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ABSTRACT

Estimating Aggregate Cattle on Feed
Placement Weights and Growth Rates

by James N. Trapp

Optimal control techniques are used to estimate aggregate cattle on feed placement weight and growth cahracteristics. The use of optimal control techniques to scientifically estimate these characteristics and its potential to estimate other unreported data series permits more information and new approaches to be used in forecasting beef supplies.

Oklahoma State Univ. Dept. of Ag Econ

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Agricultural outlook economists have made extensive use of cattle on feed data to make short-run beef supply forecasts. The traditional method outlook economists have used in making short-run supply forecasts based upon cattle on feed data, has been to assume various percentages of the cattle, in different weight groups, will be marketed within 30 days, 60 days, etc. Statistical models have been developed to predict slaughter one to six months in advance by regressing slaughter for the period in question upon current cattle on feed numbers by weight groupings. An example of such a model is specified below.

$$Slg = a + b\begin{pmatrix}\text{\# of 700-900 lb.}\\ \text{cattle on feed}\end{pmatrix} + c\begin{pmatrix}\text{\# of 900-1100 lb.}\\ \text{cattle on feed}\end{pmatrix}$$

Forecasts made by this method, however, ignore substantial amounts of information known about beef growth processes because aggregate cattle feed data do not describe the nature of the animals on feed in enough detail to make such information useful. For example, if the precise weight distribution of animals on feed were known as well as exact placement weights and rations fed, then growth models of beef animals could be used to predict the future weight of animals for a given date quite accurately. Growth models capable of such predictions have been developed by Fox and Black, and Gill. These models are heavily based upon Lofgreen and Garrett's net energy equations.

It is the premise of the modeling and optimal control applications to be described here that more detailed knowledge of the weight of cattle on feed and the weight at which they are placed, on feed coupled with beef growth models and/or common knowledge of typical beef growth rates, will permit more detail and accuracy to be developed in making short-term beef supply forecasts. With this objective in mind optimal feedback control techniques have been used in conjunction with a cattle on feed inventory and growth simulation model to estimate specific physical characteristics of cattle on feed and cattle being placed on feed.

Optimal Control and Modeling Procedure

Optimal control theory is an applied mathematical technique for analyzing systems under alternative sets of controls. The basic objective of its use is to determine a set of inputs, or controls of the system, that will generate a desired system behavior. In this case the system being dealt with is modeled by a cattle on feed inventory and growth simulation model. The desired system behavior is a capability to accurately track historical cattle on feed inventories and marketings. The control variables include placement weight, sex of animals placed on feed and the growth rates of animals on feed.

The cattle on feed inventory and growth simulation model will not be described in detail here.[1/] A basic understanding of the structure of the model can be obtained by studying Figure 1 which outlines the placement and cattle on feed categories described within the model. The model simulates the growth of cattle on feed by considering the effect of placement weight, current weight, sex and season of the year upon growth rates. Briefly, the effect of each of these factors as modeled is the following: steers have been observed to grow faster than heifers and grade choice at heavier weights than heifers and, hence, are typically slaughtered at heavier weights; animals placed at heavier weights, once on full feed experience "compensitory growth" and gain weight at faster marginal daily rates of gain than other animals of the same current weight but placed at a lighter weight; as animals on feed become heavier, their marginal daily rate of gain slows because more energy from their ration is required for

