases of six and ten years respectively. Most of the other cycles have peaked near the midpoint of a decade and hit low points late in the same decade. For example, in the past 50 years, cycles have peaked in 1934, 1945, 1956, and 1965, and have bottomed out in 1928, 1938, 1949, 1958, and 1967.

Figure A-1 in Appendix A reveals that cattle numbers on the state

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[4]That is, since hog cycles appear to be about four years long, twenty-five to thirty years of data will span about seven complete cycles. If there is any regularity at all to these cycles, an econometric model should be able to isolate it quite effectively with data on that many cycles. But, since cattle cycles seem to last about ten years, twenty-five years of data only spans two or three cycles. It is much more difficult for a model to pick out regularities with data on so few cycles.

[5]See Rosine (p. 13) for a plot of the path of total cattle numbers on a national level during this century.

level in Montana have followed the peaks and troughs of the national cattle cycle quite closely since World War II. This would be expected if cattle numbers are determined largely by cattle prices, since there is no reason the prices received by Montana ranchers should not follow the same path over time as the prices received by ranchers in other parts of the country.

An important question is "Why do cattle numbers follow this cyclical path?" Is this cyclical movement a result of factors external to the cattle production industry or is it due to forces that are internal to the process? It appears that these cycles can be attributed largely to biological constraints and lags in economic adjustments inherent in the cattle raising process. Before describing the characteristics of cattle cycles in detail, it will be useful to sidetrack somewhat and outline the process by which beef on the hoof becomes beef on the retail meat counter.[6]

For descriptive purposes, it is convenient to view the cattle industry as consisting of three sequential markets - the markets for feeder cattle, fat cattle, and beef. Each of these markets, like any other market, has a supply and a demand side. In the feeder cattle market, the suppliers are the cow-calf-yearling operators and the

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[6]A significant portion of the following discussion was adapted from Kohls and Uhl and Rosine.

demanders are feedlot operators. The feedlot operators are the suppliers of fat cattle to the packer, wholesale and retail demanders. The latter then act as suppliers in the beef market while consumers play the role of demanders. Not all beef goes through each of these steps, of course. Some cattle are slaughtered immediately after purchase from the cow-calf operator without being fattened in a feedlot. The different functions in these three markets are not always performed by separate enterprises. For example, some operations in the Midwest raise feedgrains as well as cattle. In fact, before the 1950's, most cattle production took place on these diversified crop-livestock farms. The last three decades, however, have seen the development of large specialized cattle feedlots in the West and Southwest regions.[7]

The focus in this thesis is on the suppliers in the feeder-cattle market, i.e. the cattle ranchers. It is important to point out that the organization and structure of these producing units is highly diversified. Some ranchers raise sheep and/or hogs as well as cattle. Some raise grain crops in addition to their livestock. Others view their livestock production as a secondary source of income and use it to occupy otherwise unused resources like labor and buildings. The size

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[7]For further discussion of some of the different aspects of the livestock marketing industry, the different roles played by large highly specialized feedlot operations in different sections of the country, and the movement towards decentralization of the livestock and meat packing industry see Kohls and Uhl (Chapter 23).

of these operations also varies widely, from small to very large and highly specialized. This diversity is pointed out to emphasize the problems that may be encountered when trying to develop a single equation to model such a heterogeneous group of operations. Again the merits of constructing a model for a single state initially should be clear. Cattle production operations in a given state would be expected to be fairly homogeneous since they face similar climatic and topographic as well as economic (distance to markets, etc.) conditions. Thus, it should be relatively easier to construct a model on a state level. Again, it is hoped that insights can be gained from this exercise that will be valuable in modeling the cattle industry on a national level.

The cattle production portion of the cattle industry consists primarily of cow-calf and cow-yearling operations. In Montana, the majority of cattle ranches are of the former type. Calves are generally born late in the winter and early in the spring. Ranchers will typically keep these calves until they are about seven to ten months old. At that time, a number of options are available. Steers can be sold to feedlots for backgrounding and then fattening or directly to slaughter. Ranchers may also choose to carry the steers through the upcoming winter. This option might be chosen if ranchers felt that the price of steers would be higher in the spring and/or if winter pasture and feed conditions looked promising. A rancher would probably not choose to carry steers through the winter if the summer hay yields were low and if forage conditions for the winter look poor. Male calves are not generally kept as part of the breeding herd since most herds have only one bull for every thirty to forty-five cows. These bulls are generally purchased rather than raised. In Montana the majority of steer calves appear to be sold to feedlots.[8]

