Econometric Analysis of the Cattle Cycle in the United States

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SUMMARY

This study has been made to further explain the cattle cycle in the United States and in three selected regions. Structural models of the cattle cycle are specified and estimated, and hypotheses about their parameters are tested. For this study, the cattle cycle is divided into three cycles that include the inventory cycle, the price and income cycle and the slaughter and import cycle. Further analysis is then made to determine the important explanatory variables within each cycle. Several simultaneous equation models are constructed of the form:

$$y'(t)C + x'(t)B + u'(t) = o'$$

where $y'(t)$, $x'(t)$ and $u'(t)$ are the row vectors, respectively, of the jointly dependent variables, the predetermined variables and the unobserved disturbances in the equations and where C and B are the matrices of the coefficients of the jointly dependent variables and of the predetermined variables, respectively.

Emphasis is given to an investigation of the possibility of cyclic behavior in some parameters of the model. If the parameters undergo changes in various phases of the cattle cycle, the changes between the inventory expansion phase (i.e., "upswing") and the inventory reduction phase (i.e., "downswing") should be quantifiable. These nonlinearities in the coefficients of some predetermined variables are made amenable to linear estimation methods and to ordinary significance tests by adding one or more dummy variables to the predetermined variables.

The repetitions of the cattle cycle are not of equal length over the period studied. Upswing and downswing periods are frequently unequal even within a cycle. This fluctuation provides the basis for the two arbitrarily selected cycle divisions used in the study. The dummy variables are based on these cycle divisions. Two-stage, least-squares estimation is used to derive numerical estimates of the elements of the coefficient matrices.

Annual time-series data for 1925 through 1962 are used for this study. The inventory series refer to Jan. 1, but most other series refer to the calendar year. Deviations of the observed values from trend values form the measurements and basis of the regression estimates.

At the national level, 12 variables are explained (i.e., one set of variants of an equation is specified and estimated for each variable). The 12 explained variables are grouped into the three previously mentioned cycles, and hypotheses about the coefficients of the variables are tested.

Four variables are included in the inventory cycle. Probably the most important variable in this group is the number of cows and heifers over 2 years old kept. The number of calves 1 to 2 years old kept as young heifers, the number of calves raised and the number of calves saved are the other variables deemed important in explaining this cycle.

Variables of the price and income cycle include the current weighted-average slaughter-cattle price received by farmers, the current weighted-average slaughter-calf price received by farmers and the gross farm income from cattle and calves. These three variables explain most the variation in this cycle.

The remaining variables are grouped into the slaughter and import cycle. Variables considered in this cycle include the total number of cattle slaughtered and the number of cattle of domestic origin slaughtered, the total number of calves slaughtered and the weighted-average liveweight of cattle and calves slaughtered under federal inspection. Also, the average liveweight of calves slaughtered under federal inspection and the net imports of cattle and calves are major variables estimated for this cycle. The first variable, the number of cows and heifers over 2 years old kept, of the inventory cycle is also analyzed for: Region I, western states; Region II, west north-central states; and Region III, east north-central states.

Interpretation of the Numerical Results

Models that are linear in the coefficients and in the variables explain the cattle cycle almost as well as models that are nonlinear in selected parameters. The R^2 values of nonlinear equations are usually only a little larger than those of linear equations. The differences ordinarily increase if there is a decrease in the number of variables for which significant coefficients of the correct sign are obtained.

In linear, as well as nonlinear models, most estimates of the coefficients are statistically acceptable and have the correct sign. Furthermore, the sign of an estimate usually does not change if limited changes are made in the set of explanatory variables of an equation.

The estimated changes in the intercept coefficient between upswings and downswings are significant or highly significant in most equations and in all areas where the hypothesis of change is tested. Changes also are tested between upswings

and downswings in the coefficients of two and (or) three variables in four sets of equations explaining the inventory cycle at the national level. They are significant in three sets of equations.

If the quality of prediction for any year studied is measured by the absolute magnitude of the deviation of the predicted from the observed value, the superiority of linear and nonlinear models varies among phases of the cattle cycle. Linear models predict better in years close to the turning points of the cycle. Nonlinear models perform better in years between the turning points.

Equations Explaining the Inventory Cycle

The estimated coefficients of almost all variables have the correct sign for the number of cows and heifers over 2 years old kept. Most coefficients are statistically significant or highly significant. The results are less uniform at the regional level.

The average coefficient of multiple determination, R^2, for the United States analysis is 0.908. This value is relatively high, considering that the explanatory value of time has been eliminated from the data by using deviations from time trends. The R^2 values increase from Region I to Region III, with those for Region III being larger than those for the national level.

In the analysis of price response, the elasticities of the number of cows and heifers over 2 years old kept with respect to the current weighted-average slaughter-cattle price received by farmers, are negative for all areas of the U.S. studied. The average regression coefficient for this variable suggests that an increase in the current slaughter-cattle price by $1 per 100 pounds of liveweight leads, *ceteris paribus,* to a reduction in next year's cow and heifer inventory by about 160,380 head. The absolute magnitude of the elasticities decreases from Region I to Region III as the proportion of milk cows and heifers increases. The response to the lagged weighted-average slaughter-cattle price is received by farmers is positive for all areas.

The average regression coefficient of the lagged weighted-average slaughter-cattle price indicates that, if the lagged price of slaughter cattle increases by $1 per 100 pounds of liveweight, the number of cows and heifers kept next year will increase by about 134,448 head. Since the response to prices is not the same during an upswing as during a downswing, the significance of a dummy variable is tested. The average coefficient of this dummy variable indicates that, on the average, a $1 increase (decrease) in the lagged slaughter-cattle price induces cattle producers to keep about 145,700 more (fewer) heifers over 2 years old during a downswing than during an upswing.

The opposite signs of the coefficients for current and lagged cattle prices may be interpreted in two ways. First, they may indicate that farmers interpret changes in the current slaughter-cattle price as short run and changes in the lagged slaughter-cattle price as longer-run profitability indicators. Hence, cattle farmers or ranchers keep fewer cows and heifers (i.e., sell more for slaughter) if the current slaughter-cattle price rises. If the lagged slaughter-cattle price increases, they keep more cows and heifers (i.e., they increase next year's cow and heifer inventory). Second, these coefficients may be added and interpreted as the coefficient of the variable slaughter-cattle price change, which shows the tendency to reach a lower significance level than the coefficients for the two variables separately. This tendency holds true also for equations explaining other variables. The sign of the coefficient for the current slaughter-cattle price change is correct if the price changes are interpreted in the short-run framework. In particular, the elasticities of the number of cows and heifers over 2 years old kept with respect to the lagged weighted slaughter-cattle price received by farmers are approximately twice as large during downswings as during upswings. The elasticities of the same variable with respect to the production of all types of hay are almost four times as large during upswings as during downswings. Other things remaining equal (slaughter-cattle prices, hay production, corn production, etc.), an estimated 1.2 million more cows and heifers over 2 years old are kept during an upswing than during a downswing.

Changes in the intercept coefficients between upswings and downswings are estimated for the selected regions. They are positive, as expected, and highly significant in all equations.

In the equations explaining the number of calves kept as heifers 1 to 2 years old, the effect of the current weighted-average slaughter-cattle price received by farmers is negative, as expected, for the United States. The effect of the lagged weighted-average slaughter-cattle price received by farmers again is positive. The opposite signs can be interpreted as before.

The regression coefficient for total hay production suggests that farmers respond to a 1-unit increase in the production of all types of hay by keeping about 22 more calves as heifers during an upswing than during a downswing. The coefficients for the seasonal average corn price of $1 per bushel lead to an increase in the number of calves kept as heifers 1 to 2 years old by approximately 1.45 million head. The average coefficient of the dummy variable for the intercept change indicates that, beyond the effect of other variables, about 390,000 more calves are kept as heifers 1 to 2 years old during an upswing than during a downswing.

In the equations explaining the number of calves raised, the coefficient of the current weighted-average slaughter-cattle price received by farmers is negative. A possible explanation of the negative value is that an increased slaughter-cattle price leads to an increase in the current cattle slaughter. As a result, fewer calves are saved since more cows and heifers are slaughtered before they have a calf.

The equations explaining the number of calves saved are the only ones in the over-all model that are independent of the other equations in the model. The empirical results for this set of equations imply that a $1 change in the lagged slaughter-cattle price received by farmers leads to a change in the current number of calves available by 123,000 more during a downswing than during an upswing. Also, the lagged price of slaughter calves has a significant effect on the number of calves saved only during downswings.

Equations Explaining the Price and Income Cycle and the Slaughter and Import Cycle

In equations explaining the current weighted-average slaughter-cattle price received by farmers, models linear in the coefficients and in the variables gave a satisfactory explanation of the variance. The highest significance levels in estimating the current weighted-average slaughter-cattle price were observed for current total cattle slaughter, corn price received by farmers, total disposable personal income and the supply of other meats. On the average, the estimated coefficients suggest that a change in the annual total supply of slaughter cattle by approximately 893,000 head changes the current weighted-average slaughter-cattle price by $1 per hundredweight. The coefficient of the lagged net imports of cattle implies the expected result that the origin of cattle alone has no unique effect on the slaughter-cattle price. Finally, the negative effect of increasing the average liveweight of slaughter cattle is outweighed by the positive effects of other factors intercorrelated in the phenomena of cyclical upswings.

The total number of cattle slaughtered has a highly significant effect upon the gross farm income from cattle and calves. Total disposable personal income is highly significant in equations explaining this variable. The estimated coefficients for this variable suggest that approximately 3.74 cents out of every additional $1 in total disposable personal income will go into the cattle farmers' pockets. The coefficients for total disposable personal income and for the supply of other meats indicate the dependence of the cattle-producing sector upon total economic activity and competing sectors within agriculture, respectively.

Econometric Analysis of the Cattle Cycle in the United States[1]

by Josef Gruber and Earl O. Heady [2]

This report presents an econometric analysis of the cattle cycle in the United States. Fluctuations in marketing and slaughter-cattle prices (with conflicting reasons given by farmers, ranchers and meat packers for these fluctuations) emphasize the need for further quantitative knowledge of the important variables or factors relating to the cattle cycle.

The cattle cycle is a long-standing phenomenon. It includes the recurring upward and downward swings in the number of beef cattle held in farm and ranch inventories, with associated swings in the prices and marketings of beef cattle. The term "cattle cycle" is used in this study as a generic term that includes three groups of cycles: (a) the cattle-inventory cycle, (b) the cattle-price and income cycle and (c) the cattle-slaughter and import cycle. Attention is focused on the cattle-inventory (annual inventory numbers) for four classes of cattle on farms. The word "cycle" may or may not refer to fluctuations of approximately equal times and magnitudes.

OBJECTIVES

The major objective of this study is to develop and test models that explain the magnitude of important endogenous variables relating to the cattle cycle. The variables to be explained or predicted include: the number of cows and heifers over 2 years old kept on farms, the number of calves kept as heifers 1 to 2 years old, the number of calves raised, the total number of cattle and calves slaughtered, the average liveweight of cattle and calves slaughtered under federal inspection, the net imports of cattle and calves, current weighted-average slaughter-cattle price received by farmers and gross farm income from cattle and calves.

Although these predictions and explanations provide the main objectives of the study, other objectives include: (a) comparison of different national models with respect to specification of explanatory variables and in relation to differential effects in different phases of the cattle cycle, (b) comparisons among selected regions of the relevance of different explanatory variables and (c) interpretation of the quantitative effect and meaning of the numerous variables that explain inventory numbers in the cattle cycle.

MODELS

The models used in this study are interdependent, macroeconomic models. They consist of macrovariables (including the macroerror terms) and macroparameters. In the analogy approach to aggregation proposed by Theil (1954) and described by Allen (1960, p. 696), the variables and parameters of microtheories are translated into macrolanguage. The purpose of the analogy approach is to allow us to use theories and knowledge of microvariables and microparameters in deriving hypotheses about relevant macrovariables and macroparameters, and conversely. This approach to aggregation has several weaknesses as noted by Theil (1954, pp. 133 ff.). In particular, rejection of the estimate of a macrocoefficient because of a "wrong" sign, in terms of an analogous microtheory, may be premature.

The econometric models used in this study are partial or sectoral models dealing only with the cattle-producing sector of the United States' economy. They are characterized by, among other things, the definition of some variables as exogenous, whereas these same variables are endogenous from the standpoint of the entire economy. In other words, in investigating the cattle-producing sector, we assume that some economic variables affect the endogenous variables of the cattle-producing sector but are not themselves influenced by these endogenous variables. Because of the general interdependence of economic variables, most exogenous variables used in this study are only approximately exogenous to the cattle-producing sector. Hence, we may reflect a specification error in making the assumption that they are exogenous.

The effect of this specification error upon the consistency of the parameter estimates for econometric models was investigated by Fisher (1961, pp. 161-168). He concludes that the inconsistencies in the estimates of parameters will be near zero if the following conditions are satisfied: All *a-priori* restrictions are close approximations, omitted ex-

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[1]Project 1405 of the Iowa Agriculture and Home Economics Experiment Station; Center for Agricultural and Economic Development, cooperating.

[2]Josef Gruber was a graduate student in economics at Iowa State University at the time of the study. Earl O. Heady is distinguished professor of economics and executive director of the Center for Agricultural and Economic Development, Iowa State University.

planatory variables have small coefficients, and the endogenous variables have negligible direct and indirect effects upon the assumed exogenous variables of the partial model. Fisher's study, however, deals only with the effects upon the consistency of estimators derived from approximate specifications. Other desirable properties of estimators may be affected differently. Consistency possesses special importance in this study, however, because the sample size of the data used may be considered large.

All models constructed in this study are linear in the variables. Although most of them are nonlinear in selected parameters, linear estimation methods can be applied in all cases because nonlinearities are introduced through dummy variables.[3] These dummy variables lead to abrupt changes in one or more coefficients at the turning points[4] of the cattle cycle in explaining the inventory of all cattle and calves on farms. Although gradual changes in the parameters are more realistic and can be handled theoretically,[5] they present computational difficulties.[6]

An approximation to gradual parameter changes can be achieved by introducing more than one dummy variable for each changing parameter. This procedure has the advantage that relatively simple linear estimation methods are applicable. Its main disadvantage is the loss of several degrees of freedom. Therefore, we use only one dummy variable for each coefficient for which changes are expected.

METHODS

The method of two-stage least squares, explained by Goldberger (1964, pp. 329-338) and Johnston (1963, pp. 258-260), is applied whenever a structural equation with one or more right-hand, jointly dependent variables is estimated. It gives consistent estimates and does not require assumptions of normality of errors for consistent estimation. Also, it has an advantage over the limited-information method because it is computationally simpler, but the asymptotic properties of the estimates are the same. For lack of a two-stage least squares computer program, the two-stage least squares estimates were obtained by applying an ordinary least squares program twice. This procedure may have some undesirable consequences for the standard errors and for R^2.

[3]On dummy variables see Goldberger (1964, p. 218), Johnston (1963, p. 221) and Tomek (1963).

[4]On turning points see Akerman (1960, pp. 142, 152 and p. 190), Lutz and Lutz (1951, p. 52), Tinbergen (1938, pp. 32-33) and Tinbergen and Polak (1950). For a survey on some business cycle theories, see Allen (1960), Dupriez (1959), Godeon (1952), Haberler (1955), Hicks (1950), Tinbergen (1951), Smithies (1951) and Adelman (1960).

[5]See the work of Goodwin, as restated in simplified form by Allen (1960, p. 247).

[6]See Hartley (1961).

Ordinary t-tests are used to examine the statistical significance of individual explanatory variables. Where *a-priori* knowledge exists that the effect is either positive or negative, but not both, a one-sided test is used; otherwise, a two-sided test is used.

The t-tests may be only approximate because the distribution of the errors in the equations may be only approximately normal. The "actual" number of the degrees of freedom may also be smaller than the counted number because some other stochastic specifications of the model may not be satisfied (Tintner, 1952, p. 247). Furthermore, the effects of the elimination of a linear trend upon the significance levels are unknown in the case of simultaneous equation models.[7]

A variable is included in an equation if its coefficient is significant or highly significant.[8] Also, a coefficient somewhat lower in significance is accepted if its sign is correct and its effect on the explained variable is deemed economically significant in at least a few years of each cycle. The number of explanatory variables generally is kept low enough so that significant coefficients are obtained for all or nearly all variables.

An estimation equation is included in the tables of the following sections if it possesses a satisfactory R^2 value and its coefficients satisfy the conditions just mentioned. An equation with relatively low R^2 significance levels is sometimes selected if it contains a set of explanatory variables that allows us to compare the explanatory value of two or more variables or is of interest for other reasons.[9]

TIME SERIES

Annual time series covering 1925 to 1962 for the United States and 1925 to 1963 for three of its regions are used in the study. Each time series is first regressed on time. Deviations of the observed values from the predicted or trend values are then used as the observations in the econometric analysis. If deviations from trend are used, there is no need for the inclusion of time in the group of explanatory variables (Frisch and Waugh, 1933). This procedure reduces the size of the matrices and makes rounding errors less likely. Most important, however, it also reduces multicollinearity. Most of the original time series available for this study show a pronounced trend. If time is introduced

[7]On the effects of trend elimination in single-equation models see Ramsey (1964). On time-series analysis in general see Tintner (1952, Part 3).