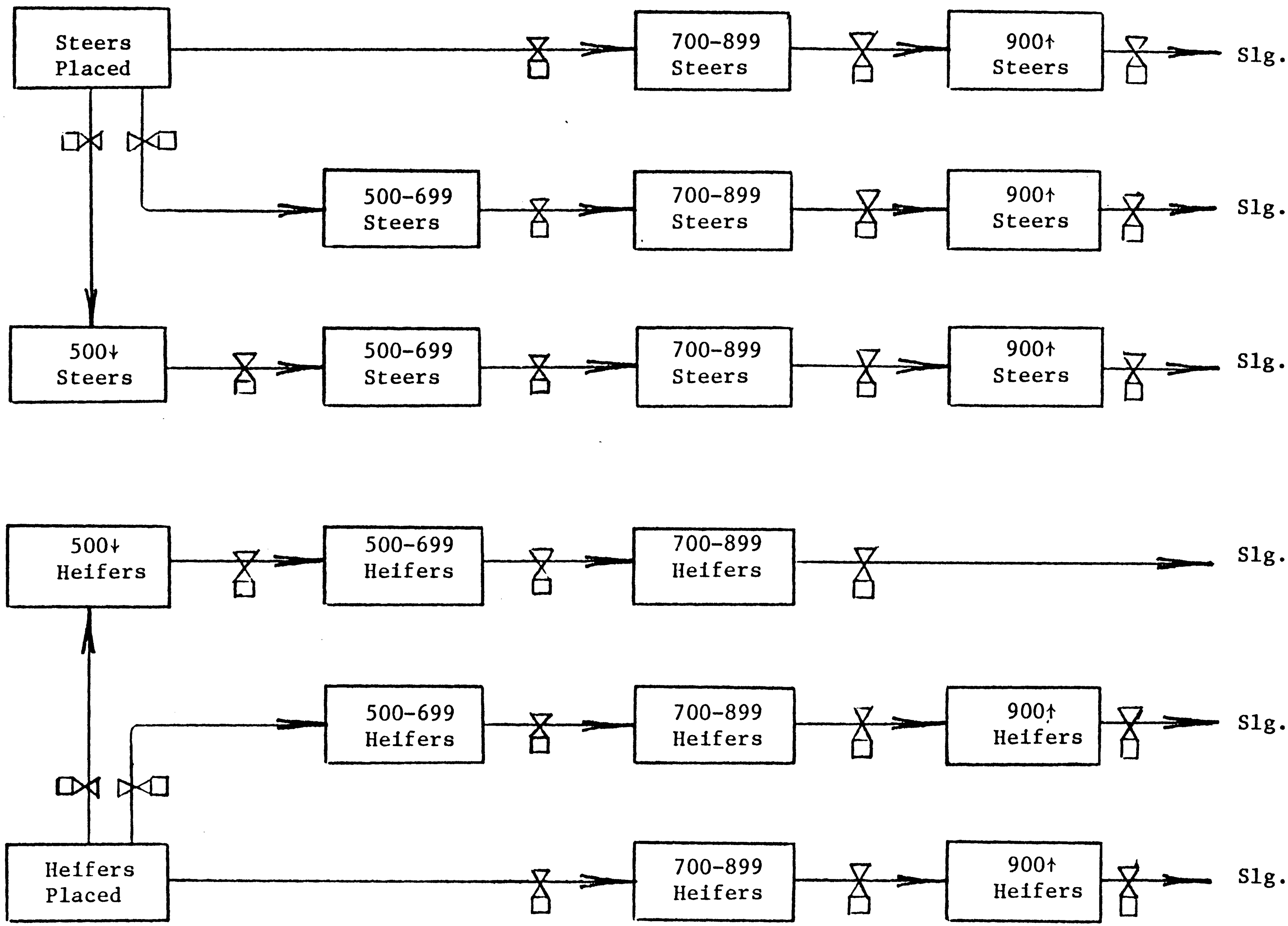

Figure 1. Cattle on Feed Population and Growth Model

body maintenance leaving less for growth; seasonal changes in temperature, rainfall, etc., cause different growth rates.

The mathematical relations used to descibe the inventory of cattle on feed and their growth process consists of a set of continuous differential equations.[2/] Because the equations describing the growth process and placement weight distribution are continuous with respect to time and weight, inventories of cattle on feed can be computationally broken into single pound increments with respect to the current weight distribution of cattle on feed and their placement weights. Even though the model is continuous in nature, tracking must be done in a discrete sense because the data to be tracked are discrete. This is achieved by integrating the continuous functions over the desired time and/or weight ranges and comparing the results with the discrete data. Hence, the continuous flows of the model interpolate between discrete data point in such a way that accurate discrete tracking is obtained.

