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A Dynamic Model of a Simulated Livestock-Meat Economy

By Richard J. Crom and Wilbur R. Maki

AS A MEANS of studying historical and projected changes in market organization and structure, a dynamic model of the livestock-meat economy during 1955-64 has been developed.[1] It can be used to trace out the effect on prices, slaughter, foreign trade, and January 1 livestock numbers resulting from an assumed change in Government or industry policy. Use of this model depends on the electronic computer. In fact, the computer is an additional tool in building the model--it allows the researcher limited control of the performance of the model throughout its development.

Early studies of the livestock-meat economy used the single-equation approach--still a useful research technique in spite of the development of simplified solution methods for systems of simultaneous equations. Simultaneous equations have been used in economic research not only because of statistical problems of correlation between the explanatory variables and the disturbance term but also because many economic variables are determined simultaneously. However, new problems were introduced with simultaneous systems.[2] For example, variables must be excluded or aggregated to meet identification requirements. In addition, estimation of the structural parameters not only limits the variables used but also requires complex and costly methods. Furthermore, because of time lags involved, many responses are not simultaneous--particularly when fairly short time periods are considered.

The model to be presented is not simultaneous but recursive, except that beef and pork prices are jointly determined. Recursiveness is maintained by restricting endogenous variables either to those that are functions of lagged variables or to those that may be estimated sequentially. When simultaneous solutions are necessary, several methods are available. One method is the use of a small block of simultaneous equations. Modern computers also make an iterative solution possible; for example, in a demand equation where the beef and pork price equations each contain the other price as an explanatory variable. Also, one equation may be solved algebraically in terms of the other by substituting one equation for the competing price variable in the other equation.

Because livestock production involves substantial delays between breeding and slaughter, the sequential nature of a recursive model better portrays the cause-and-effect relationships than a simultaneous system, especially when short periods of time are used. The shorter the time period, the more current production depends on decisions made in the past and the more recursive the model is--the more lagged reactions reflect cause-and-effect sequences. Thus, a model's recursive properties very closely reflect the biological production processes and short-term decision procedures.

Primary validation of the model is its ability to reproduce as closely as possible the "real world" using reported logical time series on selected economic phenomena. The degree of correlation can be easily determined by plotting estimated values against reported values, although more precise indicators may be

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[1] This paper is based on research conducted cooperatively by the USDA and the Iowa Agr. and Home Econ. Expt. Sta., Ames, Iowa, Project No. 1462.

[2] For a more complete discussion of simultaneous versus recursive systems see H. Wold and L. Jureen, Demand Analysis, New York, John Wiley and Sons, 1953; L. R. Klein, "Single equation versus equation system methods of estimation in econometrics," Econometrica, Vol. 28, pp. 866-871, 1960; and C. F. Christ, "Simultaneous equations, estimation, any verdict yet," Econometrica, Vol. 28, pp. 835-845, 1960.

employed.[3] The graphic method of validation provides for acceptance of a model when reproduction of reported values of the variables satisfies the researcher. Proper estimation of individual equations can compensate for the major weakness of the recursive model--the lack of a statistical measure of the overall variance.

This model of the livestock-meat economy deals with its two principal components--the beef and pork sectors. In building the model of the beef and pork sectors a series of relationships among selected variables was diagrammed in considerable detail. These relationships generally were estimated by single-equation, least-squares regression. Time series data were employed, but we also had the option of using cross-sectional and engineering data, as well as simple rules of thumb. The diagram served as a flow chart in ordering the individual relations in the computer program.

One "loop" in the computer program estimated the economic activity of both sectors of the livestock-meat economy for 1 year. The computer was programmed to operate the model over 9 years (1955 to 1964). Reported values of all lagged endogenous variables and all exogenous variables were in the first loop or year. In subsequent years, the values of endogenous variables estimated during the first year provided the input for the explanatory variables.

Subsequent trial runs over the historical period allowed modification of component relations until more precise estimates of component relations were obtained. These modifications involved changes in the length of the time lag, coefficient adjustments, limiting values, and explanatory variables.

The Economic Structure

The economic structure of the beef and pork sectors is presented in figures 1 and 2. The causal ordering is shown in the flow diagrams. The coefficients of the behavioral relations are presented in the appendix.

The economic structure of the pork sector is presented in figure 1. Endogenous variables are depicted by circles and exogenous variables are depicted by squares. Interaction between endogenous variables is shown by a diamond-shaped notation. The broken lines denote lagged variables.