[8]The following terminology is used: "highly significant" if a ≤ 0.01, "significant" if 0.01 < a ≤ 0.05, "lowly significant" if 0.05 < a < 0.50, and "nonsignificant" if a ≥ 0.50, where a is the probability of type I error.

[9]For more sophisticated criteria (but considerably more expensive criteria, computationally) see Hooper (1959), Hotelling (1940), Tedford (1960) and Wherry (1931).

directly as an explanatory variable, multicollinearity results between the time variable and other variables having a pronounced trend over time.

The sources of the data are numerous and are from obtainable public documents. Most are listed in the reference list of this study, under the U.S. Department of Agriculture (USDA) 1949 through 1964). Further sources are Jennings (1954, 1955 and 1958), Hodges (1963, 1964) and the U.S. Census Bureau (1960, 1963).

The terms "data," "time series," "series" and "variable" are used synonymously. Throughout this report, unlagged endogenous variables (i.e., jointly dependent variables) are designated by $y_i(t)$, and lagged endogenous and all exogenous variables by $x_i(t)$. Lagged variables are always placed immediately below the corresponding unlagged variables. Therefore, the definitions of the lagged variables need not be repeated in their entirety. Unless otherwise indicated, the term "lag" refers to a lag of 1 year. The same definitions of variables are used for all areas. However, if a variable refers to a region, it is marked by the superscript R. The time series refer to the calendar year unless specified otherwise. Cattle numbers are expressed in thousands. Cattle inventories on farms refer to Jan. 1 of year t. The prices of livestock are in dollars per 100 pounds of liveweight. Average prices used were computed from state-weighted average prices by quantities sold. They, too, refer to the calendar year unless specified otherwise.

List of Definitions

Inventory and disposition variables

$y_{119}(t)$: number of cows and heifers over 2 years old kept on farms during year t. This endogenous variable is $x_{47}(t+1)$; i.e., the number of cows and heifers over 2 years old "kept" on farms during year t is equal to the inventory of cows and heifers over 2 years old on farms on Jan. 1 of year t+1.

$x_{47}(t)$: inventory of cows and heifers over 2 years old on farms on Jan. 1 of year t; or $x_{47}(t) = y_{119}(t-1)$. The word "heifer" without any age specification refers to heifers over 2 years old.

$Y_{120}(t)$: number of calves kept as 1- to 2-year-old heifers on farms during year t; or $y_{120}(t) = x_{62}(t+1)$.

$x_{62}(t)$: inventory of 1- to 2-year-old (young) heifers on farms on Jan. 1 of year t; or $x_{62}(t) = y_{120}(t-1)$.

$y_{74}(t)$: number of calves raised during year t; or $y_{74}(t) = x_{56}(t+1)$.

$x_{56}(t)$: inventory of all calves on farms on Jan. 1 of year t; or $x_{56}(t) = y_{74}(t-1)$.

$y_{69}(t)$: number of calves saved. This variable is the number of calves born during year t, minus the number of calves lost during the same period.

$x_{44}(t)$: inventory of all cattle and calves on farms.

Price Variables

$y_{93}(t)$: current (i.e., unlagged) weighted-average slaughter-cattle price received by farmers (excluding the price of slaughter calves).

$x_{94}(t)$: lagged slaughter-cattle price.

$y_{96}(t)$: current weighted-average slaughter-calf price received by farmers.

$x_{97}(t)$: lagged weighted-average slaughter-calf price.

$x_{129}(t)$: wholesale price of milk received by farmers, in dollars per 100 pounds.

$x_{130}(t)$: lagged price of milk.

$x_{134}(t)$: weighted-average price of hogs received by farmers.

$x_{135}(t)$: lagged price of hogs.

$x_{132}(t)$: weighted-average price of lambs received by farmers.

$x_{133}(t)$: lagged price of lambs.

$x_{87}(t)$: weighted-seasonal-average price of corn received by farmers, in dollars per bushel. For 1937 to 1941 and 1949 to 1956, it includes an allowance for unredeemed loans at average loan value. Beginning with 1949, it also includes an allowance for purchase-agreement deliveries valued at the average rate. The season differs among regions; it is approximately Oct. 1 of year t-1 to Sept. 30 of year t.

Slaughter, Import and Meat Variables

$y_{28}(t)$: total number of cattle slaughtered, excluding calves.

$y_{24}(t)$: number of cattle slaughtered under federal inspection.

$y_{29}(t)$: number of calves slaughtered under federal inspection.

$y_{33}(t)$ total number of calves slaughtered.

$y_{34}(t)$: weighted-average liveweight in pounds of cattle (excluding calves) slaughtered under federal inspection.

$y_{35}(t)$: weighted-average liveweight in pounds of calves slaughtered under federal inspection.

$y_{36}(t)$: net imports of cattle. Although $y_{36}(t)$ also includes calves, their number is negligible.

$x_{37}(t)$: lagged net imports of cattle in numbers.

$y_{38}(t)$: estimated number of cattle slaughtered from domestic origin. It is $y_{28}(t)$, minus $x_{37}(t)$. For brevity, it is called "domestic cattle slaughter."

$x_{14}(t)$: pork (excluding lard) supply, in millions of pounds carcass-weight equivalent. It is defined as the sum of domestic pork production and net pork imports.

$x_{15}(t)$: lamb and mutton supply, in millions of pounds-carcass-weight equivalent. It is domestic production, plus net imports.

$x_{16}(t)$: poultry meat supply, in millions of pounds on a ready-to-cook basis. It includes domestic chicken and turkey meat production and net imports. Chicken production figures for the earlier part of the period have been obtained by extrapolation.

$x_{17}(t)$: supply of all meats, excluding beef and veal, in millions of pounds carcass-weight equivalent (pork, lamb and mutton) and on a ready-to-cook basis (poultry meats). It is the sum of the corresponding values of $x_{14}(t)$, $x_{15}(t)$ and $x_{16}(t)$.

Feed Variables

$x_{77}(t)$: total production of all types of hay, in thousands of tons.

$x_{78}(t)$: lagged production of hay.

$x_{81}(t)$: total production of corn (grain), in millions of bushels.

$x_{82}(t)$: lagged production of corn.

$x_{83}(t)$: corn supply, it includes $x_{81}(t)$ and corn stocks on farms on Oct. 1 (old crop only), in millions of bushels. (For lack of data on corn carryover on farms before 1934, only production data are used for the earlier period.)

$x_{84}(t)$: lagged corn supply.

$x_{131}(t)$: range feed-condition index, 17 western states, simple average April through October.

Other variables

$x_{114}(t)$: time $(1925 = 1, \ldots, 1962 = 38, 1963 = 39)$.

$y_1(t)$: gross farm income from cattle and calves in year t, in millions of dollars. No adjustments were made for cost of cattle shipped in and changes in inventory values. Gross income is cash receipts from sales of cattle, calves, beef and veal, plus value of cattle and calves slaughtered for home consumption.

$x_3(t)$: total disposable personal income, in billions of current dollars.

$D_j{}^u$ and $D_j{}^d$: dummy variables for upswing ($D_j{}^u$) and downswing ($D_j{}^d$), referring to the jth explanatory variable.

The dummy variables are based on the cycle divisions in table 1. Each dummy variable consists of the values of the variable to which it belongs (i.e., the jth explanatory variable) during the cycle phase in question (indicated by superscripts u and d on D) and zeros otherwise. For example, the intercept-shifting dummy variable $D_0{}^u$ for cycle division A (table 1) has the value 1.0 for all years of the upswing periods and the value zero for all years of the downswing periods of the cycle division A indicated in table 1.

Let another dummy variable be $D_{94}{}^d$, based on cycle division B of table 1. This variable has the value of the variable $x_{94}(t)$, the lagged weighted-average slaughter-cattle price received by farmers, in all years of the downswing periods indicated in table 1, cycle division B. In the years of the corresponding upswing periods, this dummy variable has the value zero.

In the remainder of this report, abbreviated names of the variables are frequently used for brevity.

Table 1. Upswing and downswing phases into which cattle cycles were divided for the two arbitrary divisions A and B.

Periods of downswing	Periods of upswing
Division A for cycles	
1925-1927	1928-1934
1935-1937	1938-1944
1945-1948	1949-1954
1955-1957	1958-1962
Division B for cycles	
1925-1927	1928-1933
1934-1937	1938-1943
1944-1948	1949-1953
1954-1957	1958-1962

Graphic Summary of Fluctuations and Trends

A brief discussion follows of some of the time series used. These time series are presented, together with a few derived quantities, in figs. 1 through 7.

The upper line of fig. 1 shows the total number of cattle and calves on farms on Jan. 1. The peaks and troughs of this series form the basis for two arbitrarily selected cycle divisions, A and B, presented in table 1. Dummy variables for estimating and testing parameter changes between upswing and downswing phases of the cattle cycle are based on these two cycle divisions. The divisions A and B differ slightly in the selected turning points of the cattle inventory cycle.

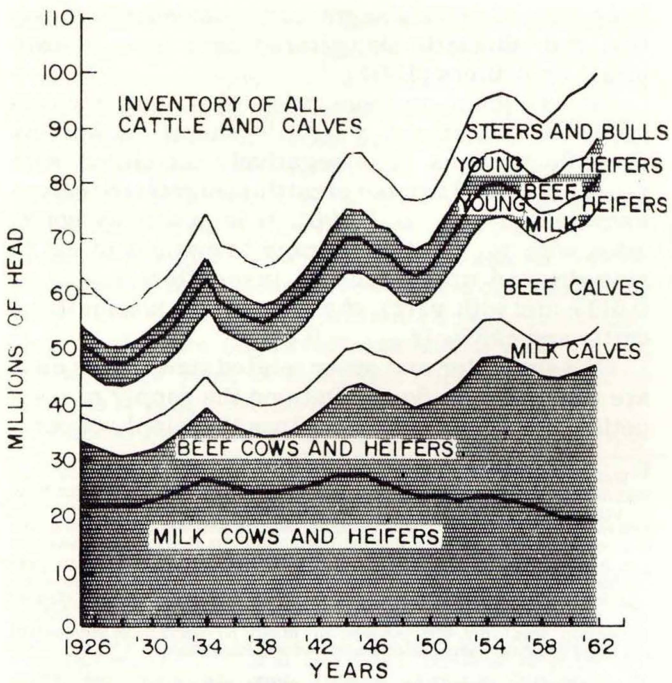

Fig. 1. Composition of total inventory of cattle and calves on farms on Jan. 1.

Fluctuations of about 10 years and of varying amplitude evolve around a pronounced trend. These fluctuations of cattle-inventory numbers are commonly termed the cattle cycle. Usually, the cattle inventory expands during about two-thirds of the cycle length. For our study, this phase is called the expansion or the upswing. During the remaining third, inventory numbers decrease. This phase of the cycle is called the contraction or the downswing.

In fig. 1 and in table 1, it is obvious that the repetitions of the cycle are not of equal length over the complete periods studied. Upswing and downswing periods are frequently unequal, even within a cycle. If deviations from trends are considered, differences in phase length are less pronounced. Even in this instance, however, it is unlikely that the cattle cycle follows a sine-like pattern.[10]

Changes in inventory numbers of the various classes of cattle can be seen clearly in fig. 2. The amplitude and regularity of the cyclical fluctuations are most pronounced for the total cow and heifer inventory. The fluctuations decrease from calf inventory, to young 1- to 2-year-old heifer inventory, to steers and bulls. The observable fluctuations in the last series are more nearly random than periodic. Milk cow and heifer inventories fluctuate less than the corresponding beef-cattle series.

The number of calves saved or available, $y_{69}(t)$, is defined as the number of calves born, minus the number of deaths. The average calf-availability rate, plotted in fig. 3, is defined as the number of calves saved (available) in year t, divided by the number of cows and heifers on farms on Jan. 1 of year t. This rate is low relative to cow numbers for two reasons: (a) deaths of calves are excluded, and (b) Jan. 1 inventories of cows and heifers on farms are perhaps higher than the average number actually available during the year because cattlemen may tend to classify some young females too young to calve as heifers over 2 years. The average calf-availability rate shows small cyclical fluctuations.

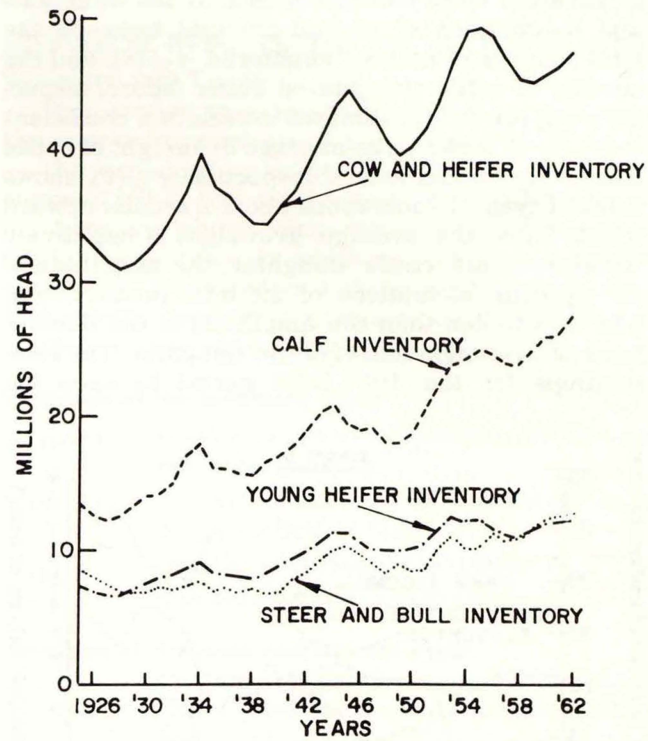

Fig. 2. Variables of cattle-inventory classes: cow and heifer (over 2 years old) inventory, calf inventory, young (1- to 2-years old) heifer inventory, inventory of steers and bulls.

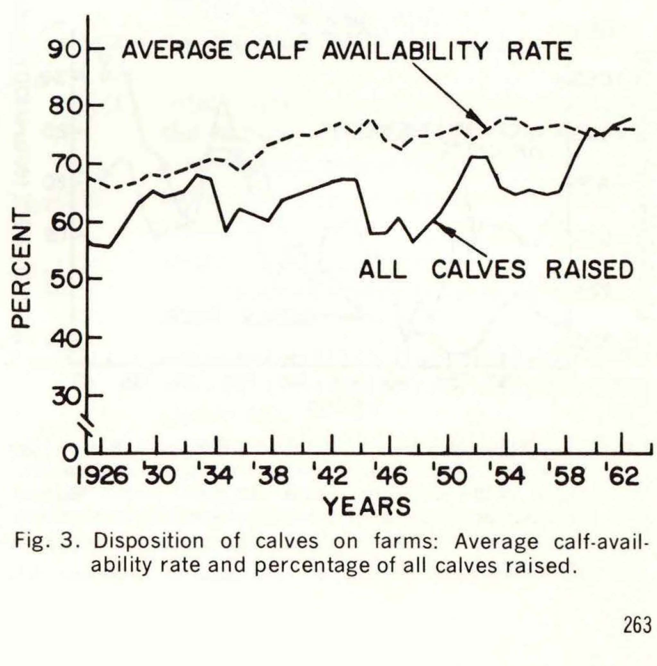

Fig. 3. Disposition of calves on farms: Average calf-availability rate and percentage of all calves raised.

[10]These are already sufficient reasons for excluding an analysis of the cattle cycle according to the approach used by Larson (1964) for the hog cycle.

The percentage of calves raised, fig. 3, shows a secular rise and recurring fluctuations of a rather regular type. Whenever cyclically high slaughter-cattle numbers result in low slaughter-cattle prices (and also with varying lags, lower prices of cattle in other classes), farmers abruptly reduce the percentage of calves raised. The calf-availability rate then stays low for a few consecutive years.

Data on the total number of cattle slaughtered and related variables are presented in fig. 4. There is a rather close correspondence in the directions and magnitudes of annual changes between the total number of cattle slaughtered, $y_{28}(t)$, and the number of cattle slaughtered under federal inspection, $y_{24}(t)$. (The estimated correlation coefficient is $\bar{r}_{28,24} = 0.948$.) The average liveweight of cattle slaughtered under federal inspection, $y_{34}(t)$, shows marked cyclical fluctuations about a secular upward trend. Since the average liveweight is negatively correlated with cattle slaughter, the amplitude of the cyclical fluctuations of the total production of beef is smaller than the amplitude of the fluctuations of liveweight and of cattle slaughter. The relationships for the 1947-1963 period between the liveweight of cattle slaughtered under federal inspection and all cattle slaughtered have been investigated by Walters (1964).[11]

The weighted-average price of slaughter cattle received by farmers, $y_{93}(t)$,[12] shows marked cyclical fluctuations. It is negatively correlated with $y_{28}(t)$, the total number of cattle slaughtered (calves excluded) ($\bar{r}_{93,28} = -0.396$). It is positively correlated with $y_{34}(t)$, the average liveweight of cattle slaughtered under federal inspection ($\bar{r}_{93,34} = 0.311$), and with $y_1(t)$, the gross farm income from cattle and calves ($\bar{r}_{93,1} = 0.836$).