Accurate tracking and calibration of the control variables is achieved by using a "closed-loop optimal feedback control" algorithm. The optimal control algorithm consists of an iterative numerical optimization procedure developed by M.J. Box called the "Complex Algorithm". The first step in the procedure is to provide the model with a set of inputs and initial experimental control values. In this case inputs include reported placements of cattle on feed, initial cattle on feed inventories by sex and weight and slaughter weight by sex. The control variables include placement weight distributions (by sex), sex of the animal being placed on feed and growth rates (by sex and placement weight) of cattle on feed. The distinction between inputs and control variables in this case is determined by data availability. With this information provided, the model can be run to generate predictions of cattle on feed slaughtered and ending cattle on feed numbers by 200 lb. weight increments.[3/] These predictions are compared to the observed values and an error squared performance measure calculated. The performance measure consists of the sum of the error squared in predicting the number of cattle on feed, cattle on feed marketed and the number of cattle on feed in each of nine sex and weight categories reported i.e. steers and heifers 500 lbs. and below, 500-700 lbs., 700-900 lbs., steers 900-1100 lbs., heifers over 900 lbs. and steers over 1100 lbs. A heavier weight or penalty is given to errors in tracking total cattle on feed since it is the summation of individual categories of cattle on feed and is believed to be reported more accurately than individual categories of cattle on feed. The numerical optimization routine receives performance "feedback" information from each setting of the control variables. By recording the marginal change in performance (improved tracking accuracy) associated with a given marginal change in the control variables (growth rates and placement weights by sex), the optimization routine iteratively adjusts the control variable settings in a systematic manner until the performance measure is minimized.

The average percentage error for tracking the number of cattle on feed in 23 states over the period 1960-1977 was 1.57 percent with the largest single error being 6.76 percent. Tracking accuracy for the number of cattle on feed marketed was somewhat less, with the average percentage error being 2.86 percent and the largest single error 14.17 percent.

Estimated Information Obtained

Operation of the model and optimal control algorithm over the period 1960-1977 yielded time paths for the control variables as well as for the simulated outputs of the model. Estimated values for the control variables (placement weight, sex of animals placed and average aggregate growth rates) will be reported here in terms of average seasonal patterns and annual averages for 1960-1977.

Table 1 presents the average seasonal patterns estimated for the control variables. Growth rates were estimated to be most rapid in the first and fourth quarters and the slowest in the third quarter. Seasonal fluctuation is felt to be due both to climatic factors and the type of backgrounding received by cattle entering the feedlot at different seasons of the year. The steer/heifer ratio (sex ratio) of cattle placed on feed indicates that proportionately fewer heifers are placed on feed in the first and fourth quarters, the implication being that these are the quarters when heifers are "held back" for replacements to the cow herd. Lastly, the estimates of the average weight of cattle on feed reported in Table 1 (which is not a control variable but a descriptive output of the model) indicates that the heaviest average weight of cattle on feed occurs in the second quarter and the lightest in the fourth quarter. The seasonal pattern of the average weight of cattle on feed is correlated with the seasonal pattern for numbers of animals being placed on feed and for the average weight of animals being placed on feed. As will be seen in Table 2 and in the following discussion the lightest placement weights occur and the largest number of animals are placed during the fourth quarter.

The placement weight information generated by the model is perhaps the most interesting and valuable. Somewhat surprisingly the estimates indicate that a significant portion of cattle placed weigh less than 500 lbs., i.e., 42.2 percent (Table 2). This is not so surprising if one considers that the turnover rate of cattle on feed under 500 lbs. is the most rapid of any reported weight group of cattle on feed. Cattle typically gain only 50-75 lbs. while in this weight classification as compared to 200 lbs. in others. Hence, to maintain a given inventory of cattle on feed

Table 1. Selected Average Estimated Characteristics of Cattle on Feed and Placed on Feed by Quarter, 1960-1977.

Quarter	Growth Rate Index	Sex Ratio of Cattle Placed on Feed Steers/Heifers	Average Wt. of Cattle on Feed
1	104	3.20	815
2	100	2.15	834
3	89	1.92	821
4	105	2.24	768

Table 2. Estimated Seasonal Distribution of Average Weight and Numbers of Cattle Placed on Feed, 1960-1977.

Quarter	Percent Placed			Average Weight	Index of Cattle Placed on Feed
	Under 500 lbs.	500-700 lbs.	700-900 lbs.		
1	53.2	40.3	6.6	508	85
2	26.7	66.3	7.6	557	83
3	26.5	43.7	29.8	581	97
4	64.4	26.5	9.1	490	135
Annual Average	42.2	44.5	13.2	534	100

under 500 lbs. requires more placements than to maintain the same inventory in wider ranged weight classes where the turnover rate is three to four times slower.