<u>Pork Sector</u>: Numbers of sows and gilts on farms January 1 are accounted for by the corn-hog ratio of the previous year and the January 1 farm stocks of corn. The coefficient for the January 1 inventory of sows and gilts is estimated in two parts. When the corn-hog ratio exceeds 20, the coefficient is reduced from 252 to 240. Similarly, the coefficient is reduced if the ratio falls below 11. It can be argued that, with an exceptionally high ratio, producers show less price response because they do not expect this favorable ratio to hold. Conversely, when the ratio is exceptionally low, producers strive to maintain their breeding herds.

The January 1 inventory of sows and gilts is highly correlated with the number of sows to farrow from December through May. In turn, these spring farrowings, along with the corn-hog ratio, establish the level of fall farrowings. In addition, a trend effect occurs that accounts for a shift toward year-round farrowings. The computer program for the model was modified, however, to prevent fall farrowings from exceeding spring farrowings. Also, an intercept adjustment was made that improved the model's predictive ability.

Since it takes approximately 6 months to raise a pig to slaughter weight, pigs produced by sows farrowing the last 6 months of the year plus cull sows make up the commercial slaughter of the first half of the year. Corn and hog prices of the previous 6 months also affect commercial slaughter; they influence both the cull rate of sows and the retention of gilts for breeding purposes.

Pork production follows from commercial slaughter. Ending stocks change from their previous level when pork production increases or decreases. In the model, however, ending stocks of neither pork nor beef are allowed to fall below minimum "pipeline" levels. Finally, net foreign trade (imports minus exports) is depicted as a function of lagged wholesale price.

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[3] Richard E. Suttor and Richard J. Crom, "Computer Models and Simulation," Jour. Farm Econ., Vol. 46, No. 5, pp. 1341-1350.