Calf-slaughter and other related time-series data are presented in fig. 5. Data on the supply of competing meats are included since the supply of pork,

[11] Walters states that these relationships remained rather stable. This may be taken, according to Walters, as an indication that, regardless of the phase of the cattle inventory cycle, the same proportionate numbers of cattle of various weight classes are slaughtered without federal inspection as with federal inspection. However, the liveweight per head of cattle slaughtered under federal inspection always exceeded that of cattle slaughtered without federal inspection. The average liveweight under federal inspection during the 17 years studied was 996 pounds, while that for cattle slaughtered without federal inspection was only 866 pounds, or about 87 percent of the weight per head of cattle slaughtered under federal inspection.

[12] As noted in definitions slaughter-cattle price, $y_{93}(t)$, excludes calves.

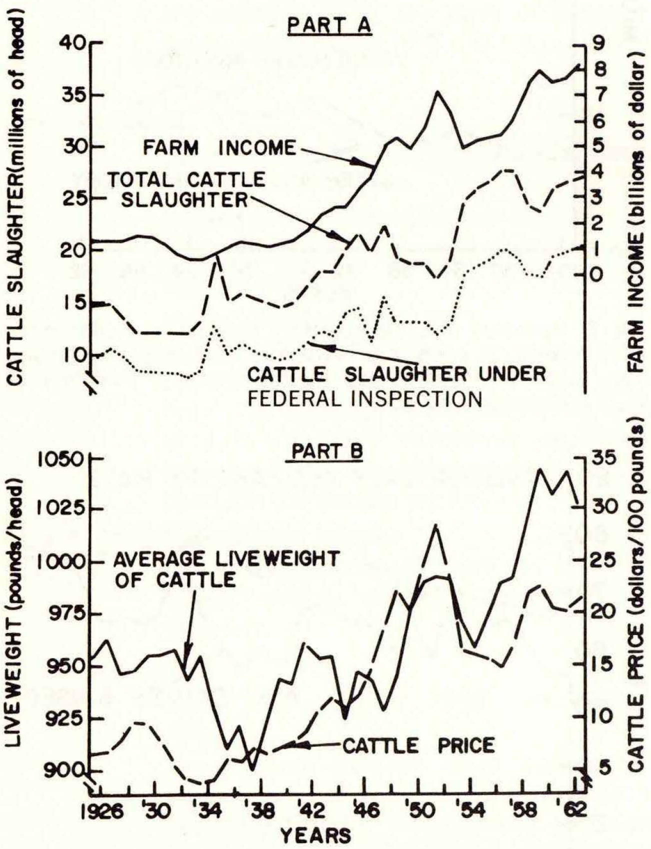

Fig. 4. Variables on cattle (excluding calves) slaughter. Figure 4A: gross farm income from cattle and calves, total cattle slaughter, cattle slaughter under federal inspection. Figure 4B: average liveweight of cattle slaughtered under federal inspection, cattle price received by farmers.

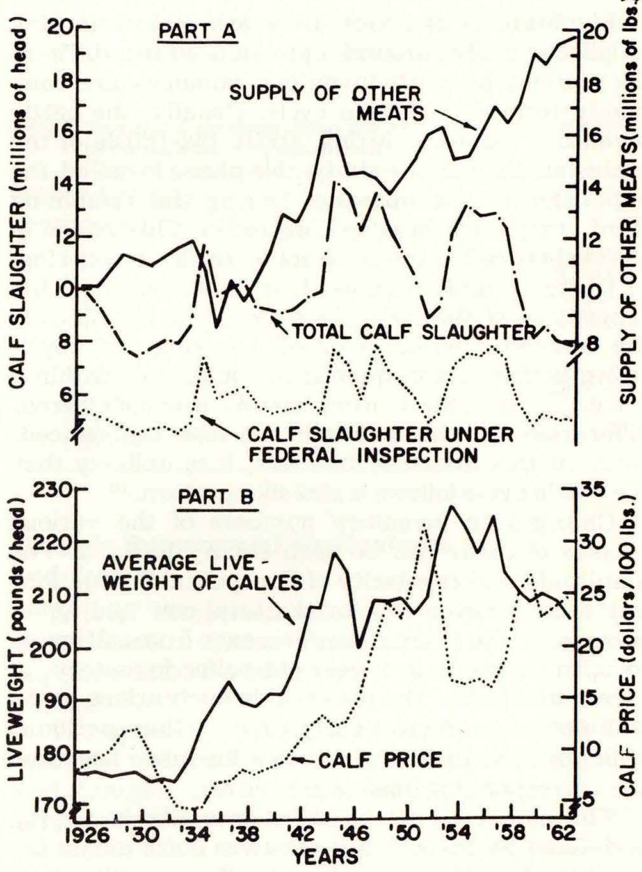

Fig. 5. Variables on calf slaughter. Figure 5A: total calf slaughter, calf slaughter under federal inspection, supply of other meats. Figure 5B: average liveweight of calves slaughtered under federal inspection, slaughter-calf price received by farmers.

lamb and mutton, and poultry should have some effect on the price and supply of slaughter cattle. The number of calves slaughtered increases secularly before 1946 and decreases thereafter. The relatively large increase in the cow and heifer inventory (and, hence, in the number of calves available) is a result of a gradual change in the disposition of calves by farmers. The total number of calves slaughtered, $y_{33}(t)$, is positively correlated with $y_{35}(t)$, the average liveweight of calves slaughtered under federal inspection ($\bar{r}_{33,35} = 0.752$). Both series are negatively correlated with $y_{96}(t)$, the average price of slaughter calves received by farmers ($\bar{r}_{33,96} = -0.264$; $\bar{r}_{35,96} = -0.108$).

Annual fluctuations in the production and supply of feed (fig. 6), especially of concentrates, result in fluctuations of about equal length in the average liveweight of slaughter cattle.[13] The total production of all types of hay, $x_{77}(t)$, is used as a proxy variable to represent the production of all types of roughage. The use of corn stocks on farms, instead of total corn stock, in the time-series on the lagged supply of corn, $x_{84}(t)$, is preferable because corn stocks on farms are more accessible to cattle feeders than corn stocks off farms. Corn stocks on farms accounted for about 50 percent of total corn stocks in the early 1950's and for about 33 percent in most years thereafter.

[13] The contribution of various types of feed to the total consumption of feed units by dairy (beef) cattle for the year beginning Oct. 1, 1959, is computed as: concentrates, 26.3 (15.0) percent; harvested roughage, 34.8 (18.0) percent; pasture and grazing, 37.1 (66.1) percent; other feeds, 1.8 (0.9) percent. In that year, feed units in hay accounted for about 76.7 (81.7) percent of all feed units in harvested roughage consumed; feed units in corn (grain) accounted for 39.5 (67.0) percent of all feed units in concentrates consumed.

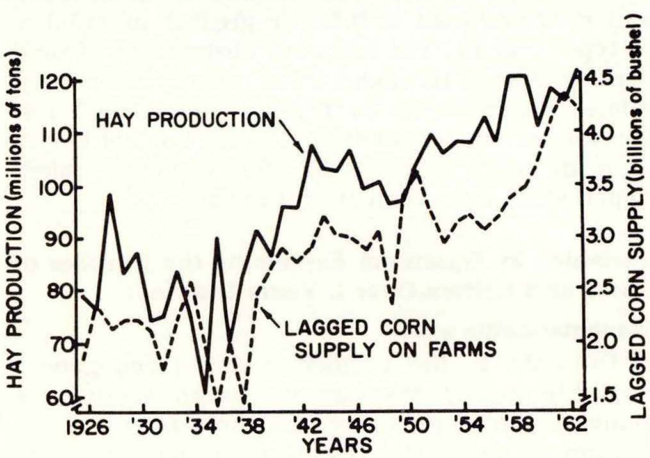

Fig. 6. Feed variables: total production of all types of hay, lagged supply of corn on farms.

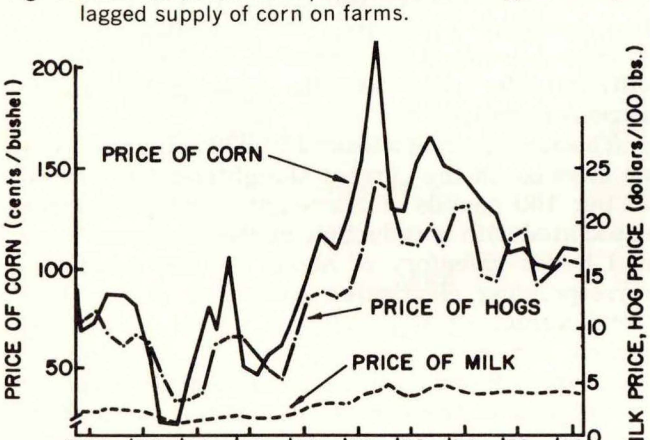

Fig. 7. Price variables: seasonal average price of corn received by farmers, price of milk received by farmers, price of hogs received by farmers.

EMPIRICAL RESULTS FOR THE UNITED STATES

Variables and Terms

This section includes the empirical results for the regression analysis of the United States data.

The explained variables used in the study are summarized in this section, and detailed definitions of these variables were given in the preceding section. The table in which the estimated coefficients are presented is indicated in parentheses. The jointly dependent variables are grouped according to the cycle to which they refer.

Variables of the inventory cycle

$y_{119}(t)$: number of cows and heifers over 2 years old kept (table 2).

$y_{120}(t)$: number of calves 1 to 2 years old kept as young heifers (table 3).

$y_{74}(t)$: number of calves raised (table 4).

$y_{69}(t)$: number of calves saved (table 5).

Variables of the price and income cycle

$y_{93}(t)$: current weighted-average slaughter-cattle price received by farmers (table 6).

$y_{96}(t)$: current weighted-average slaughter-calf price received by farmers (table 7).

$y_1(t)$: gross farm income from cattle and calves (table 8).

Variables of the slaughter and import cycle

$y_{28}(t)$ and $y_{38}(t)$: total number of cattle slaughtered and the number of cattle of domestic origin slaughtered, respectively, (table 9).

$y_{33}(t)$: total number of calves slaughtered (table 10).

$y_{34}(t)$: weighted-average liveweight of cattle slaughtered under federal inspection (table 11).

$y_{35}(t)$: weighted-average liveweight of calves slaughtered under federal inspection (table 12).

$y_{36}(t)$: net imports of cattle and calves (table 12).

The number of predetermined variables in the model vary slightly, the variation depending on the number of dummy variables included. The following 14 predetermined variables defined in the preceding section were used in the first stage of two-stage least squares if no parameter changes were estimated: $x_3(t)$, $x_{17}(t)$, $x_{37}(t)$, $x_{44}(t)$, $x_{47}(t)$, $x_{56}(t)$, $x_{62}(t)$, $x_{77}(t)$, $x_{78}(t)$, $x_{81}(t)$, $x_{83}(t)$, $x_{84}(t)$, $x_{87}(t)$ and $x_{94}(t)$. If parameter changes were estimated, the respective dummy variables were added to this set of predetermined variables.

The table headings that follow later indicate the inventory items, the explained variables in the equations. (They also are indicated in the second column if the table contains more than one explained variable.) The explanatory variables also are indicated in the column headings of the tables. Jointly dependent explanatory variables are designated by $y_i(t)$. The estimates of the coefficients of the explanatory variables are given in the cells of the tables. They are unit effects and are expressed in the same units as the explained variable to which the unit effect refers. Standard errors are included in parentheses below the corresponding regression coefficients. The estimate of any parameter is marked by a bar (-). The estimates in one line of the table multiplied by the respective variables form an equation explaining one endogenous variable. The equations are numbered consecutively. There usually are several equations to explain the same variable, which are variants of versions of the same basic equation. Equations that are not footnoted as to the division of the cattle cycle used (A or B) are based on the undivided cattle cycle. These equations do not contain any dummy variables; i.e., no parameter changes between upswings and downswings are estimated and tested.

When one variant of each of the 12 basic equations of the model is selected, a large number of different combinations (and, hence, of different structural models) results. It is advisable, therefore, to check the identification of an equation only after a particular model has been selected. However, according to the order condition for identifiability, all variants of all equations should be statistically identified or overidentified.

An equation is said to predict well if the predicted and the observed values of the explained variable agree well, given the observed values of the explanatory variables.

The line called "average"[14] contains simple averages of the coefficients in all equations presented in the respective table for specified variables, with exceptions to this rule stated in footnotes.

[14]The word "average" in connection with any type of coefficient has two mutually nonexclusive meanings. Usually, it refers to the simple average of the individual unit effects or to the elasticities derived therefrom. If used in connection with upswing and downswing coefficients or with the corresponding elasticities, it refers also to the average over-all phases of the cattle cycle.

The following average elasticity estimates[15] for the United States as a whole are also given in the tables: the trend elasticities, $\bar{e}_{T62}$, and the mean elasticities, $\bar{e}_M$. The trend elasticities are computed from the 1962 trend values of the respective variables. The mean elasticities are calculated from the mean values of the variables over the period of measurement. $D_j{}^u$ and $D_j{}^d$ designate a dummy variable referring to the jth explanatory variable where superscripts u and d designate upswings and downswings, respectively. Upswing ($\bar{e}_{T62}{}^u$ and $\bar{e}_M{}^u$) and downswing elasticities ($\bar{e}_{T62}{}^d$ and $\bar{e}_M{}^d$) are calculated from the respective upswing and downswing average coefficients. These average upswing and downswing coefficients are obtained by adding the average effect of the dummy variable to the average effect of the respective explanatory variables.

Significance levels mentioned in the text discussion have these meanings: *highly significant* = 0.01 probability or lower of type I error, *significant* = larger than 0.01, but not greater than a 0.05 probability level, *lowly significant* = larger than 0.05, but smaller than a 0.50 probability level, and *nonsignificant* = 0.50 or greater probability of type 1 error. The following designation of time periods is used throughout this report: "Short-run" refers to periods up to 1 year; "longer-run" designates periods longer than 1 year, but not longer than an entire cattle cycle; and "long-run" refers to periods of more than 10 to 12 years.

Variables in Equations Explaining the Number of Cows and Heifers Over 2 Years Old Kept

Slaughter-cattle price

In table 2, the coefficient of the endogenous variable $y_{93}(t)$, the current weighted-average slaughter-cattle price received by farmers, is significant or highly significant in four of the six variants of the equations presented. In the remaining two equations (variants), the probability level of a type I error is still smaller than 0.10. All coefficients for this variable are negative in the various equations.

The average coefficient, -160.3797, suggests that an increase in the current slaughter-cattle price of $1 per 100 pounds of liveweight is, *ceteris paribus,* associated with a reduction in the next year's cow and heifer inventory of about 160,380 head. The corresponding elasticities computed at the 1962 trend values of $y_{119}(t)$ and $y_{93}(t)$ and at the means are $\bar{e}_{T62} = -0.074$ and $\bar{e}_M = -0.052$, respectively. Hence, a higher elasticity is predicted at the end of the period than at the mean of the period.

[15]The elasticity estimates are probably still short-run elasticities. On the effect of time upon elasticities, see Shepherd (1963, pp. 63 ff.). See also, Ladd and Tedford (1959) and Nerlove (1958a, 1958b, 1958c, 1959).

The sign of the coefficients for $y_{93}(t)$ agrees with the short-run microtheory of production. A cattle producer will, other things remaining equal, react to a temporary or short-run increase in the current slaughter-cattle price by selling more cattle, including cows and heifers, for slaughter. Hence, the number of cows and heifers kept decreases. The opposite influences would prevail for a short-run decrease in cattle price.

This explanation of the negative values for the $y_{93}(t)$ coefficients is valid only in the short-run. Cattle farmers, in aggregate, may take temporary changes in slaughter-cattle prices as a means for equally short-run adjustments in the stock of cattle resources on hand. If the resource is more valuable in the market, farmers will sell some of it and reduce its inventory. However, they need not similarly base expectations about future profitability conditions of the cattle enterprise entirely upon these short-run changes. We can hypothesize that, after a price change, the profitability expectations are altered only after the slaughter-cattle price has been at or near some particular level for a longer period. For example, in using annual data it is reasonable to hypothesize that the profitability expectations are altered if last year's slaughter-cattle price received by farmers shows a change and if the current developments of the slaughter-cattle price do not give rise to contrary expectations.

The coefficient of $x_{94}(t)$, the lagged weighted-average slaughter-cattle price received by farmers, is positive in all selected equations and highly significant, significant or lowly significant, depending on the particular equation considered. The average coefficient for this variable, 134.4877, indicates that, if the lagged price of slaughter cattle increases by $1 per 100 pounds of liveweight, the number of cows and heifers kept will increase by about 134,488. The estimated elasticities corresponding to the same coefficient are $\bar{e}_{T62} = 0.060$ and $\bar{e}_M = 0.042$, respectively, with the larger elasticity again indicated for the end of the period. The contrast between the negative effect of $y_{93}(t)$ and the positive effect of its lagged value $x_{94}(t)$ on $y_{119}(t)$ may have the following explanation:

Cattle producers take the current slaughter-cattle price, the estimated response reflected in the coefficients for $y_{93}(t)$, as an indicator of short-run developments, and the lagged slaughter-cattle price or several lagged slaughter-cattle prices as an indicator of longer-run profit prospects of the cattle enterprise. More explicitly, the lagged cattle prices may form the basis for expectations about future profitability conditions. Hence, the size of cow herds tends to be positively associated with lagged slaughter-cattle prices.

Table 2. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{119}(t)$, the number of cows and heifers over 2 years old kept, United States.