Ranchers face basically the same set of alternatives for their heifers with the additional option of keeping a certain portion in their herds for breeding purposes. Heifers might be added to the breeding herd either as replacements for old cows that are culled from the herd or as net additions to the herd. If the heifers are "plowed back" into the herd, it usually takes about two years for them to have the first calf. The gestation period for cows is about nine or ten months. The useful reproductive life of a cow is generally about six to eight years. After that the cows are "culled" from the herd and sold for slaughter. The age at which these cows are culled will depend in part

[8]Whether ranchers sell their cattle to feedlots or for direct slaughter depends on which buyer offers them a higher price. Changes in the price of feeder cattle relative to non-fed slaughter cattle will depend in part on changes in the demand by consumers for high quality as compared to low quality cuts of meat. However, the critical factor in the determination of these relative cattle prices is probably the composition of beef made available by suppliers. This composition will be affected by where the economy is located in the cattle cycle at the time in question and by the number of older animals (which rarely go to feedlots) being marketed.

on whether the rancher is trying to expand or contract his herd. If cattle prices are rising and the rancher is expanding his herd, he will keep these older cows in the herd longer. If prices are falling and he is reducing his herd size, he will be more likely to cull the older cows earlier.

Steers and heifers sold to feedlots are fattened on high concentrate rations (e.g. soybeans and/or cottonseed oil meals) and grains for approximately 130 to 160 days, after which they are referred to as fat, fed, or slaughter cattle. The length of time the feedlot operator keeps the cattle in the feedlot will depend partly on the price of feed relative to the price of fat cattle. From the feedlots, fed cattle are sold to packing plants where they are slaughtered and fabricated, then sold to wholesalers or directly to retail stores (possibly for further processing), and then purchased by consumers.

At this point it is helpful to describe a "typical" cattle cycle. An ordinary cycle consists of three distinct phases:[9] (1) the rapid growth stage, (2) the deceleration stage, and (3) the turnaround stage.

The rapid growth stage is characterized by (1) favorable beef prices, (2) rapid increases in cattle numbers, (3) a low ratio of slaughter to inventory, and (4) higher than average financial returns

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[9]These classifications, as well as much of the information content in the discussion and description of cattle cycles was obtained from Hasbargen and Egertson.

to beef producers. During this stage favorable beef prices induce ranchers to increase their breeding herds to try to capitalize on those prices. This increase is accomplished by keeping older cows in the herd longer and by retaining more than the normal number of heifers. Calf slaughter drops because more heifers are kept in the breeding herds and because feedlot operators (who are also benefiting from high beef prices) bid more of the lower quality heifers away from slaughter accounts.[10] The holding back of heifers and reduction in calf slaughter results in reduced production of beef which causes prices to rise still more. The normal ratio of cattle and calf slaughter to January 1 inventories for the United States is about 36 percent. During the rapid growth stage this ratio falls to about 30 percent. Notice that according to economic theory, the normal response of a supplier to an increased price is to increase output. However, the biological characteristics of cattle production dictate that an increase in output can only be accomplished by first reducing current beef supplies by selling fewer calves to feedlots. Thus, the short run effect of rising prices

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[10]Actually, this representation of the relationship between the prices of feeder cattle and the profitability of feedlot operations is probably an oversimplification of reality. Rising prices of feeder cattle will mean increased costs for feedlot operators. Unless fat cattle prices rise by a similar amount, feeding margins will be pinched. Similarly, in the deceleration stage, when feeder cattle prices start falling, margins will improve if fat cattle prices fall at a slower rate.

on beef production would be expected to be negative. Prices and herd sizes will continue to rise until breeding herds become large enough that (although heifers are still being held back) the number of cattle being slaughtered begins to increase. When this happens, the production of beef will increase and prices will begin to fall. Falling prices are then passed from the retailers on down the market channel to the cattle producers. These falling prices and the resulting cutbacks in the rate at which herd sizes are being increased mark the end of the rapid growth stage and the start of the deceleration stage.