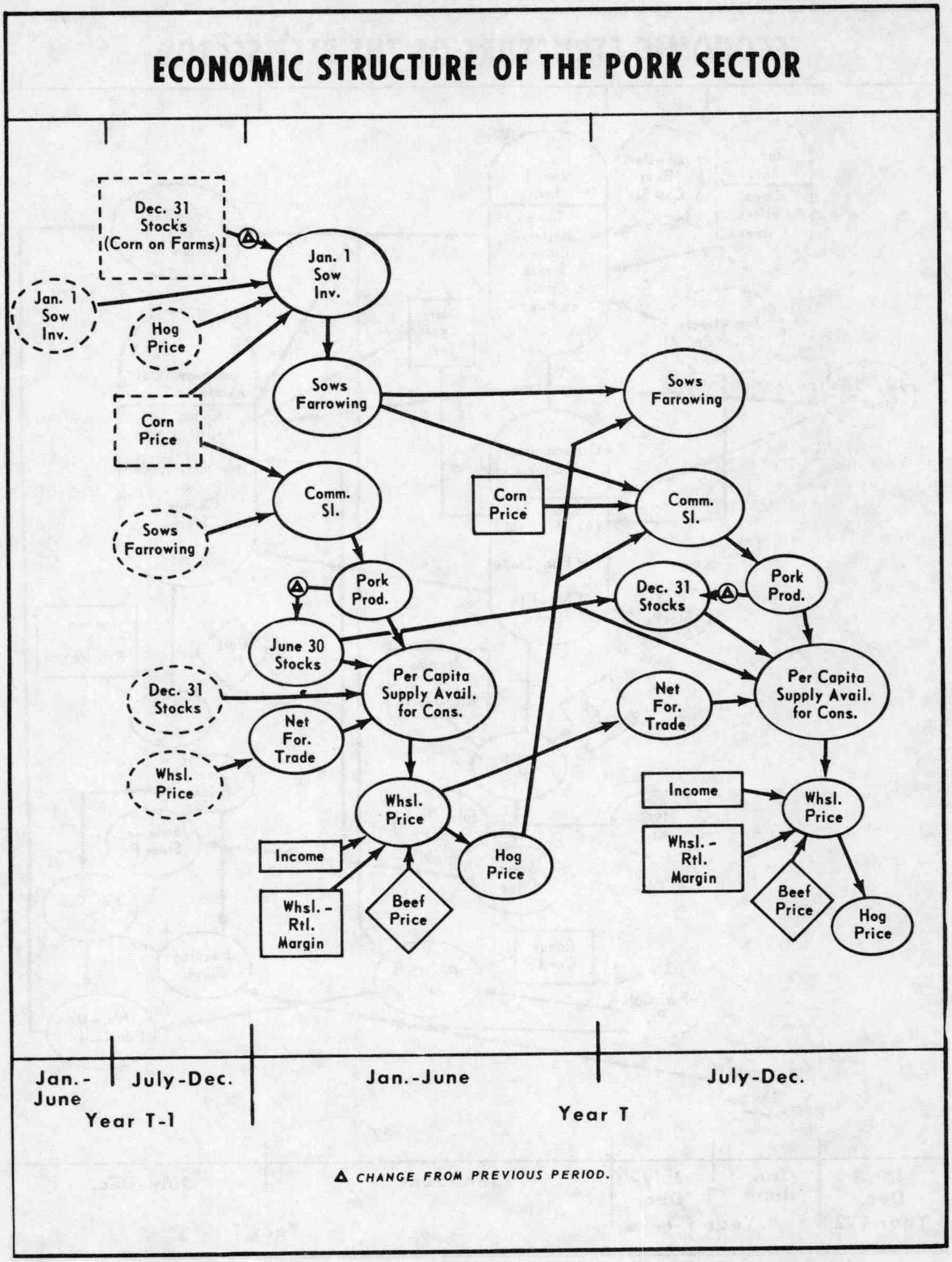
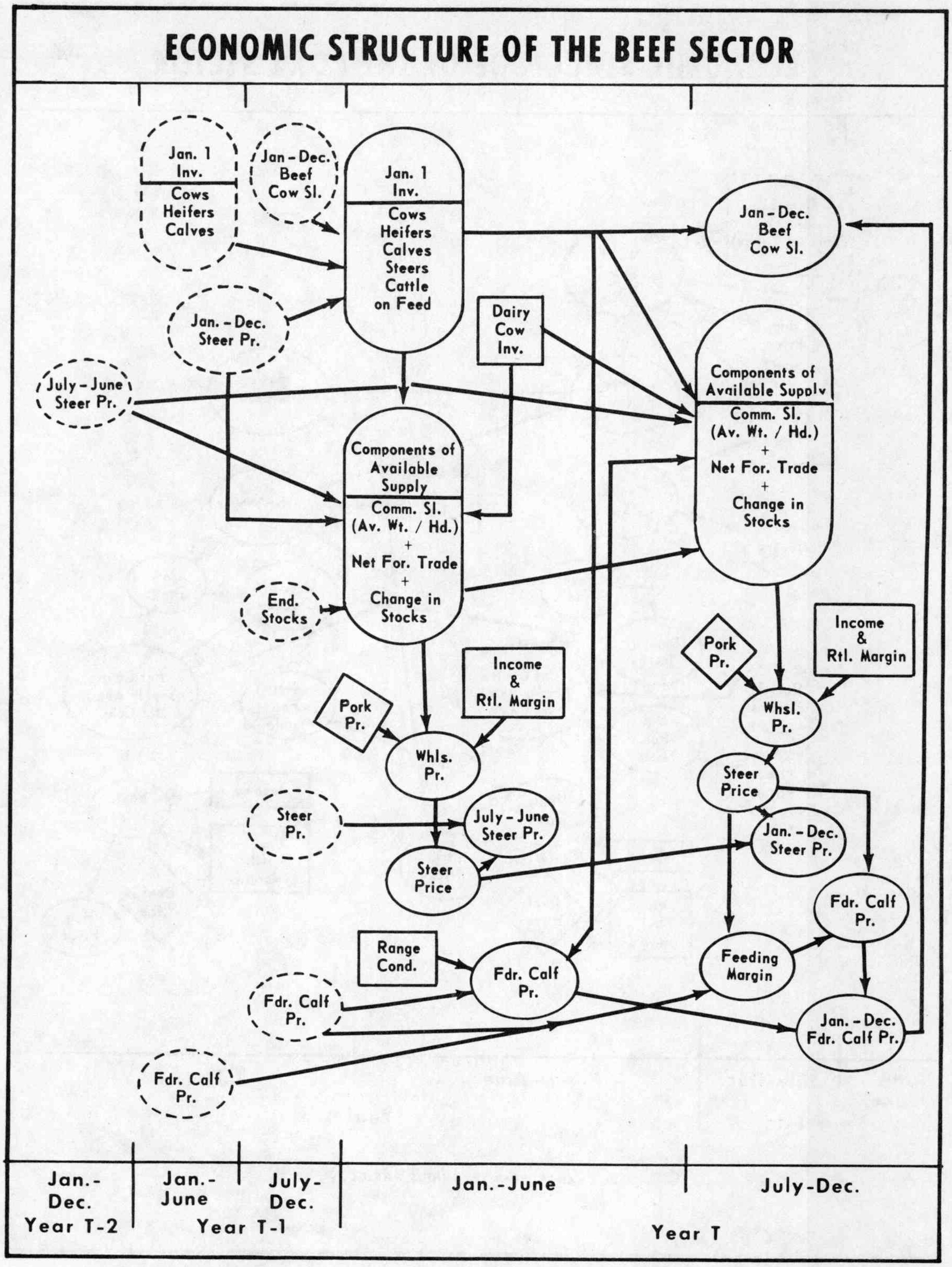