Equation number	$y_{93}(t)$ Average current slaughter-cattle price	$y_{28}(t)$ Total cattle slaughter	$x_{47}(t)$ Cow and heifer inventory	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{62}(t)$ Young heifer inventory	$x_{77}(t)$ Total hay production	$x_{81}(t)$ Total corn production	$x_{84}(t)$ Lagged corn supply	D_{94}^d Dummy variable downswing	D_{77}^u Dummy variable upswing	x_0 Intercept	D_0^u Dummy variable upswing	R^2 Coefficient of determination
1[a]	-138.4353	-0.3553	0.9377	125.1392	0.6677	0.0309		0.4333			-623.2540	947.3092	0.92
	(77.6364)	(0.1146)	(0.1668)	(68.9514)	(0.4377)	(0.0158)		(0.4134)			(260.5463)	(361.2305)	
2[a]	-116.2766	-0.2911	0.8679	111.9598	0.8072	0.0346					-761.4549	1,1157.3745	0.92
	(74.8251)	(0.0970)	(0.1532)	(67.9065)	(0.4176)	(0.0154)					(225.0900)	(301.0292)	
3	-147.2751	-0.3699	0.7006	125.1945	1.3507		0.4547				-0.0239		0.88
	(81.7449)	(0.1136)	(0.1801)	(77.0494)	(0.4724)		(0.3822)				(130.5572)		
4	-201.7211	-0.3867	0.7331	175.6574	1.1665	0.0313					-0.0239		0.88
	(87.0328)	(0.1119)	(0.1776)	(79.8183)	(0.4839)	(0.0183)					(127.6332)		
5[b]	- 92.2067	-0.2887	1.0247	60.3278	0.7644	0.0180			104.6339		-810.1038	1,500.5707	0.95
	(66.8260)	(0.0877)	(0.1373)	(58.5014)	(0.3527)	(0.0131)			(68.5534)		(211.78408)	(311.9902)	
6[b]	-226.3636	-0.4623	0.9219	195.9591	0.7454	0.0161			186.8436	0.0454	92.4178		0.90
	(93.1490)	(0.1152)	(0.1975)	(83.4044)	(0.5217)	(0.0198)			(95.5989)	(0.0414)	(134.1796)		
Average:	-160.3797	-0.3590	0.8643	134.4877[c]	0.9170	0.0287	0.4547	0.4333	145.7388	0.0454		1,201.7515	
Elasticities:													
$\bar{e}_{T62}$	-0.074	-0.193	0.855	0.060	0.235	0.071	0.032	0.034					
$\bar{e}_{T62}^u$				0.058		0.152							
$\bar{e}_{T62}^d$				0.123		0.040							
$\bar{e}_M$	-0.052	-0.167	0.856	0.042	0.222	0.069	0.029	0.030					
$\bar{e}_M^u$				0.040		0.147							
$\bar{e}_M^d$				0.086		0.039							

[a] Based on cycle division A indicated in table 1.
[b] Based on cycle division B indicated in table 1.
[c] Computed from coefficients in equations 1-4 only.

The contrast between the negative coefficient for $y_{93}(t)$ and the positive coefficient for $x_{94}(t)$ in table 2 also may be interpreted relative to price changes. Let the slaughter-cattle price change be $\Delta y_{93}(t) = y_{93}(t) - y_{93}(t\text{-}1) = y_{93}(t) - x_{94}(t)$. Then, letting $\bar{c}_{93}$ and $\bar{b}_{94}$ represent the respective regression coefficients for $y_{93}(t)$ and $x_{94}(t)$, $\bar{c}_{\Delta 93} = \bar{c}_{93} + \bar{b}_{94}$ (i.e., the coefficient of the variable $\Delta y_{93}(t)$ is a linear combination of two regression coefficients). For example, for the coefficients of equation 1, we have as estimated values: $\bar{c}_{\Delta 93} = -13.2961$ and $\bar{s}_{c(\Delta 93)} = 34.6729$, where $\bar{s}_{c(\Delta 93)}$ is the standard error. Hence, $\bar{c}_{\Delta 93}$ of equation 1 is not significant. In equation 5, we have $\bar{c}_{\Delta 93} = -31.8789$, and $\bar{s}_{c(\Delta 93)} = 33.4712$. Therefore, $\bar{c}_{\Delta 93}$ of equation 5 is lowly significant at a probability level of type I error of 0.35. In summary, there is a tendency for the coefficient of $\Delta y_{93}(t)$, the annual change in the slaughter-cattle price, to reach a lower significance level than the coefficients of the separate current and lagged slaughter-cattle price variables. The sign of $\bar{c}_{\Delta 93}$ is correct only if price changes are interpreted in the short-run framework.

Nonlinearity in lagged slaughter-cattle price

The null hypothesis on nonlinearities in the coefficient of $x_{94}(t)$ is $b_{94}^{u} = b_{94}^{d}$, where b_{94}^{u} and b_{94}^{d} are the coefficients for x_{94} during periods, respectively, of upswing and downswing in the cycle (i.e., the lagged slaughter-cattle price has the same effect upon the number of cows and heifers kept during the upswings as during the downswings). An appropriate alternative hypothesis is that $b_{94}^{u} < b_{94}^{d}$ (i.e., the effect in question is smaller during the upswings than during the downswings). Since $b_{94}^{u} = b_{94}$ and $b_{94}^{d} = b_{94} + b_{94}^{Dd}$, a procedure for testing the null hypothesis is to test the statistical significance of b_{94}^{Dd}, the coefficient of a dummy variable, D_{94}^{d}, to $x_{94}(t)$. During an upswing, cattle producers tend to expand their breeding herds at a rate close to the maximum feasible rate posed by breeding stock. During a downswing, however, there is slack. Cows may be held longer and more heifers may be bred in response to an increase in the lagged slaughter-cattle price. Hence, during a downswing, there is a relatively large possibility for expanding the cow herds in response to rises in the lagged slaughter-cattle price received by farmers.

The coefficient of the dummy variable D_{94}^{d} for equation 6 is significant, but the one for equation 5 is lowly significant. Therefore, we reject the null hypothesis and accept the alternative hypothesis.

The average coefficient $b_{94}^{Dd} = 145.7388$ indicates that a $1 increase (decrease) in the lagged slaughter cattle price $x_{94}(t)$ induces cattle producers in the United States to keep about 145,700 more (fewer) cows and heifers over 2 years old during a downswing than during an upswing. The estimated elasticity of cow numbers and heifers over 2 years old held with respect to the lagged slaughter-cattle price is more than twice as large during downswings than during upswings.

Slaughter and Inventory Variables

The coefficient of the endogenous variable $y_{28}(t)$, total number of cattle slaughtered, excluding calves, is highly significant and negative in all equations in table 2. The sign of this change is as expected: Cows and heifers over 2 years old always constitute a fairly large proportion of the total number of cattle slaughtered.[16]

The coefficient of $x_{47}(t)$, the inventory of cows and heifers over 2 years old on farms on Jan. 1 of year t, is highly significant and positive in all selected equations. The average coefficient for this variable, 0.8643, indicates that an increase of 1,000 in the inventory of cows and heifers on Jan. 1 of year t leads to an increase in this inventory on Jan. 1 of year t+1 by 864.

The coefficient of the explanatory variable $x_{62}(t)$, the young heifer inventory, is significant or highly significant in all equations of table 2. The regression coefficients, 1.3507 and 1.1665, in equations 3 and 4, respectively, are larger than in other equations, evidently because of the collection of variables represented in each.

Feed variables

The coefficient of the exogenous[17] variable $x_{77}(t)$, total hay production, is positive in all and significant in almost all equations presented in table 2. Again the hypothesis is proposed that the elasticity of the response of the number of cows and heifers over 2 years old kept to a change in hay production is greater during an upswing than during a downswing of the cattle cycle. There are reasons against, but even better reasons for, this hypothesis. During an upswing, farmers tend to expand their cow herds near the maximum feasible rate relative to forage supplies. Forage land, especially pasture, is not used as closely to full capacity during a downswing as during an upswing (i.e., there is relatively more overcapacity during a downswing). Hence, with overcapacity in forage supply, a change in forage production in either direction will probably have relatively little effect on the number of cows and heifers over 2 years old kept during a downswing. The computed elasticities indicate that the number of cows and heifers kept, relative to a 1-percent increase in total forage

[16] On the average from 1959 to 1962, cows constituted 21.5 percent of all cattle slaughtered under federal inspection; heifers of all age groups, 21.7 percent.

[17] In some areas, the total supply of feed from pasture and grazing is by no means an exogenous variable to the cattle-producing industry. On the effect of the stocking level on feed supply see Breimyer and Thodey (1964).

production, is nearly four times greater in an upswing than in a downswing.

The positive coefficients in table 2 for $x_{81}(t)$ and $x_{84}(t)$, corn production and lagged corn supply, respectively, are acceptable only if interpreted in a long-run context. In the short-run, an increase in corn production or supply increases the supply of concentrate feed. This effect tends to increase the number of cattle sold for slaughter in the short-run. Hence, in the short-run, the regression coefficients for x_{81} and x_{84} would need to be negative. But, if these coefficients express long-run effects, they would correctly be positive. In the longer run, an increase in corn production or corn supply, which stand as proxy variables for the supply of concentrate feeds in general, will improve the profit expectations of cattle producers and induce them to expand the size of their cow herds.

Other variables

Knowledge of the behavior of cattle producers suggests that there are nonlinearities in the intercept coefficient. Hence, we can examine the null hypothesis that the intercept coefficient, b_o, is of the same magnitude for upswings, $b_o{}^u$, and for downswings, $b_o{}^d$, or $b_o{}^u = b_o{}^d$. Alternatively, the better hypothesis is that the function shifts upward during upswings, or $b_o{}^u > b_o{}^d$.

For the cycle division B (table 1), on which equation 5 in table 2 is based, the estimate of the regression coefficient $D_o{}^u$ is 1,500.6 and highly significant. This coefficient predicts that the number of cows and heifers over 2 years old kept will be about 1.5 million larger during an upswing than during a downswing. We interpret these estimated intercept changes to result from a number of factors for which individual empirical effects cannot be easily isolated. The intercept change may reflect a change in the profit expectations of cattle producers from optimism during an upswing to pessimism [18] during a downswing. In this sense, the intercept-shifting or dummy variable takes the place of a crude index of expected profitability. The index is crude because it assumes the change from an upswing to a downswing and *vice versa* to occur suddenly at the turning points of the cycle. The reason for this abrupt change is that the coefficient serving as an estimate of $b_o{}^u$ either is or is not in an equation predicting the annual number of cows and heifers over 2 years old kept. The changes in the intercept coefficient or in any other macrocoefficient also may be caused by changes in the number of cattle farmers responding to changes in economic conditions.

The statistical results allow the inference that cattle farmers, in determining the size of their cow herds, do respond to current and lagged slaughter-cattle prices. Since the slaughter-cattle prices received by farmers are used as substitutes for unavailable profit variables, the statistical results may suggest that profit for the cattle enterprise is the major factor in the development of the cow and heifer inventory.

Equations without dummy variables would allow better prediction at the turning points of the cycle, although equations with these dummy variables predict somewhat better in other years. To improve predictions further, the simple division of the cycle into "upswing" and "downswing" phases might better be replaced by a division with a larger number of phases. The number of dummy variables, or the degree of nonlinearity, would need to be increased correspondingly.

In the equations of table 2 explaining the number of cows and heifers over 2 years old kept, the proportion of the explained variance, as expressed in the R^2 values, is relatively high, especially since the equations do not reflect the explanatory value of time. All coefficients and predictions are based on deviations of the observed values of the original variables from their respective trend values. In most equations presented in table 2, all regression coefficients are statistically significant or highly significant. The signs of all coefficients also agree with economic theory and are of the same sign in all equations.

Variables in Equations Explaining the Number of Calves Kept as Heifers 1 to 2 Years Old

Slaughter-cattle prices

The estimates of the coefficient of the endogenous variable $y_{93}(t)$, the current weighted-average slaughter-cattle price received by farmers are negative in all equations of table 3. The estimates are highly significant in all equations, except equations 8 and 9. In these two equations, respectively, corn supply and corn production replace corn price as exogenous variables. Comparing the coefficients for $y_{93}(t)$ in equations 10 and 12, it can be seen that the omission in equation 12 of the lagged slaughter cattle price, $x_{94}(t)$, leads to an increase (i.e., a reduction in absolute values) in the size of the $y_{93}(t)$ coefficient from about -137 to -52. The difference of 85 is of the same order of magnitude as the coefficient for $y_{94}(t)$ in equation 10. If the cattle price with a double lag were also included and if a small positive coefficient were obtained for it, the summation would more closely correspond to the coefficient for $y_{94}(t)$ in equation 10. Therefore, the coefficient for $y_{93}(t)$ in equation 12 can be considered as the sum of the effects of the current and of one or more lagged cattle prices.

The coefficient of $x_{94}(t)$, the lagged slaughter-cattle price, is significantly larger than zero in all

[18] Instead of optimism and pessimism, one could as well say high and low optimism or high and low expectations. Walters (1965, pp. 10) uses the terms "spontaneous optimism" and "simultaneous pessimism," respectively.

selected equations. Its positive value can be reconciled with the negative value of the coefficient for $y_{93}(t)$ by interpreting the coefficient of $x_{94}(t)$ within a long-run framework and the coefficient of $y_{93}(t)$ within a short-run framework as explained previously.

A linear combination (i.e., addition) of the two regression coefficients $\bar{c}_{93}$ and $\bar{b}_{94}$ results in only a minor reduction in the significance levels of $\bar{c}_{\Delta 93}$, where $\bar{c}_{\Delta 93} = \bar{c}_{93} + \bar{b}_{94}$. For example, in equations 7 and 10, we calculate the coefficients as $\bar{c}_{\Delta 93} = -59.1179$ and -65.8212, respectively, and the t-ratios as -2.30 and -2.70, respectively. The negative values of $\bar{c}_{\Delta 93}$ are plausible if the response to slaughter-cattle price changes is interpreted in the short-run framework.

The coefficient for the dummy variable $D_{94}{}^{d}$ in table 3 is significant and positive. Therefore, the alternative hypothesis that an increase in the lagged slaughter-cattle price received by farmers over some normal or average price will lead to a larger response during a downswing than during an upswing may be accepted. This difference in the response of farmers is plausible if it is interpreted in either one or both of these ways: During a downswing, a relatively small proportion of calves is raised. Therefore, the proportion of potential female breeding material is relatively large during a downswing. Also, use of factors such as feed, labor and building facilities is, on the average, lower relative to capacity during a downswing than during an upswing. Therefore, a given change in the lagged slaughter-cattle price received by farmers can bring forth a larger response in $y_{120}(t)$ during a downswing than during an upswing. Hence, the expected sign of the coefficient is positive for the dummy, $D_{94}{}^{d}$.

Slaughter and inventory variables

The coefficient of the endogenous variable $y_{28}(t)$, total cattle slaughter, is highly significant in all selected equations of table 3. The coefficient of the variable $x_{56}(t)$, calf inventory, also has the expected sign and is highly significant.

Table 3. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{120}(t)$, the number of calves kept as heifers 1 to 2 years old, United States.

Equation number	$y_{28}(t)$ Total cattle slaughter	$y_{93}(t)$ Current slaughter-cattle price	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{56}(t)$ Calf inventory	$x_{77}(t)$ Total hay production	$x_{87}(t)$ Seasonal-average corn price	$x_{83}(t)$ Corn supply	$x_{81}(t)$ Total corn production	$D_{94}{}^{d}$ Dummy variable downswing	$D_{77}{}^{u}$ Dummy variable upswing	x_0 Intercept	$D_0{}^{u}$ Dummy variable upswing	R^2 Coefficient of determination
7	-0.2695	-139.6084	80.4905	0.4348	0.0226	1,454.3683					-0.0196		0.78
	(0.0388)	(47.5098)	(33.6076)	(0.0717)	(0.0074)	(257.6350)					(53.2716)		
8	-0.1767	-18.2026	54.5837	0.4238	0.0241		-0.3061				-0.0199		0.58
	(0.0483)	(58.2710)	(47.1020)	(0.1010)	(0.0121)		(0.2474)				(74.0562)		
9	-0.1788	-9.0162	53.9065	0.4456	0.0260			-0.4105			-0.0199		0.60
	(0.0472)	(55.4220)	(45.3506)	(0.0974)	(0.0115)			(0.2370)			(72.4396)		
10[a]	-0.2032	-136.6233	70.8021	0.3601	0.0238	1,538.0471					-252.6703	384.0289	0.81
	(0.0456)	(44.2187)	(31.2882)	(0.0755)	(0.0070)	(245.7383)					(114.1101)	(155.8586)	
11	-0.2903	-42.4530		0.5304	0.0173	1,323.5420					-0.0198		0.74
	(0.0405)	(26.4972)		(0.0637)	(0.0076)	(269.7668)					(57.0777)		
12[a]	-0.2196	-52.0665		0.4411	0.0193	1,429.8370					-260.0869	395.3020	0.78
	(0.0479)	(25.1663)		(0.0708)	(0.0073)	(256.6108)					(121.4076)	(165.8096)	
13[b]	-0.2575	-160.0536	79.6324	0.4169	0.0130	1,504.6340			80.4754	0.0218	39.1849		0.79
	(0.0396)	(51.9850)	(36.6437)	(0.0764)	(0.0086)	(270.0632)			(39.2958)	(0.0178)	(58.2830)		
Average:													
	-0.2279	-79.7177	64.9457[c]	0.4361	0.222[d]	1,450.0857	-0.3061	-0.4105	80.4754	0.0218		389.6650	
Elasticities:													
$\bar{e}_{T62}$	-0.207	-0.141	0.112	0.888	0.211	0.163	-0.094	-0.110					
$\dot{e}_{T62}{}^{u}$			0.138		0.331								
$\dot{e}_{T62}{}^{d}$			0.277		0.124								
$\dot{e}_{M}$	-0.190	-0.105	0.083	0.838	0.217	0.148	-0.089	-0.108					
$\dot{e}_{M}{}^{u}$			0.102		0.341								
$\bar{e}_{M}{}^{d}$			0.205		0.127								

[a] Based upon cycle division A indicated in table 1.
[b] Based upon cycle division B indicated in table 1.
[c] Computed from coefficients of equations 7-10 only.
[d] Computed from coefficients of equations 7-12 only.