The characteristics of the deceleration stage include (1) unfavorable cattle prices, (2) the growth rate in herd sizes declines sharply and then inventories actually drop, (3) the ratio of slaughter to inventory begins to increase, and (4) returns to beef producers are below average. The falling prices that marked the end of the rapid growth stage affect cattle feeders. They receive lower fed cattle prices and must then lower prices for feeder cattle to protect feeding margins. Ranchers then begin to slow down the rate of growth of their herds. They do this by plowing back fewer heifers into the breeding herd and culling more of their older cows. Since cattle producers are trying to cut back on production to reduce their losses, this period is marked by an increase in slaughter relative to inventories. Examples of this rise in recent deceleration stages includes a jump from a 30 percent slaughter rate in 1973 to a 36 percent rate in 1975 and from 32 percent in 1952 to 42 percent in 1955-56. Between 1973 and 1975 the culling rate rose from 12 to 20 percent which implies an accompanying increase in cow slaughter. Probably the only type of cattle not showing an increase in slaughter during this stage is choice finished slaughter cattle. This is because reduced demand and prices paid by feedlots allow slaughter accounts to outbid feeder accounts.

At the beginning of this stage, when prices initially start to fall, ranchers do not immediately decrease their herd sizes. This is because prices have been rising for several years and ranchers expect them to continue rising. They initially view the falling prices as temporary and are thus hesitant to decrease their herd sizes. If ranchers did reduce their herds and prices started rising again, they would not be able to capitalize on those high prices.[11] But the increased slaughter rates at the beginning of this stage lead to increased beef supplies which lead in turn to further price reductions.

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[11] One interesting characteristic of the cattle production process is that increases in herd sizes are constrained by the rate at which cattle can reproduce but that decreases in herd sizes can occur as rapidly as producers are able to liquidate their herds. The tendency for producers' price expectations to adjust slowly (which causes them to hesitate in liquidating their herds) may act to make the cattle cycle somewhat more symmetrical than it would be if its shape was dictated solely by the biological constraints of the industry. It was noted by Lorie that during the beginnings of this stage, prices are falling, but they are still above their average or "normal" level. As long as this is the case, one might expect producers to continue increasing their herds, depending of course, on how much their price expectations are affected by anticipated cyclical behavior of prices.

After a while, cattle producers realize that the falling prices are not an aberration and actually reduce their herd sizes. This, of course, leads to further decreases in prices. This continues until herd sizes are small enough that the supply of beef begins to fall and prices start to recover. When this happens, the cattle cycle enters the turnaround stage.

The basic characteristic of the turnaround stage is "normality"; prices recover from the low levels of the deceleration stage, herd sizes stabilize, the slaughter to inventory ratio is near normal, and returns to beef producers are about average. This stage begins when prices start to recover (even though producers are still marketing more than a normal proportion of heifers and may be culling at fairly high rates) due to herd sizes being small enough that beef production is reduced. Prices and herd sizes level off for awhile, but if population and per capita incomes continue to grow, the demand for beef will increase. Prices will begin to rise again and feedlot operators will respond by increasing their production levels and bidding up the price of feeder cattle. These rising prices induce cattle producers to start increasing their herds again. The cycle has entered the rapid growth stage once more.

From the preceding discussion, it can be seen that the cattle cycle is caused basically by the physical and biological constraints of the production process and by the manner in which producers form their price expectations. That is, cattle ranchers decide to increase (decrease) their herd sizes because current and past price increases (decreases) lead them to expect future increases (decreases). One influence that is required for the continuation of the cattle cycle but is not inherent in the industry is the increase in population and incomes that acts to start prices rising and moves the cycle from the turnaround to the rapid growth stage. (Even in a rather stagnated economy, it seems that the phasing of the business cycle would sooner or later disturb the cattle cycle from the "normality" of the turnaround stage.) Other "outside" factors also affect the shape and length of the cycles even though they are not necessary for the continuation of the cyclical path. These factors may explain why the stages of different cycles vary so much in magnitude and duration. Examples of these influences include the end of the Korean War in 1952 which resulted in a slowdown in demand for beef and a break in beef prices, and the economy-wide boom of the late 1960's that kept consumer demand high and resulted in a shortening of the deceleration stage that started around 1965. Random variations in weather and feedgrain crop yields also affect feeder cattle demand and hence, cattle prices.

Another factor that may be contributing to the cyclical nature of this industry is related to forage conditions. When prices are rising, producers are likely to overgraze their range lands. When prices begin to fall, the depleted condition of this pasture acreage will contribute to incentives to reduce herd sizes. By the time prices bottom out, pasture conditions should have recovered. Thus, readily available forage will contribute to the incentives provided by rising prices to increase herd sizes.