The estimates reported in Table 2 indicate that the majority of the under 500 lb. placements occur during the first and fourth quarters. This factor contributes to causing the low average weight estimates for cattle on feed during these quarters as reported in Table 1. The heaviest average placement weights occur in the second and third quarters. The largest percentage of cattle placed in the second quarter is in the 500-700 lbs. weight range, i.e., 61 percent. This group of cattle likely consists of spring calves that have been wintered, grazed on spring pasture and sent to the feedlot. The third quarter average placement weight, unlike the other quarters, is derived from a relatively uniform distribution of placement weights.

The time series paths of the annual average values found for the control variables are presented in Figures 2A-2C. The sex ratio (Figure 2A) is correlated with the cattle cycle (Figure 2D) as measured in terms of the annual index of the rate of change in the size of the cow herd. The simple correlation coefficient is +.67. The sex ratio is hypothesized to rise during periods of expansion due to more heifers being held for replacements, thus causing the steer/heifer ratio to rise. The placement weight series is not strongly correlated to the cattle cycle as measured here but does appear to be cyclical. During 1974 and 1975 when feed prices were high relative to cattle prices and "grass fed" beef was common, placement weights were estimated to be the highest observed for the period 1960-1977.

The index of growth rates does not seem to follow the cycle either. When regressed against time it shows a significant positive trend (a t-value of 3.76 was found). This trend is primarily due to the unprecedented rise in growth rates occurring since 1973. The drop in growth rates estimated from 1970 to 1973 may be due to the legal actions taken against growth hormones and feed additives being used at that time.

Application of the Results

Information generated from the estimated time paths of the control variables can likely be used to aid making cattle on feed forecasts via the traditional approaches. Their best use for assisting in making forecasts would appear to be in conjunction with continuous models of the beef growth process such as the one described and used in this study. By forecasting the control variables and using them as inputs to the continuous cattle on feed inventory and growth model, continuous (with respect to time and weight) projections of cattle on feed inventories and marketing can be made. Forecasts of the control variables (placement weight, sex

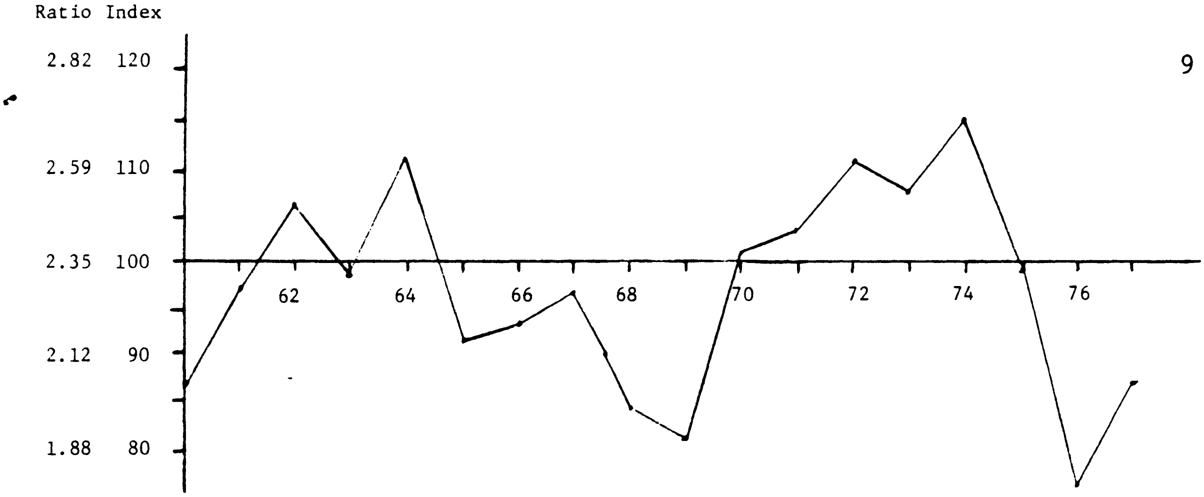

Figure 2A. Steer/Heifer Sex Ratio of Cattle Placed on Feed, 1960-1977.