Feed variables

The coefficient of $x_{77}(t)$, total hay production, is significant in almost all equations of table 3. Again the hypothesis can be tested that it changes between upswings and downswings. The regression coefficient for $D_{77}{}^{u}$, the dummy variable to $x_{77}(t)$ for the upswing, is 0.0218 (equation 13 in table 3), and it is significant. Therefore, we accept the hypothesis that the value 0.0218 indicates that farmers respond to a 1-unit increase in $x_{77}(t)$, the production of all types of hay, by keeping about 22 more calves as heifers during an upswing than during a downswing.

All coefficients for $x_{87}(t)$, the seasonal-average corn price received by farmers, are positive and highly significant in table 3. The average coefficient of 1,450.0857 implies that an increase in the current corn price of $1 per bushel leads to an increase in the number of calves kept as heifers 1 to 2 years old by approximately 1.45 million head. The corresponding average elasticities are $\bar{e}_{T62} = 0.163$ and $\bar{e}_{M} = 0.148$. Although the positive values of the corn price coefficients may seem inconsistent with reality, they may reflect these effects: Cattle feeders will respond to an increase in the current feeding cost by reducing the number of cattle fed. Since calves on farms on Jan. 1 of the current year are either kept as heifers or fed and, in most cases, slaughtered during the same year, a reduction in the number of cattle fed is associated with an increase in the number of calves kept as heifers 1 to 2 years old. If the rise in the corn price received by farmers is caused by a reduction in the production of corn or the supply of corn, reduced feed availability also favors a positive coefficient of $x_{87}(t)$ in this set of equations in table 3. If the exogenous variable $x_{87}(t)$, seasonal-average current corn price received by farmers, is replaced by either $x_{81}(t)$, current corn production, or $x_{83}(t)$, current corn supply, the R^2 values are reduced.

Other variables

The intercept coefficient in table 3 shows highly significant differences between upswings and the downswings. The average coefficient for $D_o{}^{u}$ is 389.6650: indicating that, beyond the effect of other variables, about 390,000 more calves are kept as heifers 1 to 2 years old during an upswing than during a downswing.

Variables in Equations Explaining the Number of Calves Raised

Slaughter-cattle and calf prices

The coefficient for $y_{93}(t)$, the current weighted-average slaughter-cattle price received by farmers, is highly significant and negative in all equations presented in table 4. A possible explanation of the negative value is: An increased slaughter-cattle price leads to, or is associated with, an increase in the current cattle slaughter. In turn, a decrease follows in the number of calves saved because, as the cattle slaughter increases, more cows and heifers are slaughtered before they have a calf. The negative effect of $y_{93}(t)$, the current weighted-average slaughter-cattle price, upon $y_{69}(t)$, the number of calves saved, possibly outweighs the positive effect of $y_{93}(t)$ on $y_{74}(t)$, the number of calves raised.

The coefficients of the current and of the lagged slaughter-cattle price may be combined, and the combined coefficient may be interpreted as the effect of changes in the slaughter-cattle price upon the number of calves raised. This effect is negative in all and significant or highly significant in most selected equations in the table.

The coefficient of the variable $y_{96}(t)$, the current weighted-average slaughter-calf price, is highly significant in most equations and positive in all equations presented in table 4. If the calf-price increase is caused by a reduction in the number of calves slaughtered, the proportion of calves raised increases. The coefficient of $y_{69}(t)$, the number of calves saved, is highly significant and, as expected, positive in all selected equations in table 4.

Feed variables

The estimated coefficient for total hay production, $x_{77}(t)$, in relation to the number of calves raised is not statistically significant in most equations. The estimated effect of $x_{87}(t)$, seasonal-average corn price, is significant or highly significant in equations 15 and 21. On the average, an increase of 10 cents per bushel in the corn price received by farmers is predicted to result in a decrease of about 158,599 in the number of calves raised. Since corn is a major input in calf feeding and profitability of cattle production is inversely related to the price of corn, the sign of this coefficient is consistent with the microtheory of production.

The estimates of the intercept changes between upswings and downswings are highly significant in all equations of table 4, indicating that 1.4 million more calves are raised during an upswing than during a downswing.

In the equations of table 4 explaining $y_{74}(t)$, the number of calves raised, the current weighted-average slaughter-cattle and slaughter-calf prices received by farmers are important explanatory variables. The inclusion and significance of the intercept-shifting dummy variable emphasizes that factors not ordinarily included in time-series data and previous analyses are important in helping to explain the cattle cycle.

Table 4. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{74}(t)$, the number of calves raised, United States.

Equation number	$y_{69}(t)$ Calves available	$y_{93}(t)$ Current slaughter-cattle price	$y_{96}(t)$ Current slaughter-calf price	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{81}(t)$ Total corn production	$x_{83}(t)$ Corn supply	$x_{84}(t)$ Lagged corn supply	$x_{87}(t)$ Corn price	$x_{77}(t)$ Total hay production	x_0 Intercept	D_0^u Dummy variable upswing	R^2 Coefficient of determination
14	0.4188	-1,282.1644	849.1771	255.3914					0.0236	0.0026		0.57
	(0.1257)	(315.6531)	(280.5102)	(79.1793)					(0.0210)	(147.6757)		
15	0.6118	-751.4336	603.2966	127.6098				-2,137.5202	0.0099	0.0017		0.64
	(0.1403)	(363.0293)	(277.9741)	(89.8054)				(863.1148)	(0.0203)	(137.0894)		
16[a]	0.4211	-948.4389	633.8780	153.2020					0.0255	-662.5368	1,007.0572	0.67
	(0.1122)	(297.1662)	(258.4658)	(75.6210)					(0.0188)	(242.7196)	(309.7205)	
17[b]	0.5739	-925.9256	657.4817	97.4415					0.0093	-792.2608	1,368.4517	0.73
	(0.1075)	(260.8982)	(226.5933)	(73.0605)					(0.0172)	(209.1505)	(297.6686)	
18[b]	0.5567	-1,020.8272	724.8439	116.3479		-0.4381			0.0200	-818.8947	1,414.4557	0.74
	(0.1091)	(278.8721)	(237.2027)	(74.7164)		(0.4516)			(0.0204)	(211.1430)	(301.7037)	
19[b]	0.7067	-1,276.6408	1,004.0830	78.2128			-0.9898		0.0121	-985.7911	1,702.7309	0.77
	(0.1181)	(293.4462)	(265.7578)	(68.5536)			(0.4508)		(0.0162)	(216.1304)	(319.4695)	
20[b]	0.7600	-1,213.8525	1,017.3740				-1.0555		0.0066	-1,085.4321	1,874.8381	0.76
	(0.1089)	(289.6348)	(266.7881)				(0.4493)		(0.0156)	(198.6571)	(282.9757)	
21[b]	0.6974	-581.3911	515.5420					-1,394.8172	0.0002	-726.4950	1,254.8558	0.75
	(0.1012)	(266.1529)	(227.8379)					(684.1483)	(0.0158)	(205.188)	(294.0815)	
22[a]	0.4318	-868.7939	576.1573	133.2438	0.3635				0.0167	-671.3640	1,020.4746	0.67
	(0.1138)	(316.9182)	(271.0267)	(80.5146)	(0.4769)				(0.0222)	(244.6519)	(312.3327)	
23[b]	0.6713	-661.8190	544.3144	39.5493				-1,225.6449		-705.5772	1,218.7269	0.76
	(0.1055)	(293.9163)	(223.0490)	(69.0909)				(722.0835)		(205.7451)	(297.3926)	
Average:												
	0.5850	-953.1288	713.1148	125.1248	0.3635	-0.4381	-1.0227	-1,585.9941	0.0138		1,357.6989	
Elasticities:												
$\dot{e}_{T62}$	0.874	-0.807	0.666	0.104	0.047	-0.065	-0.147	-0.085	0.063			
$\dot{e}_M$	0.926	-0.642	0.548	0.082	0.049	-0.065	-0.148	-0.083	0.069			

[a]Based upon cycle division A indicated in table 1.
[b]Based upon cycle division B indicated in table 1.

Variables in Equations Explaining the Number of Calves Saved

The equations of table 5 explaining $y_{69}(t)$, the number of calves saved, is the only set of equations in the over-all model that is independent of the other equations in the model. The model contains no endogenous variable other than $y_{69}(t)$. Thus, ordinary least-squares estimation can be used.

Numerous hypotheses about parameter changes between upswings and downswings are tested in predicting $y_{69}(t)$ in table 5.[19] Each hypothesis is treated under the two periods, A and B of table 1, with the cycle divided into upswing and downswing phases. The null hypotheses formally tested, the corresponding alternative hypotheses and the numbers of the respective equations are (in the order discussed):

$b_{94} = 0$ against $b_{94} > 0$; equations 25 and 26;

$b_{94}^d = b_{94}^u$ against $b_{94}^d > b_{94}^u$; equations 27 and 28.

$b_{97} = 0$ against $b_{97} > 0$; equation 29;

$b_{97}^d = b_{97}^u$ against $b_{97}^d > b_{97}^u$; equation 30;

$b_{47}^o = k$ against $b_{47}^o = f(t)$;

$b_{47}^u = b_{47}^d$ against $b_{47}^u > b_{47}^d$; equations 31 and 32;

$b_{78} = 0$ against $b_{78} > 0$; equations 33 and 34; and

$b_o^u = b_o^d$ against $b_o^u > b_o^d$; equations 35 and 36.

Cattle and calf price variables

In table 5, the estimates of the coefficient of the lagged slaughter-cattle price received by farmers, $x_{94}(t)$, are 40.1116 and 35.2489, respectively, in equations 25 and 26 without the dummy variable. Since this coefficient is the average over all phases of the cattle cycle, it is again relevant to test the hypothesis that the response to price differs between upswings and downswings.

The estimated coefficients of the dummy variable for the downswing in equations 27 and 28 of table 5 are 123.5152 and 122.8351, respectively; statistically, both are lowly significant. From equations 27 and 28, we derive the average estimates for the coefficient of $x_{94}(t)$ of 12.6837 during the upswing and 135.8592 during the downswing. These empirical results imply that a $1 change in the lagged slaughter-cattle price received by farmers

[19]For lack of a two-stage least-squares computer program (the program was prepared while the computations for this study were done), all two-stage least-squares estimates were obtained by applying an ordinary least-squares program twice. The additional time requirements for preparing the output of the first stage as in input for the second stage were prohibitive. Several relevant hypotheses could have been tested if a two-stage least-squares computer program had been available.

leads to a change in the current number of calves available by about 123,000 larger during a downswing than during an upswing. During an upswing, cattle producers operate closer to the biological upper limit of calf availability. Less short-run possibility exists for further expansion as slaughter-cattle prices received by farmers rise. In contrast, flexibility for response to a price rise during a downswing is relatively large. Finally, the statistical results in table 5 show that the lagged price of slaughter calves has a significant effect on the number of calves available only during downswings.

Inventory variables

The marginal calf availability rate is defined as the coefficient of $x_{47}{}^{o}(t)$ in a linear regression equation with $y_{69}{}^{o}(t)$ as the dependent variable. The o superscript refers to the original observations. A null hypothesis that can be tested is: The marginal calf availability rate, $b_{47}{}^{o}$, does not change secularly. Or alternatively, we can test the hypothesis that it does.[20] To make this null hypothesis

[20] By the definition of economic secularity commonly accepted by economists, this information does not exclude the possibility that $b_{47}{}^{o}$ assumes different values during different phases of the cattle cycle.

Table 5. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{69}(t)$, the number of calves available, United States.

Equation number	$x_{47}(t)$ Cow and heifer inventory	$D_{47}{}^{u}$ Dummy variable upswing	$x_{94}(t)$ Lagged slaughter-cattle price	$D_{94}{}^{d}$ Dummy variable downswing	$x_{97}(t)$ Lagged slaughter-calf price	$D_{97}{}^{u}$ Dummy variable upswing	$x_{78}(t)$ Lagged hay production	x_0 Intercept	$D_0{}^{u}$ Dummy variable upswing	R^2 Coefficient of determination
24	0.6999							-0.0001		0.7334
	(0.0703)							(149.7291)		
25[a]	0.7285	-0.0297	40.1116					-19.1285		0.7409
	(0.1142)	(0.1831)	(41.1116)					(192.3297)		
26[b]	0.5957	0.1656	35.2489					58.1398		0.7480
	(0.1393)	(0.1667)	(39.8686)					(160.8782)		
27[a]	0.7449		11.3579	123.5152				69.2500		0.7518
	(0.0755)		(45.2673)	(100.1123)				(158.9514)		
28[b]	0.7267		14.0094	122.8351				46.7289		0.7522
	(0.0719)		(44.0662)	(97.8516)				(153.1909)		
29[a]	0.7263	-0.0214			28.1345			-13.8066		0.7383
	(0.1163)	(0.1837)			(35.2810)			(193.1873)		
30[a]	0.7873	-0.0732			116.6133	-114.4679		39.7644		0.7509
	(0.1245)	(0.1863)			(77.3415)	(88.6071)		(195.7571)		
31[a]	0.6980	0.0042						2.7327		0.7336
	(0.1098)	(0.1797)						(190.9097)		
32[b]	0.5732	0.1790						62.8495		0.7422
	(0.1366)	(0.1655)						(160.2877)		
33[a]	0.8385		-5.8409	73.1007			0.0160	-456.8374	859.8738	0.7957
	(0.0898)		(42.8924)	(102.5045)			(0.0194)	(262.2690)	(371.2365)	
34[b]	0.7679		4.3905	35.3807			0.0216	-559.6907	871.1880	0.8093
	(0.0695)		(40.0762)	(94.7909)			(0.0178)	(253.6892)	(312.6046)	
35[a]	0.8386							-565.6001	976.9452	0.7816
	(0.0816)							(245.9266)	(352.1954)	
36[b]	0.7748							-636.3548	967.2590	0.7947
	(0.0667)							(237.9808)	(299.6572)	
Average:	0.7702[c]		37.6803[d]		28.1345[e]		0.0188		918.8165	
Upswing:	0.7568[f]		12.6837[g]		2.1454[h]					
Downswing:	0.5845[f]		135.8592[g]		116.6133[h]					
Elasticities:										
$\dot{e}_{T62}$	0.938		0.021		0.017		0.045			
$\dot{e}_{T62}{}^{u}$	0.912		0.007		0.001					
$\dot{e}_{T62}{}^{d}$	0.712		0.075		0.071					
$\dot{e}_{M}$	1.001		0.016		0.013		0.072			
$\dot{e}_{M}{}^{u}$	0.977		0.005		0.001					
$\dot{e}_{M}{}^{d}$	0.759		0.056		0.055					

[a] Based upon cycle division B indicated in table 1.
[b] Based upon cycle division A indicated in table 1.
[c] Computed from coefficients of equations without $D_{47}{}^{u}$.
[d] Computed from coefficients of equations 25 and 26 only.
[e] From equation 29.
[f] Computed from coefficients of equations 26 and 32 only.
[g] Computed from equations 27 and 28 only.
[h] From equation 30.

amenable to a statistical test, we express $b_{47}{}^{o}$ as a function of time and obtain $b_{47}{}^{o}(t) = a_o{}^{o} + a_1{}^{o}t$, where t refers to time. Time is for ease of computations set at -18.5 for 1925, -17.5 for 1926, . . . , and 18.5 for 1962. Hence, the original regression model, $y_{69}{}^{o}(t) = b_o{}^{o} + b_{47}{}^{o}x_{47}{}^{o}(t) + e(t)$, becomes $y_{69}{}^{o}(t) = b_o{}^{o} + a_o{}^{o}x_{47}{}^{o}(t) + a_1{}^{o}tx_{47}{}^{o}(t) + e(t)$. These hypotheses now become $a_1{}^{o} = 0$ and $a_1{}^{o} > 0$, respectively.

The estimate of the coefficient $a_1{}^{o}$ and its standard error, respectively, are 0.00386 and 0.0008874. The calculated value of t, 4.35, indicates statistical significance of a_o at 0.0005 probability level. Hence, we reject the null hypothesis and accept the alternative hypothesis.

From $\bar{b}_{47}{}^{o}(t) = 0.72279 + 0.00386t$, we calculate, for example, $\bar{b}_{47}{}^{o}(1925) = 0.65138$ and $\bar{b}_{47}{}^{o}(1962) = 0.79420$, indicating that the secular marginal calf-availability rate increased linearly from about 0.65 to about 0.80 during the period studied.