The econometric model that will be used in this thesis will be a distributed lag model. These models are employed when there is a time lag between the point at which a change in an independent variable occurs and the point at which all of the effects of this change on the dependent variable have been felt. This type of a model seems appropriate in the estimation of cattle numbers for at least three reasons. First, if an event occurs that induces ranchers to decide to change their herd sizes, it takes a significant length of time for these desired changes to be implemented. Cattle do not reproduce instantaneously and it is not possible, in the aggregate, for all ranchers to buy cattle to enlarge their breeding herds at the same time. Second, ranchers face rigidities in addition to those associated with the biological constraints of cattle reproduction. For example, if cattle producers decide they want to enlarge their herds, they will want to be reasonably certain of having adequate feed available. This may require developing additional hay acreage or purchasing (or leasing) more grazing land, which again takes time. Third, ranchers' actions with regard to expanding or contracting their herd sizes will depend largely on their expectations about future price levels. Although little is known about the precise manner in which these price expectations are formed, it is generally agreed that they are based on some type of weighted average of past prices. Thus the complete effects of a price change in a given time period on a decision maker's future price expectations will not be felt until several periods have elapsed. The uses and precise forms of the distributed lag models to be employed in this paper will be discussed in detail in ensuing chapters.

The next chapter of this thesis contains a review of the literature related to the estimation of cattle (and other livestock) cycles and the use of distributed lag models. In the third chapter, a number of the theoretical aspects of the problem of estimating cattle numbers are considered. The estimated models are presented and discussed in the fourth chapter. The final chapter summarizes the accomplishments of this project and suggests some possibilities for extending our work. The raw data used to estimate the models and graphs of this data are presented in Appendix A. Appendix B contains plots of the lag distributions implied by the estimated models.

## Chapter 2

## REVIEW OF THE LITERATURE

This chapter contains summaries and discussions of many of the important past works related to the subject of cattle cycles. The literature that will be reviewed can be divided into two sections. The first contains articles that dealt directly with discussions and modeling of cattle numbers and the cyclical nature of the industry. These articles include studies that attempted to develop empirical models and make predictions as well as works that discussed the theoretical nature of the industry without attempting to do any quantitative work. Prices and numbers of other types of livestock besides cattle have been observed to follow cyclical paths over time. As was mentioned in the previous chapter, much attention has been directed toward the study of hog cycles. Since the nature of the cycles for cattle and hogs is essentially the same (the basic difference is the length of the cycles) and since a significant portion of the early work on livestock cycles was done on hog cycles, a few articles dealing only with hogs will also be reviewed. The analysis in these studies is easily modified to apply to cattle numbers.

The second section of literature to be reviewed deals with studies on the subject of distributed lags. The topics of these studies range from theoretical discussions of when the use of a distributed lag model is appropriate to quite technical works discussing how such models might be estimated under conditions of widely varying complexity. Within this section of the literature, a topic of particular relevance to later work in this thesis pertains to the use of "stochastic" vs. "non-stochastic" difference equations.

Literature on Cattle and Other Livestock Cycles

The first section of this literature review will be further divided into two sub-sections. The first sub-section will review articles that deal specifically with cattle numbers and cattle cycles. The articles in this sub-section will be reviewed in chronological order and will consist of, (1) studies of a purely qualitative nature which are of value because of the ideas presented or because they contain exceptional descriptions of some aspect of the cattle industry or its cyclical nature, and (2) works of a quantitative nature that attempted empirical analysis and prediction of the cattle cycles. The second sub-section will contain descriptions of articles that have focused on other types of animal cycles. Once again, the reason for looking at these studies is that the techniques they used for estimating cycles may prove to be useful in studying the cattle cycle.

One of the first studies that attempted to develop a concrete analytical framework for analyzing livestock and crop cycles was conducted by Mordecai Ezekiel (1938). The framework he used to look at these cycles is referred to as the "cobweb theorem". The basic idea of this theorem is that cycles in prices and/or production can be attributed largely to lags between the time a production decision is made and the time the output from that decision is actually produced.[1] Ezekiel began his article by giving credit to the originators of the "theorem" and then discussed the conditions that must be satisfied for the theorom to be appropriate for analyzing cyclical fluctuations in the "real world". These conditions essentially require that supply in a given period is inelastic and is determined by price in the preceding period and that demand in a given period is determined by the price in that period. After this, Ezekiel gave verbal and graphical descriptions of the three types of fluctuations (continuous, convergent, and divergent) that might occur. The type of fluctuation that actually occurs depends on the relative slopes of the supply and demand curves.