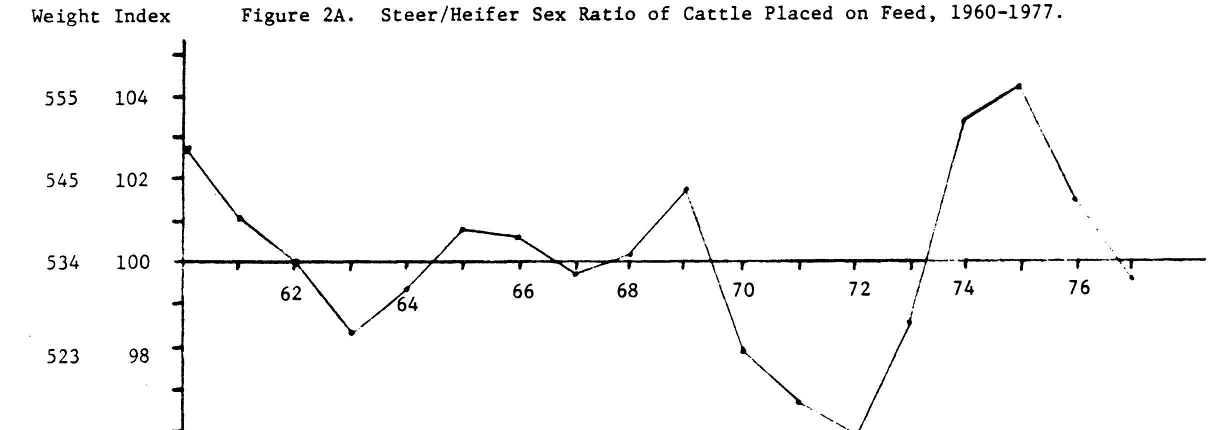

Figure 2B. Average-Weight of Cattle Placed on Feed.

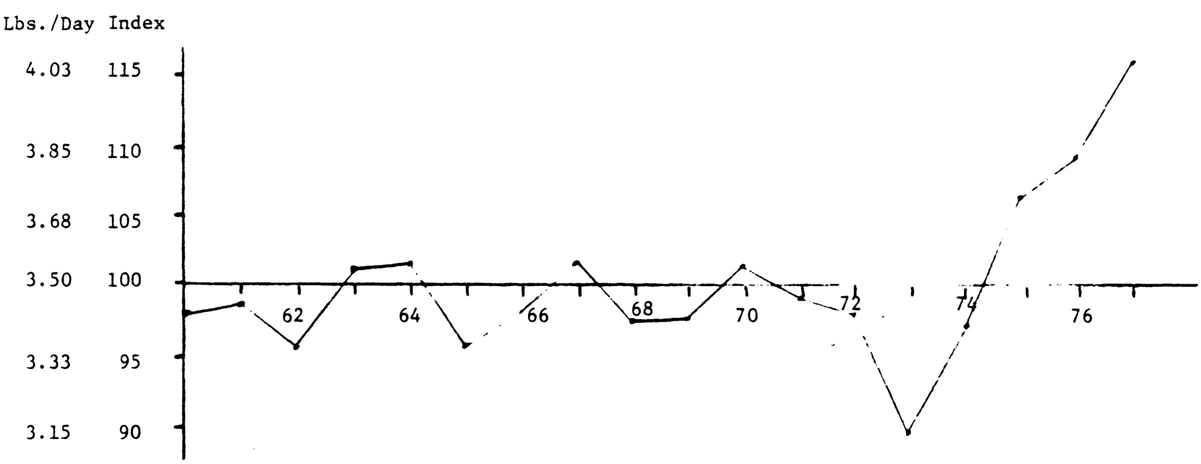

Figure 2C. Daily Growth Rates for 900 lb. Cattle on Feed, 1960-1977.