Factors directly contributing to the secular rise may be an increase in the fertility rate of cows and heifers and a decrease in the death losses of calves. Together, these two factors are due mainly to progress in cattle breeding, veterinary hygiene and management practices. The magnitude of $\bar{a}_1{}^{o} = 0.00386$ amounts to an annual increase during the study period of about 4 calves saved per 1,000 cows and heifers over 2 years old on farms as of Jan. 1.

The average coefficient for the intercept change of 918.8165 indicates that the number of calves available for the United States as a whole will, *ceteris paribus,* be about 919,000 larger during upswings than during downswings. With a cow and heifer inventory predicted from a regression of $x_{47}{}^{o}(t)$ on time of approximately 48.5 million head for 1962, this amounts to a difference of about 2 calves per 100 cows and heifers over 2 years old.

The coefficients for lagged hay production on calf availability are only lowly significant or nonsignificant in equations 33 and 34 of table 5.

When predictions from the equations with and without a dummy variable $D_{47}{}^{u}$ are compared, the deviations of $y_{69}(t)$ from the predicted values show a slightly more pronounced cyclical pattern in the equations without a dummy variable than in the equations with a dummy variable. Therefore, the best predictions may be obtained by using different equations for different phases of the cattle cycle.

In table 5, $x_{47}(t)$, the inventory of cows and heifers over 2 years old, explains 73 percent of the variance of $y_{69}(t)$, the number of calves available. The inclusion of other explanatory variables including dummy variables leads to only modest increases in the values of R^2. Division of the cycle into the A groups of table 1 gives somewhat better results than the B groups.

Variables in Equations Explaining Cattle Price, Calf Price, and Gross Farm Income from Cattle and Calves

Variables in equations explaining the current weighted-average slaughter-cattle price received by farmers

The coefficient of the endogenous variable $y_{28}(t)$; total cattle slaughter, is highly significant and negative as expected in all equations presented in table 6. From the average coefficient, -0.00112, we calculate that a change in the annual total supply of slaughter cattle of approximately 893,000 head is required to change the current weighted-average slaughter-cattle price by $1 per hundred-weight. The elasticity estimates $\bar{e}_{T62} = -1.310$ and $\bar{e}_M = -1.607$ indicate that a change in the total supply of slaughter cattle will result in a proportionately smaller change in the current weighted-average slaughter-cattle price and, hence, in the gross farm income from cattle and calves.

The coefficient of the weighted-average liveweight of cattle slaughtered under federal inspection, $y_{34}(t)$, is highly significant in only two equations and is positive in all selected equations of table 6. If the average liveweight of cattle slaughtered increases, other things remaining constant, it would be expected that the current weighted-average slaughter-cattle price would decrease because a change in the liveweight of slaughter cattle changes the supply of beef in the same direction. Fig. 4 illustrates that increasing values of $y_{34}(t)$, average liveweight of cattle slaughtered under federal inspection, occur mainly during upswings and, decreasing values, during downswings. We may assume, therefore, that the negative effects of liveweight changes on the cattle price are outweighed by the positive effects of other factors intercorrelated in the phenomena of cyclical upswings.

The coefficient of $x_{37}(t)$, lagged net imports of cattle, is lowly significant only in equation 41 and nonsignificant in equation 42 of table 6. The average coefficient of lagged imports, -0.00116, is of about the same magnitude as the average coefficient for total cattle slaughter, -0.00112. This relationship is expected because the origin of the cattle alone should have no unique effect on the slaughter cattle price.[21]

The coefficients relating hay production, $x_{77}(t)$, in the current year to the current weighted-average

[21] This comparison clarifies to some extent a possible cause of the slump of slaughter-cattle prices in 1963 and 1964. The size of the supply of slaughter cattle (and not their origin) determines the slaughter-cattle price.

In 1962, the net imports of cattle amounted to 1,231,000 head. Most of these cattle appeared on the slaughter-cattle market in 1963. If the 1962 net imports had been zero, the 1963-slaughter-cattle price would have been approximately $1.43 per hundredweight higher, according to the average coefficient. If the prediction is based upon the largest estimate, the difference is $2.02 per hundredweight. It would have been $21.33 or $21.92, respectively, instead of $19.90 per hundredweight. However, our model also predicts that the same price increase could have been achieved by reducing the supply of slaughter cattle of domestic origin by approximately the magnitude of the lagged net imports.

slaughter-cattle prices were not significant. Although a sufficient reduction in hay output causes liquidation of range cattle, the lower weights and the normal movement of cattle into feedlots may have less effect on slaughter-cattle prices than on feeder-cattle prices.

The coefficient of $x_{87}(t)$, the seasonal-average corn prices received by farmers, is positive and highly significant in all selected equations of table 6. This result can be interpreted only in a long-run context. Since corn price is inversly related to profits for the cattle feeding enterprise, an increase in the price of corn is predicted to lead to a reduction in the supply of slaughter cattle. This in turn leads to or is associated with an increase in the price of slaughter cattle, making plausible a positive sign for the coefficient of $x_{87}(t)$.

The coefficient of $x_3(t)$, total disposable personal income, is highly significant in all equations of table 6. It expresses the demand effect upon cattle price due to a change in the total disposable income. The coefficient of $x_{17}(t)$, the supply of other meats, also is lowly significant in all equations.

Evidently, models that are linear in these coefficients and variables give a satisfactory explanation of the variance in the current weighted-average slaughter-cattle price received by farmers. The gain in information from inclusion of an intercept-shifting dummy variable was negligible. In summary, the highest significance levels were obtained for coefficients of $y_{28}(t)$, total number of cattle slaughtered excluding calves, $x_{87}(t)$, the seasonal-average corn price received by farmers, $x_3(t)$, the total disposable personal income, and $x_{17}(t)$, the supply of other meats. The coefficients of $x_3(t)$ and $x_{17}(t)$ indicate the degree of dependency of the cattle prices upon the level of activity in the economy as a whole and upon competing agricultural sectors.

Variables in equations explaining the current weighted-average slaughter-calf price received by farmers

The coefficient of $y_{33}(t)$, total calf slaughter, is significant in two of three selected equations in table 7. But the positive sign of the predicted change does not agree with the evidence in fig. 5. The predicted effect of the average liveweight of calves slaughtered under federal inspection, $y_{35}(t)$, upon the current weighted-average price of slaughter calves received by farmers is significant in one and highly significant in two selected equations of table 7. The negative sign of the predicted response is as expected.

Statistical tests indicate that lagged slaughter-cattle price, $x_{94}(t)$, has a highly significant effect upon the slaughter-calf price received by farmers. The positive sign of the predicted response is as expected: If the lagged slaughter-cattle price received by farmers increases, more female calves will be retained for breeding purposes. Therefore, fewer calves are available for slaughter.

Total hay production exerts a significant effect upon calf price. The positive sign of the predicted change is appropriate if interpreted as follows: An increase in the total hay production will in-

Table 6. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and other statistics in selected equations explaining $y_{93}(t)$, the current weighted-average price of slaughter cattle received by farmers, United States.

Equation number	$y_{28}(t)$ Total cattle slaughter	$y_{34}(t)$ Average live-weight of cattle	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{37}(t)$ Lagged net imports of cattle	$x_{77}(t)$ Total hay production	$x_{87}(t)$ Corn price	$x_3(t)$ Total disposable personal income	$x_{17}(t)$ Supply of other meats	x_0 Intercept	$D_0{}^u$ Dummy variable upswing	R^2 Coefficient of determination
37	-0.00115	0.00319	0.12214			7.6556	0.06001	-0.00039	0		0.84
	(0.00024)	(0.03921)	(0.13860)			(1.60003)	(0.02119)	(0.00038)	(0.27533)		
38	-0.00130	0.00855			-0.00001	8.5936	0.06692	-0.00046	0		0.84
	(0.00021)	(0.04314)			(0.00004)	(1.185665)	(0.02364)	(0.00041)	(0.27861)		
39	-0.00132					8.41456	0.07060	-0.00042	0		0.84
	(0.00015)					(0.87594)	(0.00969)	(0.00028)	(0.27061)		
40	-0.00116		0.12504			7.57602	0.06130	-0.00037	0		0.84
	(0.00023)		(0.13183)			(1.24547)	(0.01379)	(0.00028)	(0.27102)		
41[a]	-0.00111	0.09484		-0.00164		9.10791			0.97588	-1.48334	0.78
	(0.00019)	(0.01527)		(0.00145)		(1.08656)			(0.66343)	(0.88776)	
42	-0.00067	0.05735	0.27972	-0.00068		7.27659			0		0.78
	(0.00024)	(0.02296)	(0.16528)	(0.00166)		(1.67096)			(0.31496)		
Average:											
	-0.00112	0.04098	0.17563	-0.00116	-0.00001	8.10443	0.05471	-0.00041		-1.48334	
Elasticities:											
$\dot{e}_{T62}$	-1.310	1.822	0.172	-0.030	-0.054	0.514	0.943	-0.334			
$\dot{e}_M$	-1.607	3.016	0.170	-0.036	-0.074	0.627	0.812	-0.432			

[a]Based upon cycle division A indicated in table 1.

Table 7. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and other statistics in selected equations explaining $y_{96}(t)$, the current weighted-average slaughter-calf price received by farmers, United States.

Equation number	$y_{33}(t)$ Total calf slaughter	$y_{35}(t)$ Average live-weight of calves	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{77}(t)$ Total hay production	$x_{17}(t)$ Supply of other meats	$x_3(t)$ Total disposable personal income	x_0 Intercept	$D_0{}^u$ Dummy variable upswing	R^2 Coefficient of determination
43	0.00111 (0.00049)	-0.36570 (0.11634)	1.05245 (0.12811)	0.00015 (0.00006)			0 (0.41716)		0.71
44[a]	0.00036 (0.00060)	-0.20827 (0.12440)	0.97575 (0.14024)		0.00035 (0.00042)		0.91807 (0.93785)	-1.39546 (1.24810)	0.66
45[a]	0.00111 (0.00063)	-0.44953 (0.14549)	1.18388 (0.15825)	0.00018 (0.00007)	0.00036 (0.00049)	-0.03130 (0.01985)	0.76020 (1.01053)	-1.15550 (1.39774)	0.73
Average:	0.00086	-0.34117	1.07069	1.00017	0.00036	-0.03130		-1.27548	
Elasticities:									
$\bar{e}_{T62}$	0.387	-3.056	0.949	0.830	0.266	-0.414			
$\bar{e}_M$	0.585	-4.551	0.910	1.105	0.332	-0.344			

[a]Based upon cycle division A indicated in table 1.

crease the number of calves raised and reduce the number of calves slaughtered. A reduction in the number of calves slaughtered, due to greater addition to herds, is expected to cause an increase in the price of slaughter calves.

Variables in equations explaining the gross farm income from cattle and calves

Obviously, the total number of cattle slaughtered, $y_{28}(t)$, has a highly significant effect upon gross farm income from cattle and calves. The average coefficient, -0.298 in table 8, indicates that a change in cattle slaughter of 1 head is associated with an opposite change in the gross farm income of \$298. Total calf slaughter, $y_{33}(t)$, also has a highly significant and positive effect on gross farm income from cattle and calves. A change by 1 head in the number of calves slaughered is predicted to cause a positive change of about \$342 in the gross farm income from cattle and calves.

All significant estimates of the coefficient of $y_{34}(t)$, the average liveweight of cattle slaughtered under federal inspection, are negative. The average coefficient of -29.490 can be used to predict that the supply of each additional pound of liveweight in the U.S. will reduce the aggregate farm income from cattle and calves by about \$1.10.[22] The sign of the predicted change is plausible: With an increase in the average liveweight of slaughter cattle, other things remaining constant, the greater supply of beef is accompanied by a reduction in the current slaughter-cattle price received by farmers.

The coefficient of $x_{77}(t)$, total hay production, is negative in all equations in table 8. A change in hay production by 1 ton is predicted to lead to an opposite change in the gross farm income from cattle and calves by \$22, all other things remaining equal. Over the long run, an increase in the production of hay and of other forage allows the production of a greater number of cattle for slaughter. Also, cattle may be finished at heavier weights.

Total disposable personal income, a variable exogenous to the cattle sector, is one of the most important explanatory variables in the equations explaining $y_1(t)$, the gross farm income from cattle and calves. The coefficient for $x_3(t)$ is highly significant in all selected equations but one in table 8. On the basis of the average coefficient for $x_3(t)$, approximately 3.74 cents out of every additional \$1 in total disposable personal income is predicted to go into the cattle farmers' pockets.

From the statistical results, we infer that models that are linear in both the coefficients and variables serve (in the equations explaining $y_1(t)$, the gross farm income from cattle and calves) at least as well as equations with nonlinearities in the intercept coefficient. Most of the estimated coefficients are statistically significant and of the expected sign. The absolute values of the coefficients indicate that a few variables, such as the slaughter-cattle price received by farmers, total number of cattle slaughtered and total disposable personal income, have the main effect on gross farm income from cattle and calves.

[22]This figure was obtained as follows: The 1962-trend value for $y_{28}(t)$. total cattle slaughter, is 26.442 million head. Hence, a 1-pound increase in the average liveweight amounts to an increase in the total supply of liveweight by 26.442 million pounds. By dividing the estimated average coefficient $\bar{c}_{34}$ = -29.490 by 26.442, we obtain \$1.10. (We assume that the relationships are the same for slaughter with federal inspection as without federal inspection.)

Table 8. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and other statistics for selected equations explaining $y_1(t)$, the gross farm income from cattle and calves, United States.

Equation number	$y_{28}(t)$ Total cattle slaughter	$y_{33}(t)$ Total calf slaughter	$y_{34}(t)$ Average live-weight of cattle	$y_{93}(t)$ Average current slaughter-cattle price	$x_{84}(t)$ Lagged corn supply	$x_{77}(t)$ Total hay production	$x_3(t)$ Total disposable personal income	$x_{17}(t)$ Supply of other meats	x_0 Intercept	$D_0{}^u$ Dummy variable upswing	R^2 Coefficient of determination
46	-0.300		-29.249	11.419		-0.024	40.897	0.147	0		0.75
	(0.062)		(12.369)	(18.797)		(0.013)	(6.310)	(0.119)	(84.791)		
47[a]	-0.312		-22.262			-0.018	36.455	0.133	156.316	-270.000	0.75
	(0.074)		(16.553)			(0.014)	(8.571)	(0.112)	(304.537)	(504.423)	
48	-0.301		-33.494			-0.023	41.658	0.175	0		0.75
	(0.062)		(10.105)			(0.013)	(6.123)	(0.108)	(83.959)		
49[a]	0.011		5.115	163.422		-0.007	11.760	-0.015	63.943	-110.447	0.87
	(0.080)		(13.033)	(30.356)		(0.010)	(7.723)	(0.086)	(222.444)	(366.888)	
50	-0.383	0.353			0.449	-0.015	35.519	-0.113	0		0.80
	(0.065)	(0.080)			(0.316)	(0.011)	(3.827)	(0.108)	(77.388)		
51	-0.363	0.330			0.386		34.085	-0.121	0		0.78
	(0.064)	(0.079)			(0.317)		(3.734)	(0.109)	(78.472)		
52	-0.435		-67.560		1.583	-0.047	61.218	0.024	0.001		0.84
	(0.059)		(11.400)		(0.371)	(0.012)	(6.733)	(0.094)	(67.673)		
Average:											
	-0.298	0.342	-29.490	87.421 163.422[c]	0.806	-0.022	37.370	0.152[b] -0.117[d]		-190.224	
Elasticities:											
$\bar{e}_{T62}$	-1.049	0.511	-3.943	0.263	0.412	-0.356	1.638	-0.287			
$\bar{e}_M$	-1.567	0.972	-7.949	0.320	0.634	-0.597	1.718	-0.451			

[a] Based upon cycle division B indicated in table 1.
[b] Computed from coefficients of equations 46-48 only.
[c] From equation 49 only.
[d] Computed from the coefficients of equations 50 and 51 only.

Variables in Equations Explaining the Number, Liveweight and Net Imports of Cattle and of Calves Slaughtered

Variables in equations explaining the total number of cattle slaughtered and the number of cattle of domestic origin slaughtered

The estimates of the coefficient for $y_{93}(t)$, the current weighted-average slaughter-cattle price received by farmers, are larger than zero in all equations explaining $y_{28}(t)$ or $y_{38}(t)$ (table 9), except for equation 53. A short-run change in the current slaughter-cattle price is associated with a change in the same direction in the number of cattle slaughtered. The estimated lagged cattle-price coefficient is negative in all equations and is highly significant in all except the first equation presented in table 9. The sign of the predicted change is reasonable only if it is interpreted in the longer-run framework. The average response is larger for $y_{38}(t)$ than for $y_{28}(t)$. Again, the coefficients of the current and of the lagged slaughter-cattle price may be combined, and the combined coefficient interpreted as the effect of changes in the slaughter-cattle price upon the total number of cattle slaughtered. The combined coefficient is negative in all equations explaining $y_{28}(t)$. Its significance levels are considerably reduced in comparison with those of the separate coefficients. For example, in equation 54, $\bar{c}_{\Delta 93} = -110.892$ and has a t-ratio equal to 1.71. Hence, $\bar{c}_{\Delta 93}$ is lowly significant at a probability level of 0.10. The negative sign of the combined coefficients is correct only if the price changes are interpreted in the longer-run framework.