He then pointed out that his theory explained short cycles, or cycles in which high and low levels of production alternate year

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[1]For a more detailed description of the cobweb theorem, see Mansfield (pp. 240-242).

after year, but did not fully explain the long cycles observed in many commodities.[2] To remedy this, Ezekiel extended the analysis of the theorem by changing the assumptions about the length of time it takes production to respond to price changes. In the original formulation of the theorem, it was assumed that this lag was one year. This resulted in a two year cycle. By assuming that production in a given year depends solely on prices two years earlier, a four year cycle results. Using this technique, cycles of any length can be obtained using the framework of the cobweb theorem, simply by adjusting the assumption about the time lag between price changes and production response. He then made a visual comparison between these theoretically derived cycles and the actual price and production cycles of hogs and cattle. He pointed out the evident similarities, noted that the actual cycles differ from the theoretical cycles in that they are more irregular, and left the reader with the impression that his modified cobweb theorem could be used to explain the actual cycles.

Ezekiel then stressed that "the cobweb theory can apply exactly only to commodities which fulfill three conditions: (1) where production is completely determined by the producers' response to price

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[2]A long cycle would be one in which production levels are higher than normal for several consecutive periods and then below normal for several consecutive periods.

under conditions of pure competition (where the producer makes plans for future production on the assumption present prices will continue and that his own production plans will not affect the market); (2) where the time needed for production requires at least one full period before production can be changed, once the plans are made; and (3) where the price is set by the supply available" (p. 272). Finally Ezekiel discussed some of the shortcomings of the theroy. These included,

- there is some elasticity of response in the supply of most commodities, especially on the contractionary side.[3]

- for most commodities, production in a given period depends on price levels in more than one preceding period.

- intended and actual output may differ due to weather factors. These influences, if they occur frequently, may tend to distort the shape of the actual cycle so that it does not appear to follow a pattern predicted by the "cobweb theory".

- frequently, production levels do not bounce from very high to very low levels in succeeding years in response to fluctuations in prices as the theory predicts. For example, producers may expand herd sizes slowly in response to rising prices, but contract rapidly in response to falling prices.

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[3]For example, once a production decision has been made it may not be possible to significantly increase output but it may be feasible to decrease output by plowing a crop under rather than harvesting it or by slaughtering cattle or hogs earlier than would be the case if prices were higher.

- there is no commodity for which supply alone determines the price. Other factors, like prices and availability of substitutes and income levels, also affect prices. Because these other factors are usually not constant, it is difficult to isolate any underlying cyclical movements.

It seems apparent that one of the most obvious shortcomings of this theory is related to the second fault Ezekiel discussed. Producers make their production decisions on the basis of the prices they expect to receive at harvest time. The assumption that is made in the cobweb theory about the manner in which these expectations are formulated is remarkably naive.[4] For this theory to be useful as a tool for analyzing real-world cycles, it must be adapted to incorporate a more complex model of the formation of price expectations.

In a 1947 publication, James Lorie presented an extensive discussion of the nature and mechanics of the cattle cycle. Actually this study had a considerably broader scope than simply looking at the cattle cycle. Lorie looked first at the fluctuations in feed consumption and then focused on fluctuations in the number of animal units on farms (he developed an index to measure these units in his opening chapter). He found that there were four distinct cycles in these numbers between 1891 and 1945. He then attempted

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[4]The assumption, once again, is that the price in a single period in the past (usually the immediately preceding period) will continue into the current period.

to determine which of the component cycles (cattle, hogs, or sheep) seemed to be accounting for the largest proportion of the deviations in the total number of animal units. He found that movements in cattle numbers accounted for the major cyclical fluctuations in numbers of all animal units on farms. Because of this finding, he devoted considerable effort to trying to determine the factors that cause the cattle cycle.