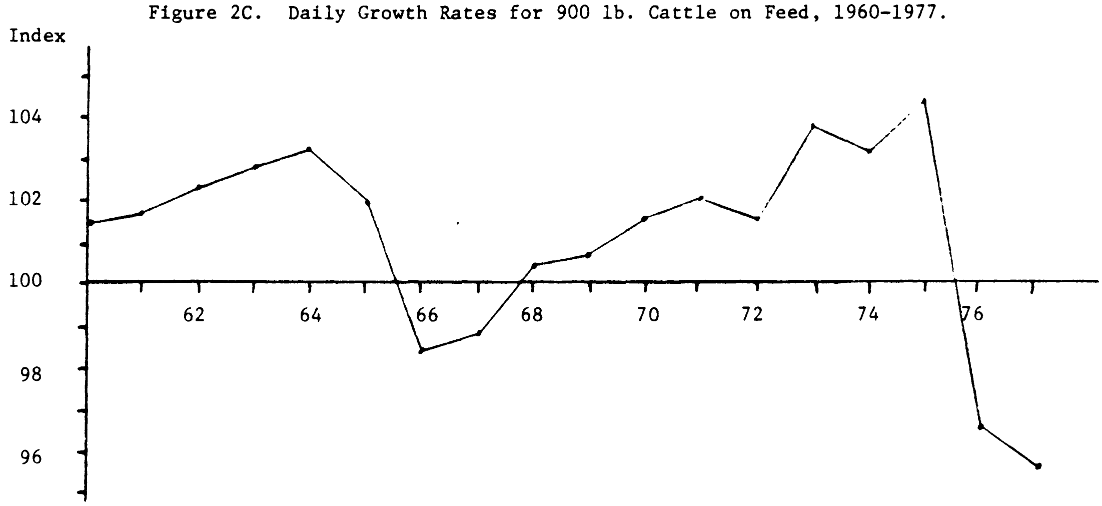

Figure 2D. Rate of Change in the Size of the Beef Cow Herd, 1960-1977.

ratios and growth rates) can be made either subjectively or via econometric methods. Research using econometric methods to estimate structural relations between the estimated values for the control variables and other observed economic variables is currently underway.

Figure 3 is presented as an example of the type of forecasts that can be made with the continuous cattle on feed inventory and growth model. It compares the 1977 optimal tracking path for cattle on feed marketed against a simulated 1978 projection. The daily slaughter rate simulated for January 1 of 1977 is used as a base value.

The 1978 projection depicted in Figure 3 was made immediately after the release of the 1977 fourth quarter cattle on feed report. The detailed (broken into one pound weight increments) December 31st ending cattle on feed estimates made by the model were used as an input into the projection. All other inputs were provided by making subjective assumptions of the expected changes from the reported or estimated (estimated in the cases where input data are not reported) 1977 values for the inputs. The input assumptions were as follows: a) placements would decline by 5 percent; b) slaughter weights would decline by 20 pounds; c) placements weights would decline by 30-40 pounds; d) growth rates would slow by 5 percent; and e) the steer/heifer ratio would increase by 15 percent.

At the date of this writing the January and February seven state cattle on feed reports were available. They indicate that 1978 seven state cattle on feed marketings as a percent of 1977 seven state cattle on feed marketings were 109 and 106 percent respectively for January and February. The model is based upon 23 state quarterly marketings, hence comparisons of absolute values is not possible but ratio comparisons are valid. The model forecasts of 1978 marketings as a percent of simulated 1977 marketings for January and February were 111 percent and 108 percent respectively.