The statistics for other variables explaining the magnitude of the total number of cattle slaughtered and the number of domestic cattle slaughtered are included in table 9. The important and consistently significant coefficients in all these equations are the coefficients for the inventory of all cattle, a quantity that is the focus of the study.

Variables in equations explaining the total number of calves slaughtered

Statistics for regression equations explaining the total number of calves slaughtered are included in table 10. The consistently significant variables are the current weighted-average slaughter-cattle and slaughter-calf prices, calves saved and corn price received by farmers. The negative coefficients for $y_{96}(t)$ suggest that, when calf prices are higher, more calves are being held back for breeding stock. Intercept changes also are highly significant in explaining calf-slaughter magnitudes.

Table 9. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables, and related statistics in selected equations explaining $y_{28}(t)$, the total number of cattle slaughtered and $y_{38}(t)$, the number of cattle of domestic origin slaughtered, United States.

Equation number	Explained variable	$y_{93}(t)$ Current slaughter-cattle price	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{37}(t)$ Lagged net imports of cattle	$y_{34}(t)$ Average live-weight of cattle	$x_{44}(t)$ Inventory of all cattle	$x_{77}(t)$ Total hay production	$x_{84}(t)$ Lagged corn supply	$x_3(t)$ Total disposable personal income	$x_{17}(t)$ Supply of other meats	x_0 Intercept	D_0^u Dummy variable upswing	R^2 Coefficient of determination
53[a]	$y_{28}(t)$	-231.681	-29.757		-11.691	0.090	-0.075	2.894	80.364		404.435	-614.738	0.84
		(142.208)	(113.934)		(31.137)	(0.075)	(0.025)	(0.839)	(18.126)		(392.720)	(543.268)	
54	$y_{28}(t)$	292.485	-403.377			0.406	-0.022		29.379	-0.687	0		0.78
		(121.445)	(101.169)			(0.057)	(0.026)		(6.940)	(0.197)	(183.556)		
55	$y_{28}(t)$	366.829	438.614	0.222		0.471	-0.030	1.940	30.356	-1.227	0		0.83
		(116.936)	(94.327)	(1.011)		(0.069)	(0.024)	(0.711)	(6.074)	(0.302)	(169.177)		
56	$y_{28}(t)$	222.592	-406.735	-1.757		0.302	-0.030		23.083		0		0.73
		(135.057)	(113.179)	(0.928)		(0.066)	(0.029)		(6.874)		(205.080)		
Average:		162.556	-407.955	-1.757 [b]	-11.691	0.317	-0.039	2.417	27.566	-0.957		-614.738	
Elasticities:													
$\dot{e}_{T26}$		0.139	-0.341	-0.038	-4.243	1.183	-0.151	0.351	0.468	-0.667			
$\dot{e}_{M}$		0.113	-0.275	-0.038	-5.727	1.312	-0.203	0.362	0.328	-0.702			
57	$y_{38}(t)$	402.593	-441.768		11.452	0.532		1.739	24.649	-1.458	0.001		0.83
		(240.779)	(172.845)		(43.127)	(0.139)		(0.817)	(21.039)	(0.427)	(172.347)		
58	$y_{38}(t)$	647.242	-604.242		59.844	0.678		1.298		-1.809	0.002		0.82
		(120.588)	(103.785)		(12.480)	(0.062)		(0.730)		(0.305)	(173.379)		
Average:		524.918	-523.005		35.648	0.605		1.519	24.649	-1.634			
Elasticities:													
$\dot{e}_{T62}$		0.459	-0.447		1.385	2.308		0.225	0.314	-1.164			
$\dot{e}_{M}$		0.374	-0.361		1.868	2.559		0.232	0.220	-1.225			

[a]Based upon cycle division A indicated in table 1.
[b]From equation 56 only.

Table 10. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{33}(t)$, the number of calves slaughtered, United States.

Equation number	$y_{93}(t)$ Current slaughter-cattle price	$y_{96}(t)$ Current calf-slaughter price	$y_{69}(t)$ Calves saved	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{77}(t)$ Total hay production	$x_{87}(t)$ Corn price	$x_{17}(t)$ Supply of other meats	$x_3(t)$ Total disposable personal income	x_0 Intercept	D_0^u Dummy variable upswing	R^2 Coefficient of determination
59[a]	921.107	-863.133	0.227	-93.831	-0.022	2,165.522			807.183	-1,226.918	0.73
	(422.523)	(328.107)	(0.183)	(112.756)	(0.026)	(1,183.402)			(341.644)	(445.228)	
60[a]	1,337.098	-1,026.199	0.422	-186.756	-0.037				1,040.093	-1,580.940	0.70
	(369.404)	(327.197)	(0.154)	(104.418)	(0.026)				(328.842)	(415.912)	
61	888.883	-836.799	0.221	-151.288		3,130.420	-0.278	3.716	0.001		0.70
	(778.683)	(708.958)	(0.289)	(115.726)		(1,179.437)	(0.253)	(9.427)	(187.356)		
Average:	1,040.029	-908.710	0.290	-143.958	-0.030	2,647.971	-0.278	3.716		-1,403.929	
Elasticities:											
$\dot{e}_{T62}$	2.113	-2.017	1.030	-0.283	-0.325	0.339	-0.456	0.109			
$\dot{e}_{M}$	1.352	-1.336	0.879	-0.180	-0.287	0.265	-0.377	0.060			

[a]Based upon cycle division A indicated in table 1.

Variables in equations explaining the average liveweight of cattle slaughtered under federal inspection[23]

The estimate of the coefficient of $y_{28}(t)$, total cattle slaughter, is negative and highly significant in all selected equations of table 11. Fig. 4 shows that cattle slaughter and average liveweight are generally inversely related. The linkage in price, number and weight changes probably is this: Following an increase in slaughter-cattle price received by farmers or favorable developments associated with other factors relating to profit outlook, cattle producers offer more cattle for slaughter. After a lag in production, the slaughter-cattle supply increases, and the price decreases. Cattle producers then realize that their original profit expectations have been too high and are altered. An increased number of cattle and lower prices causes producers to reduce the liveweight of slaughter-cattle. Or, when profit expectations have been too low, cattle farmers tend to keep or feed their cattle to heavier weights. In general, however, the coefficients for slaughter-cattle prices in table 11 are not satisfactory; they suggest that the higher the price, the lower is the average liveweight of slaughter cattle. Results in table 11 do not seem sufficient, and improved estimates must await specification and estimation of other models.

Equations explaining the average liveweight of calves slaughtered under federal inspection

Results are only slightly better in equations explaining calf-slaughter weights (table 12) than in equations explaining cattle-slaughter weights (table 11). The signs of coefficients for slaughter-cattle prices received by farmers, calf slaughter and total hay production are positive as expected. The coefficients for slaughter-calf price, however, are negative and have t-values causing them to be significant at a probability level of 0.05 or lower. The coefficient for the intercept change suggests that the average liveweight of calves slaughtered under federal inspection is about 3.11 pounds greater during the upswing than during the downswing phase of the cycle.

Equations explaining the net imports of cattle and calves

Equations explaining net imports of cattle and calves (table 12) also gave poor results. The R^2 values indicate that less than half the variance of net import numbers is explained by the variables specified in the equations. To obtain statistically significant estimates of the coefficients of the variables in these equations, the number of variables in an equation has to be kept relatively small. Low R^2 values result probably for two reasons: First, net imports of cattle and calves also depend upon the economic conditions in the exporting countries. These conditions are not considered in any equation estimated. And second, the volume of the international trade in cattle and calves is determined by the market mechanism only to a limited extent. Trade agreements of various types are important regulators of the volume of net imports of cattle and calves.

[23] In 1956 through 1962, 73.7 percent of the total number of cattle slaughtered were slaughtered under federal inspection. From 1951 through 1957 the average liveweight was as follows: steers, 1,012 pounds; cows, 974 pounds; and heifers, 853 pounds.

Table 11. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{34}(t)$, the average liveweight of cattle slaughtered under federal inspection, United States.

Equation number	$y_{28}(t)$ Total cattle slaughter	$y_{93}(t)$ Current slaughter-cattle price	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{84}(t)$ Lagged corn supply	$x_{77}(t)$ Total hay production	$x_3(t)$ Total disposable personal income	x_0 Intercept	$D_0{}^u$ Dummy variable upswing	R^2 Coefficient of determination
62	-0.00575	-1.81838		0.02377	-0.00056	0.66052	0.00002		0.83
	(0.00119)	(0.67914)		(0.00547)	(0.00026)	(0.07110)	(1.84754)		
63	-0.00514		-1.14217	0.02445	-0.00067	0.63434	0.00002		0.81
	(0.00127)		(0.67678)	(0.00579)	(0.00027)	(0.07800)	(1.95873)		
64	-0.00564	-2.12592	0.37958	0.02371	-0.00053	0.65245	0.00002		0.83
	(0.00124)	(1.06216)	(0.99838)	(0.00555)	(0.00027)	(0.07513)	(1.87274)		
65[a]	-0.00555	-1.76007		0.00308	-0.00054	0.65706	0.76542	1.16347	0.83
	(0.00156)	(0.73727)		(0.00661)	(0.00027)	(0.07396)	(4.37128)	(6.00097)	
Average:									
	-0.00552	-1.90146	-1.14217	0.02375	-0.00058	0.65109			
Elasticities:									
$\bar{e}_{T62}$	-0.145	-0.043	-0.025	0.091	-0.070	0.213			
$\bar{e}_M$	-0.195	-0.026	-0.015	0.069	-0.058	0.111			

[a] Based upon cycle division A indicated in table 1.

Table 12. Estimated unit effects (regression coefficients), standard errors (parentheses), average elasticities of variables and related statistics in selected equations explaining $y_{35}(t)$, the average liveweight of calves slaughtered under federal inspection and $y_{36}(t)$, the net imports of cattle and calves, United States.

Equation number	Explained variable	$y_{93}(t)$ Current slaughter-cattle price	$y_{96}(t)$ Current calf-slaughter price	$y_{28}(t)$ Total cattle slaughter	$y_{33}(t)$ Total calf slaughter	$x_{94}(t)$ Lagged slaughter-cattle price	$x_{77}(t)$ Total hay production	$x_{17}(t)$ Supply of other meats	$x_3(t)$ Total disposable personal income	x_0 Intercept	D_0^u Dummy variable upswing	R^2 Coefficient of determination
66[a]	$y_{35}(t)$	4.90093	-4.23208		0.00306		0.00021			-2.05853	3.55567	0.69
		(2.12820)	(1.89822)		(0.00114)		(0.00011)			(1.95446)	(3.08607)	
67[b]	$y_{35}(t)$	5.87803	-5.09334		0.00236		0.00023			-1.75575	2.66877	0.66
		(2.06720)	(1.85876)		(0.00089)		(0.00011)			(1.69528)	(2.25634)	
68	$y_{35}(t)$	6.90055	-6.01517		0.00164		0.00021			0		0.65
		(1.96519)	(1.76300)		(0.00071)		(0.00011)			(0.82294)		
Average:		5.89317	-5.11353		0.00235		0.00022				3.11222	
Elasticities:												
$\dot{e}_{T62}$		0.597	-0.571		0.118		0.120					
$\dot{e}_M$		0.387	-0.383		0.120		1.107					
69[b]	$y_{36}(t)$	7.90783		-0.07038		-58.74815	0.00829	-0.01743	4.01309	-50.29516	76.44879	0.49
		(21.92756)		(0.02931)		(19.46550)	(0.00509)	(0.04056)	(1.51926)	(79.78938)	(108.92524)	
70[b]	$y_{36}(t)$			-0.07515		-53.21061	0.00805		3.84417	-28.40181	43.17090	0.48
				(0.02515)		(11.76176)	(0.00471)		(1.33309)	(66.12800)	(86.25472)	
71	$y_{36}(t)$			-0.08130		-53.64077	0.00768		3.95857	0.00009		0.48
				(0.02153)		(11.60004)	(0.00460)		(1.29756)	(33.59655)		
Average:		7.90783		-0.07561		-55.19984	0.00801	-0.01743	3.93861		59.80985	
Elasticities:												
$\dot{e}_{T62}$		0.277		-3.098		-1.889	1.510	-0.0497	2.010			
$\dot{e}_M$		0.237		-3.852		-1.603	1.779	-0.550	1.481			

[a] Based upon cycle division B indicated in table 1.
[b] Based upon cycle division A indicated in table 1.

EMPIRICAL RESULTS FOR THREE REGIONS OF THE UNITED STATES

A precise explanation of the cattle cycle is difficult for the United States because its many regions are very heterogeneous in soils, climate and competing enterprises. Hence, in an attempt at improving the ability to predict important variables of the cattle cycle, analyses were made separately for three regions. Since regions have greater internal homogeneity than the nation as a whole, it was expected that more meaningful results might be obtained in explaining certain fundamental quantities on the cattle cycle. The statistical results should be much better, for example, in predicting the effect of variables relating to competing enterprises on the number of cattle on farms and marketed during various phases of the cattle cycle. These effects could not be identified at the national level because of the great variability among regions and because a variable of importance in one region may be offset by a variable of importance in another region.

Regions and Variables

The three regions of the United States selected for study were:

Region I—the western states of Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon and California. These are also known as the ranch states. Cattle enterprises in Region I are oriented mainly toward beef production (table 13). Milk production is important only in metropolitan areas.

Region II—the west north-central states of Minnesota, Iowa, Missiouri, North Dakota, South Dakota, Nebraska and Kansas. Cattle enterprises in this region are now oriented mainly toward beef production.

Region III—the east north-central states of Ohio, Indiana, Illinois, Michigan and Wisconsin. Among the regions studied, this region is most important in milk production. Since it also includes the eastern states of the Corn Belt, beef production is greater than for other regions excluded for this particular analysis.

Division of regions as indicated is necessitated by the available data. They still contain considerable heterogeneity in types of farming and important enterprises.

The regional analysis of the cattle cycle is restricted to an explanation of a single variable. This variable is $y_{119}{}^R(t)$, the regional number of cows and heifers over 2 years old kept during year t.

Although estimates also were made for the regional number of calves and heifers 1 to 2 years old kept and for the regional number of calves raised, the results are not presented here. Estimates for the last two variables were comparable to those for cows and heifers 1 to 2 years old kept in the number and relative importance of significant variables.

No separate list of regional explanatory variables is presented since they are defined in the same manner as the national time series.

Table 13. Composition of regional cow and heifer inventories.

	Milk cows and heifers		Beef cows and heifers		All cows and heifers	
	1931-33[a]	1959-61[b]	1931-33[a]	1959-61[b]	1931-33[a]	1959-61[b]
Region I, Western States						
Number[c]	2,212	2,096	3,368	5,991	5,580	8,087
Percent[d]	39.64	25.92	60.36	74.08	100.0	100.0
Region II, West North Central States						
Number[c]	7,028	4,503	2,803	7,059	9,831	11,562
Percent[d]	71.49	38.95	28.51	61.05	100.0	100.0
Region III, East North Central States						
Number[c]	5,867	5,128	368	1,475	6,235	6,603
Percent[d]	94.10	77.66	5.90	22.34	100.0	100.0

[a]Average for 1931 through 1933.
[b]Average for 1959 through 1961.
[c]In thousands, not including heifers 1 to 2 years old.
[d]Regional inventories of cows and heifers in percentages of the respective total regional inventories of cows and heifers over 2 years old.

Comparison of Estimated Unit Effects of Variables and of Elasticity Coefficients in Equations Explaining the Regional Number of Cows and Heifers Over 2 Years Old Kept

Cattle Price Variables

The expected effect of the current weighted-average regional slaughter-cattle price received by farmers, $y_{93}{}^{R}(t)$, upon the regional number of cows and heifers kept is negative in the short run. The estimated coefficients have this sign and generally are lowly significant in all selected equations for Region I (table 14) and Region II (table 15). In Region III (table 16), the coefficient is significant in four and lowly significant in three equations. The regression coefficients have the expected sign in all equations but equation 95. The corresponding elasticity coefficients have been arranged in table 17 to facilitate their comparison. The estimated average elasticities of $y_{119}(t)$ with respect to the current slaughter-cattle price are largest for Region I and smallest for Region III. The magnitude of the regional elasticity estimates is inversely related to the regional proportion of milk cows on farms. The response to the current slaughter-cattle price received by farmers evidently is smaller for milk cows than for beef cows.

If interpreted in the longer run, the coefficient of the lagged weighted-average slaughter-cattle price received by farmers is expected to be positive. The signs of the estimated coefficients are

Table 14. Region I, western states. Estimated unit effects (regression coefficients) and related statistics of variables in selected equations explaining $y_{119}(t)$, the regional number of cows and heifers over 2 years old kept.