He opened his discussion of the cattle cycle by reviewing and critiquing previous theoretical explanations of the cycle. Two prominent theories for explaining the cycle at that time were the theories of exogenous and endogenous causation. As the names imply the first theory attributed cycles in cattle numbers to factors that were not an inherent part of the cattle cycle, while the second credited the cycle to the nature of the cattle production process itself. The leading proponent of the theory of exogenous causation was John A. Hopkins Jr.. In his A Statistical Study of the Prices and Production of Beef Cattle, Hopkins states that

> " The cattle cycles of the past 60 years are apparently due to forces outside of the cattle industry, but these forces or conditions which have caused the major crises in the cattle industry do not seem to be related to any regularly recurrent phenomena. The prices of cattle are affected, of course, by the activity or depression of business, and are therefore influenced by the general business cycles. This will probably account for a minor series of cycles but not for the major cycles which have been 12 to 15 years in length. No phenomena of a regularly recurrent nature

> and with a periodicity of 12 to 15 years have come to light to explain the major cycles. The cattle price cycles are irregular in length and in amplitude, and for each there seems to be a different reason."(p. 351)

He then attempted to determine the different causes of the individual cycles of the six decades preceding his study. Lorie levels some extremely harsh criticism on Hopkins' explanation of the factors that caused the cattle cycles. The first cycle Hopkins attempted to explain peaked in 1870. Lorie questioned Hopkins' factual data concerning the timing of the booms and depressions of the 1870's, then stated that "Hopkins explains subsequent cycles with an equal imprecision and lack of cogency"(p. 50). After critizing Hopkins' analysis of the cattle cycle of the 1880's, Lorie dismissed his discussions of subsequent cycles with the comments,

> "At no time is statistical evidence presented and seldom is the influence of factors, other than the somewhat arbitrarily chosen causal agent, considered. In the absence of any reliable measure of the demand for cattle, or the effect of population changes, or of changes in business activity, one must view with extreme caution any conclusion which posits a causal relationship between these various factors and changes in cattle prices or numbers. Hopkins seems to have proceeded on the basis of 'reasonable' assumption rather than upon a rigorous examination of the available evidence. It seems probable that a more consistent and convincing explanation of the fairly regular fourteen - to sixteen-year cycles in cattle numbers can be found." (p. 51)

Lorie then looked at the work of Professor F. L. Thomsen, a proponent of the endogenous causation explanation of the cattle cycle.

Thomsen made the following remark with regard to works such as Hopkins',

> "It appears to many . . . that these episodic influences have served merely to affect the length or emphasize the degree of the cyclical movements of cattle production and prices and that there is a residual movement of cattle prices which is attributable to the truly cyclical nature of cattle production." (p. 360)

Lorie criticized Thomsen for not being more precise in his delineation of the causes of the cyclical nature of the production process and for not discussing the effects of exogenous factors such as the weather on these cycles.

After looking at these two theories of the cattle cycle, Lorie then turned his attention to "more sophisticated" attempts at modelling the cattle cycle through the use of the cobweb theorem. In particular, he focused on Ezekiel's 1938 article. He took particular exception to Ezekiel's implication that the cobweb theorem provided a framework for analyzing the cattle cycle. Lorie, upon substituting "more precise phrasing for Ezekiel's ambiguities," found that "the actual cycle is far longer than the theorem would have led one to expect" (p. 52). In support of his argument, Lorie cited a study of the hog cycle by Coase and Fowler that concluded that the cobweb theorem simply did not explain the observed facts.

Lorie then developed his own theory to explain the cattle cycle and the interrelationships between value, marketings, and number of cattle on farms. One important aspect of Lorie's theory was his emphasis that the separate cycles in these three components of the cattle industry were really part of the same cycle. Lorie's theory of the cattle cycle began with the assumption that all exogenous factors were constant, so that the system was initially in equilibrium with no cyclical motion. Then a change occurs; perhaps the weather is exceptionally good or there is a change in tastes (which leads to a greater demand for beef). As a result of this, ranchers decide to increase their herd sizes. This leads to a decline in marketings and increased cattle prices. At this point, Lorie pointed out that theoretically, farmers could react to these higher prices either by increasing sales to take advantage of high prices immediately, or by decreasing sales to build their herds so they can benefit to a greater extent from continued high prices in the future. Lorie felt that the available evidence indicated that ranchers most often took the latter course. The result is further declines in marketings, accumulation of cattle on ranches, and increases in values. In other words, the initial forces set off other forces that move the system away from equilibrium. This trend continues for three or four years until "the increased production on farms resulting from the greater breeding capacity of the herds can be expected to reverse the downward trend in marketing" (Lorie, p. 54). This increase in marketings will (other factors constant) lead to a fall in beef prices. Lorie maintained that ranchers would continue to increase their herd sizes (although at a slower rate), despite falling prices, as long as prices remained above their "normal" level. Because of increasing herd sizes, marketings would continue to increase and prices would continue to fall. When prices fall below their equilibrium level, ranchers would begin to cut back on their herd sizes. According to Lorie's theory, this decline in cattle numbers would begin about seven years after the initial disturbance that moved the system away from its equilibrium position.