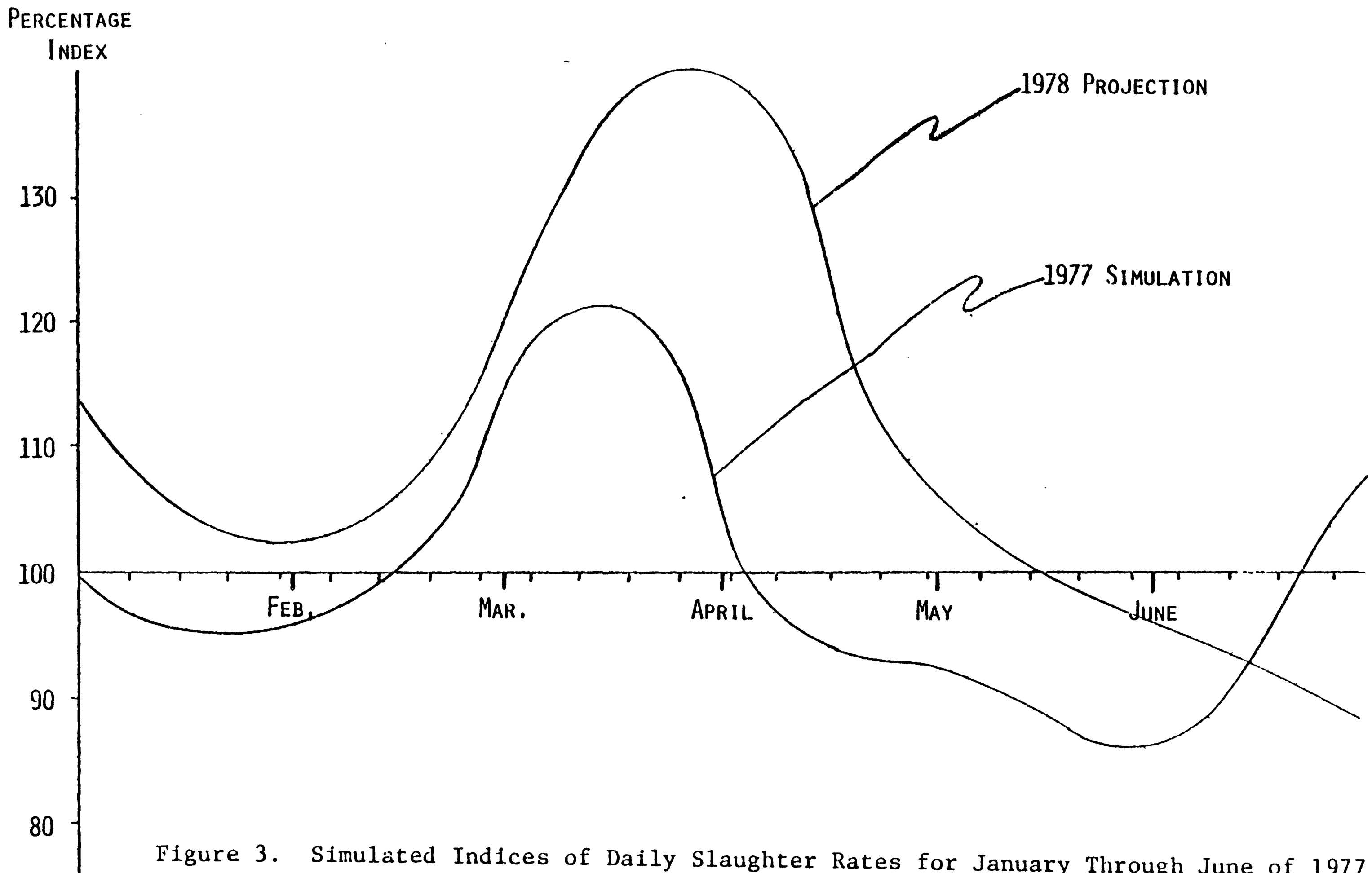

Figure 3. Simulated Indices of Daily Slaughter Rates for January Through June of 1977 and 1978.

Summary

Optimal control techniques provide a scientific method for making estimates of cattle on feed characteristics not currently reported in U.S.D.A. data series. This capability removes many data restrictions and therefore expands the variety of modeling techniques that can be applied toward developing forecasts of beef supply. Initial research efforts reported here which incorporate optimal control estimates of cattle on feed placement weights, sex of animals placed and growth rates of cattle on feed into a continuous cattle on feed inventory and growth model to make short-run forecasts of cattle on feed marketings appear promising.

Footnotes

[1]/See Trapp, James N., "A New Approach to Beef Supply Modeling Using Differential Equations and Optimal Control Techniques," forthcoming Oklahoma State University Experiment Station Technical Bulletin.

[2]/See Llewellyn, "FORDYN-An Industrial Dynamics Simulater" or Manetsch and Park, "Systems Analysis and Simulation With Application to Economic and Social Systems" for presentations of computerized numerical methods for modeling systems of differential equations.

[3]/More precise breakdowns of the weight distributions of ending cattle on feed inventories are available from the continuous functions but are not used for calculating tracking accuracy. They are however used to assist in defining the beginning inventories of cattle on feed for the next period.

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