Equation number	$y_{93}{}^{R}(t)$ Current slaughter-cattle price	$x_{94}{}^{R}(t)$ Lagged slaughter-cattle price	$x_{47}{}^{R}(t)$ Cow and heifer inventory	$x_{62}{}^{R}(t)$ Young heifer inventory	$x_{77}{}^{R}(t)$ Total hay production	$x_{3}(t)$ Total disposable personal income	$x_{81}{}^{R}(t)$ Total corn production	$x_{82}{}^{R}(t)$ Lagged corn production	$x_{130}{}^{R}(t)$ Lagged price of milk	$x_{132}{}^{R}(t)$ Price of lambs	$x_{133}{}^{R}(t)$ Lagged price of lambs	x_0 Intercept	$D_0{}^{u}$ Dummy variable upswing	R^2 Coefficient of determination
	(standard errors in parentheses)						(standard errors in parentheses)							
72	-74.5677	72.3833	0.7890	-0.3498	0.0698	-2.7879	0.0070		-263.4133	49.1976		-1.3508		0.72
	(50.6840)	(24.7923)	(0.3079)	(0.8816)	(0.0334)	(2.4690)	(0.0071)		(117.6718)	(37.0105)		(31.2566)		
73	-8.4921	36.5415	0.5662	0.5995	0.0417				-183.1996			0.9396		0.67
	(17.0546)	(19.2531)	(0.2034)	(0.6726)	(0.0233)				(96.8951)			(32.5123)		
74	-10.4931	34.7504	0.6690	0.3712	-4.2989[c]				-148.5884			3.0018		0.64
	(18.0134)	(20.2110)	(0.2068)	(0.6945)	(7.2138)				(98.1358)			(34.4902)		
75[a]	-41.2899	0.5347	0.5247	0.7603	0.0401					34.9388		-180.2175	270.3261	0.74
	(35.6001)	(16.2338)	(0.1853)	(0.6157)	(0.0212)					(24.4959)		(58.2285)	(75.4484)	
76[b]		-8.8698	0.8569	0.3151	0.0359	0.3944		-0.0127				-189.7085	336.3032	0.75
		(15.4608)	(0.2365)	(0.7208)	(0.0334)	(2.3807)		(0.0068)				(62.7078)	(98.8447)	
77[a]	-59.2598	10.0514	0.7358	0.1928	0.0282					39.0527		-146.2393	259.2424	0.72
	(35.1448)	(16.5375)	(0.2122)	(0.6540)	(0.0222)					(26.0937)		(57.9427)	(87.1413)	
78	-11.3351	41.7778	0.8000	-0.2006	0.0819	-3.7493		0.0013			-10.2036	-0.0001		0.67
	(20.6695)	(27.1116)	(0.2796)	(0.8856)	(0.0364)	(2.4071)		(0.0064)			(24.6362)	(33.5944)		
Average:	-34.2396	32.6732[d]	0.7059	0.4478[e]	0.0496[f]	-3.2686[g]	0.0070	-0.0127[h]	-198.3938	41.0630	-10.2036		288.6232	

[a]Based upon cycle division A indicated in table 1.
[b]Based upon cycle division B indicated in table 1.
[c]The variable $x_{131}{}^{R}(t)$, the range feed condition index, is used in this single equation rather than $x_{77}{}^{R}(t)$.
[d]Coefficient of equation 76 is not included.
[e]Coefficients of equations 72 and 78 are not included.
[f]Coefficient of equation 74 is not included.
[g]Coefficient of equation 76 is not included.
[h]Coefficient of equation 78 is not included.

Table 15. Region II, west north-central states. Estimated unit effects (regression coefficients) and related statistics of variables in selected equations explaining $y_{119}{}^{R}(t)$, the regional number of cows and heifers over 2 years old kept.

Equation number	$y_{93}{}^{R}(t)$ Current slaughter-cattle price	$x_{94}{}^{R}(t)$ Lagged slaughter-cattle price	$x_{47}{}^{R}(t)$ Cow and heifer inventory	$x_{62}{}^{R}(t)$ Young heifer inventory	$x_{77}{}^{R}(t)$ Total hay production	$x_3(t)$ Total disposable personal income	$x_{81}{}^{R}(t)$ Total corn production	$x_{82}{}^{R}(t)$ Lagged corn production	$x_{129}{}^{R}(t)$ Price of milk	$x_{130}(t)$ Lagged price of milk	$x_{132}{}^{R}(t)$ Price of lambs	$x_{133}{}^{R}(t)$ Lagged price of lambs	$x_{134}{}^{R}$ Price of hogs	$x_{135}{}^{R}(t)$ Lagged price of hogs	x_0 Intercept	$D_0{}^{u}$ Dummy variable upswing	R^2 Coefficient of determination
	(standard errors in parentheses)																
79	-33.4933	117.9793	0.8181	0.3023	0.0290		0.0004			-555.2738					-2.8271		0.79
	(30.2586)	(33.8167)	(0.1508)	(0.4630)	(0.0189)		(0.0004)			(170.6146)					(57.2438)		
80		106.4623	0.9301	0.1731	0.0328	-4.7544	0.0007		-391.9300			-26.2985			-0.8443		0.81
		(48.3342)	(0.1642)	(0.5195)	(0.0184)	(2.1203)	(0.0004)		(176.0121)			(48.3066)			(54.9098)		
81	-54.6674	137.0933	0.8035	0.2884	0.0575	-4.3712		0.0003		-491.4602					-2.5203		0.81
	(29.0491)	(32.9311)	(0.1344)	(0.4713)	(0.0169)	(2.2149)		(0.0003)		(171.1338)					(55.5327)		
82		105.6568	0.8526	0.2785	0.0266		0.0004			-582.9789	-19.4268				-2.6821		0.78
		(30.0568)	(0.1484)	(0.4713)	(0.0188)		(0.0004)			(185.8008)	(23.8693)				(57.7492)		
83		91.8144	0.8347	0.3908	0.0241		0.0004			-498.8737			-13.0482		-2.5558		0.78
		(28.7133)	(0.1528)	(0.4778)	(0.0184)		(0.0004)			(222.4876)			(21.6551)		(58.0275)		
84		93.8203	0.8522	0.3098	0.0194		0.0005			-490.6144				-14.1463	-2.5162		0.78
		(28.1720)	(0.1494)	(0.4713)	(0.0190)		(0.0004)			(245.3161)				(26.3841)	(58.0999)		
85	-15.2992	35.4534	0.9446		0.0272	-4.0322	0.0005								-337.7218	506.5827	0.85
	(26.4810)	(26.1834)	(0.0827)		(0.0163)	(1.8449)	(0.0003)								(91.1917)	(116.0913)	
86[a]			0.9327		0.0216	-2.8457	0.0006								-372.4031	558.6046	0.84
			(0.0753)		(0.0151)	(1.7312)	(0.0003)								(87.3274)	(109.4248)	
87[a]	-12.8815	65.8146	0.9569	0.0355	0.0313	-3.6172	0.0005			-243.6103					-280.3972	418.7218	0.86
	(26.4673)	(33.4330)	(0.1310)	(0.3952)	(0.0169)	(1.8674)	(0.0003)			(164.9164)					(99.3287)	(130.9367)	
Average:	-29.0869	94.2618	0.8806	0.2541	0.0299	-3.9241	0.0005	0.0003	-391.9300	-467.1352	-19.4268	-26.2985	-13.0482	-14.1463		494.6364	

[a]Based upon cycle division A in table 1.

Table 16. Region III, east north-central states. Estimated unit effects (regression coefficients) and related statistics of variables in selected equations explaining $y_{119}{}^{R}(t)$, the regional number of cows and heifers over 2 years old kept.

Equation number	$y_{93}{}^{R}(t)$ Current slaughter-cattle price	$x_{94}{}^{R}(t)$ Lagged slaughter-cattle price	$x_{47}{}^{R}(t)$ Cow and heifer inventory	$x_{62}{}^{R}(t)$ Young heifer inventory	$x_{77}{}^{R}(t)$ Total hay production	$x_3(t)$ Total disposable personal income	$x_{81}{}^{R}(t)$ Total corn production	$x_{130}{}^{R}(t)$ Lagged price of milk	$x_{132}{}^{R}(t)$ Price of lambs	$x_{133}{}^{R}(t)$ Lagged price of lambs	$x_{134}{}^{R}(t)$ Price of hogs	x_0 Intercept	$D_0{}^{u}$ Dummy variable upswing	R^2 Coefficient of determination
			(standard errors in parentheses)							(standard errors in parentheses)				
89	-18.8511	54.5352	0.8342	0.9893	0.0073			-227.8507				-1.686		0.95
	(8.4774)	(10.5049)	(0.0774)	(0.3048)	(0.0080)			(45.5258)				(16.3414)		
90[a]	-15.3368	40.5589	0.9249	0.6840				-156.7863				-85.2508	126.6700	0.96
	(8.0149)	(10.5621)	(0.0796)	(0.3152)				(48.5780)				(32.2440)	(42.8993)	
91	-21.1361	24.3912	0.6331	1.3278	0.0080		-0.0004					-0.0001		0.92
	(10.8922)	(10.9861)	(0.1122)	(0.4260)	(0.0105)		(0.0002)					(20.2729)		
92[a]	-16.1578	18.4021	0.8831	0.7263	0.0114		-0.0002					-118.0832	177.1247	0.95
	(9.1398)	(9.2681)	(0.1131)	(0.4000)	(0.0090)		(0.0002)					(35.5211)	(46.5786)	
93		22.0911	0.8638	1.0970							-22.9376	-0.0002		0.92
		(7.4042)	(0.1005)	(0.3506)							(7.1931)	(19.7287)		
94[a]	-10.5293	20.1731	0.9692	0.5817	0.0114						-8.9365	-114.1445	171.2165	0.95
	(10.4914)	(9.2876)	(0.0926)	(0.3551)	(0.0089)						(8.0064)	(35.7638)	(47.0878)	
95	26.8942	23.7784	0.8556	1.1342					-42.1410			-0.0002		0.92
	(23.3579)	(10.5679)	(0.1015)	(0.3537)					(18.2760)			(20.1116)		
96[a]	-10.8308	37.0184	0.9568	0.6025	0.0142					-20.4612		-108.4674	162.7008	0.95
	(9.7865)	(15.7352)	(0.0893)	(0.3516)	(0.0089)					(14.3836)		(35.8287)	(47.3634)	
97[a]	-12.0253	19.3113	0.6380	1.2695	0.0047	-2.4555						-65.5342	98.3012	0.96
	(7.7802)	(7.7973)	(0.1121)	(0.3553)	(0.0078)	(0.6586)						(32.8557)	(44.2094)	
Average:	-14.9810	28.9177	0.8436	0.9347	0.0095	-2.4555	-0.0003	-192.3185	-42.1410	-20.4612	-15.9371		147.2026	

[a]Based upon cycle division in table 1.

Table 17. Trend ($\bar{e}_{T62}$) and mean elasticities ($\bar{e}_M$) of $y_{119}(t)$, the number of cows and heifers over 2 years old kept in the United States and in three selected regions.[a]

Area to which $y_{119}(t)$ refers	$y_{93}(t)$ Current slaughter-cattle price		$x_{94}(t)$ Lagged slaughter-cattle price		$x_{47}(t)$ Cow and heifer inventory		$x_{62}(t)$ Young heifer inventory		$x_{77}(t)$ Total hay production	
	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$
United States	-0.074	-0.052	0.060	0.042	0.855	0.856	0.235	0.222	0.071	0.069
Region I (Western States)	-0.093	-0.068	0.087	0.063	0.693	0.698	0.119	0.115	0.141	0.152
Region II (West North Central States)	-0.055	-0.039	0.180	0.125	0.869	0.872	0.072	0.067	0.096	0.086
Region III (East North Central States)	-0.047	-0.031	0.090	0.058	0.850	0.842	0.288	0.238	0.032	0.029

Table 17. (cont'd)

Area to which $y_{119}(t)$ refers	$x_{81}(t)$ Total corn production		$x_{82}(t)$ Lagged corn production		$x_{129}(t)$ Price of milk		$x_{130}(t)$ Lagged price of milk		$x_{132}(t)$ Price of lambs	
	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$
United States	0.032	0.029	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]
Region I (Western States)	0.020	0.022	-0.036	-0.040	n.a.[b]	n.a.[b]	-0.107	-0.089	0.105	0.087
Region II (West North Central States)	0.065	0.055	0.037	0.032	-0.149	-0.116	-0.176	-0.136	-0.035	-0.027
Region III (East North Central States)	-0.056	-0.041	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	-0.123	-0.088	-0.128	-0.093

Table 17. (cont'd)

Area to which $y_{119}(t)$ refers	$x_{133}(t)$ Lagged price of lambs		$x_{134}(t)$ Price of hogs		$x_{135}(t)$ Lagged price of hogs		$x_3(t)$ Total disposable personal income	
	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$	$\bar{e}_{T62}$	$\bar{e}_M$
United States	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]
Region I (Western States)	-0.026	-0.021	n.a.[b]	n.a.[b]	n.a.[b]	n.a.[b]	-0.127	-0.080
Region II (West North Central States)	-0.047	-0.037	-0.020	-0.016	-0.022	-0.018	-0.106	-0.062
Region III (East North Central States)	-0.062	-0.045	-0.043	-0.032	n.a.[b]	n.a.[b]	-0.113	-0.061

[a]The entries are the estimated elasticities of $y_{119}(t)$ for the area stated in the first column with respect to the variables in the column headings.
[b]Not available.

positive (tables 14, 15 and 16) in all selected equations but one. The coefficients have t-values that are significant in 22 out of 25 selected equations. The significance levels are least satisfactory for Region I and are highest for Region II. This difference is reflected in the magnitudes of the trend elasticity estimates presented in table 17.

Inventory variables

The coefficient of the inventory of cows and heifers over 2 years old, $x_{47}{}^{R}(t)$, is positive as expected and highly significant in all selected equations (tables 14, 15 and 16). The effect of the regional inventory of heifers 1 to 2 years old, $x_{62}{}^{R}(t)$, on the regional number of cows and heifers over 2 years old kept is significant or highly significant only in Region III (table 16). The increase in the significance levels from Region I to Region III may again relate to the proportions of beef and dairy stock in the inventory. Milk cow inventory numbers fluctuate less than the beef cow inventory numbers (see fig. 1).

Feed variables

The range feed condition, $x_{131}{}^{R}(t)$, was included in the place of $x_{77}{}^{R}(t)$ in equation 74 of table 14 for Region I or the western states. The coefficient was negative, and the R^2 value was lower than for equations including $x_{77}{}^{R}(t)$. Hence, the range feed condition index, $x_{131}{}^{R}(t)$, was considered to have no predictive value even for Region I.

All selected estimates of the coefficient for $x_{77}(t)$, total hay production, are positive as expected and at least lowly significant (tables 14, 15 and 16). Perhaps this variable serves most effectively as a proxy variable to represent range grass production even for Region III. The magnitude of the elasticity estimates decreases from Region I to Region III. The elasticity coefficient for Region I, for example, is approximately four times that of Region III. These differences in magnitude can be attributed to the relative preponderance of hay and pasture feed in the rations fed to cattle in Region I where soils and climate are mainly adapted to forage and where cattle production is largely geared to hay and grass.

The effect of corn production on the number of cows and heifers over 2 years old kept, varies among regions. It is uniformly positive in all equations estimated for Region II. As expected, the variable appears to have little explanatory value for Region I (table 14), which includes the range states. In Region III (table 16), the coefficient for corn production has only a negative sign. An increase in corn supply in Region III may lead to an increase in hog production, which draws labor and capital resources away from cattle. The lagged variable for corn production plays an insignificant explanatory role where it is used.

Other variables

Variables representing competing enterprises were included to allow expression of price effects in bringing about reallocation of resources between cattle and other enterprises. Contrary to expectations, only a few useful coefficients could be obtained relating cattle and sheep numbers (table 14) through $x_{132}{}^{R}(t)$, the weighted-average price of lambs received by farmers. For Region I, the coefficients of $x_{132}{}^{R}(t)$ are positive, indicating complementary conditions between sheep and cattle—perhaps due to forage-supply effects on both. For regions II and III (tables 16 and 17), where forage supplies are more stable, the negative regression coefficients of $x_{132}{}^{R}(t)$ indicate that cattle and sheep are competitive enterprises.

Hog production competes with cattle production for resources mainly in regions II (table 15) and III (table 16). Therefore, the effect of changes in the current and lagged regional weighted-average price of hogs received by farmers upon the regional number of cows and heifers over 2 years old kept is investigated only for these two regions. Negative values for current and lagged prices of hogs are obtained, as expected, in both regions (tables 15 and 16).

The negative coefficients of the total disposable personal income are at most lowly significant in the selected equations for Region I (table 14) and significant or highly significant in the equations for regions II (table 15) and III (table 16). If the total disposable personal income in the United States increases, the number of cows and heifers over 2 years old kept in these regions is predicted to decrease.

The expected changes in the intercept coefficient during upswings are positive for all three regions. The estimates are positive and highly significant in all selected equations in which the intercept change is estimated. This result again suggests that the expectations used by farmers in all three regions cause a greater response to the same collection of variables during the upswing phase of the cycle than during a downswing phase.

A relatively large number of variables affects the number of cows and heifers over 2 years old kept in the three selected regions of the United States. Not all these variables can be included simultaneously in an equation without greatly reducing the significance levels of the individual coefficients. The differences among regions in the magnitude of the predicted response are attributed mainly to two factors: One is the varying proportion of milk cows and heifers in all cows and heifers over 2 years old on farms; the other is the varying degree of specialization of resources. As the proportion of milk cows increases, the magnitude of the response to changes in certain variables, especially slaughter-cattle price variables, decreases. The magnitude of the response increases as the specialization of resources decreases and (or) as the number of competing enterprises increases.

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