As the liquidation of herds continues, marketings continue to rise and prices continue to fall. These trends continue until the herds are small enough that "the productive capacity of breeding herds will have declined so much that the lessening in the flow to market of young animals will more than offset the continued liquidation of breeding stock" (Lorie, p. 57). At this point, marketings begin to fall, prices begin to rise and the rate of liquidation is lessened (although liquidation does continue as long as prices are below their equilibium level). When prices eventually rise above their equilibrium values, ranchers begin to expand their inventories once again and the cycle repeats itself.[5] Lorie's cycle took about fourteen years to complete a full rotation. The length of this cycle is determined by the assumption that cattle are marketed at an average age of about two and one-half years. The development of large scale feed-lots, technological changes in feeding, and possibly shifts in consumer demand have caused a reduction in average marketing age. This may explain part of the discrepency between Lorie's cycle length and observed cycle lengths in recent decades of ten to twelve years.

Lorie ran some fairly crude tests and found that his theory was confirmed by the observation that accumulation (liquidation) of cattle seems to occur "with great regularity" when cattle values are above (below) normal. He then tried to determine the effects of exogenous factors on the cycle and concluded that weather fluctuations seemed to have a considerable effect on cattle numbers while the business cycle seemed to have had a relatively minor

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[5]It is interesting to note that Lorie's breakdown of the cattle cycle is essentially the same as that of Hasbargen and Egertson (described in the preceding chapter). The basic difference between their analyses is that in Lorie's story the cycle, once kicked off by an initial exogenous shock, seems to continue indefinitely while in Hasbargen and Egertson's model, each period of the cycle is begun with exogenous boosts, e.g. increasing population and/or incomes.

effect on the cattle cycle.

In 1955, Harold Breimyer published an article in which he suggested a number of different ways of looking at data on cattle prices, inventories, and slaughter. His hope was that by breaking the data down in a variety of ways, different aspects of the industry and cycle could be concentrated on and improved forecasts of different variables could be obtained. Breimyer opened his article by describing the price-decline phase of the cycle that started in 1952 and then commented on the inability of economists of the 1920's to empirically demonstrate a connection between cattle prices in one time period and cattle numbers in later periods. He felt that the cattle cycle, "more than any recurring fluctuation within agriculture resembles cycles of industrial origin. Basic to all such cycles is the management of capital goods of high investment cost and long productive life. In cattle those 'goods' are breeding stock" (p.2). Next, Breimyer commented on the conflict between those who felt the cattle cycle was self-generated and those who felt it was due to outside forces. He concluded this discussion by saying that

> "In making their responses to *all* factors, producers are affected by the complicating features of large financial investment, long life cycle, and scarcity of alternatives. As a result, responses by cattlemen are not quick, simple and direct but take on the slow evolutions known as the cattle cycle. It is the special features of the cattle industry, converting all responses into cyclical responses, that largely account for the historical cattle cycle. The

> cyclical effect comes about regardless of whether the forces responded to arise from within or outside the cattle industry." (p. 3)

Breimyer did not specify what "special features" of the industry he was referring to. His statement implied that he did not consider the discussion of endogenous or exogenous causation of the cattle cycle to be very relevant since the cycle would occur in either case. In the next section of this paper, Breimyer presented some of the devices he thought would be useful as tools for predicting upcoming trends in the cycle. These devices included free-hand graphic extensions of the trend and tabular arrangements of the data that he referred to, as "balance sheets" and "progressive balance sheets" of cattle numbers. The balance sheets basically broke total cattle numbers down into different categories according to how they were disposed of (death loss, slaughter, exports, etc). He felt these could be used as aids for prediction. The progressive balance sheets traced different categories of cattle (milk heifer calves, beef heifer calves, and cows and heifers) through time to see how they were disposed of. Breimyer felt there was enough regularity in these patterns of disposition that "forecasts based on this progressive balance sheet would have much validity" (p. 4). He did not make any actual predictions using these balance sheets, probably because the data base necessary to construct them was too weak. In the final section of his paper, Breimyer looked at the