ECONOMIC STRUCTURE OF THE PORK SECTOR
Dec. 31 Stocks (Corn on Farms)
Jan. 1 Sow Inv.
Jan. 1 Sow Inv.
Hog Price
Sows Farrowing
Sows Farrowing
Corn Price
Comm. Sl.
Corn Price
Comm. Sl.
Sows Farrowing
Pork Prod.
Dec. 31 Stocks
Pork Prod.
June 30 Stocks
Per Capita Supply Avail. for Cons.
Dec. 31 Stocks
Net For. Trade
Per Capita Supply Avail. for Cons.
Net For. Trade
Whsl. Price
Income
Whsl. Price
Whsl. Price
Hog Price
Income
Whsl. - Rtl. Margin
Beef Price
Whsl. - Rtl. Margin
Beef Price
Hog Price
Jan.- June
July-Dec.
Jan.-June
July-Dec.
Year T-1
Year T
▲ CHANGE FROM PREVIOUS PERIOD.

Figure 1



ECONOMIC STRUCTURE OF THE BEEF SECTOR
Jan. 1 Inv.
Cows Heifers Calves
Jan-Dec. Beef Cow Sl.
Jan. 1 Inv.
Cows Heifers Calves Steers Cattle on Feed
Jan-Dec. Beef Cow Sl.
Jan. - Dec. Steer Pr.
Dairy Cow Inv.
July - June Steer Pr.
Components of Available Supply
Comm. Sl. (Av. Wt. / Hd.) + Net For. Trade + Change in Stocks
Components of Available Supply
Comm. Sl. (Av. Wt. / Hd.) + Net For. Trade + Change in Stocks
End. Stocks
Pork Pr.
Income & Rtl. Margin
Whls. Pr.
Pork Pr.
Income & Rtl. Margin
Whsl. Pr.
Steer Price
Steer Pr.
July - June Steer Pr.
Steer Price
Jan. - Dec. Steer Pr.
Fdr. Calf Pr.
Range Cond.
Fdr. Calf Pr.
Feeding Margin
Fdr. Calf Pr.
Jan. - Dec. Fdr. Calf Pr.
Fdr. Calf Pr.
Jan.-Dec. Year T-2
Jan.-June
July-Dec.
Year T-1
Jan.-June
July-Dec.
Year T

Figure 2

Thus, the supply of pork available for civilian consumption may be determined as an identity--ending stocks of the previous period plus commercial pork production and the foreign trade balance, minus ending stocks and military consumption. The wholesale price of pork is a function of per capita pork consumption, wholesale beef price, income, the retail margin, and a trend term which represents shifts in consumer tastes. The retail margin is viewed as an exogenous variable inasmuch as it is largely determined by wages and other exogenous elements.

Beef Sector: The economic structure of the beef sector used in the computer model is much more complex than that of the pork sector (fig. 2). The inventory classification of an animal changes every year, with the exception of cows, bulls, and a few 2-year-old steers. Since cows retain the same classification for several years, they are considered the basic pool of breeding stock to which heifers are added and from which cows are culled. The inventory of beef calves less than 1 year old is related to cow numbers the previous year and the preceding year's feeder calf price. January inventories of beef heifers, steers, and cattle on feed are determined by the calf inventory the previous year and either the slaughter steer or feeder calf price of the preceding year.

In the January 1 cattle inventory equations, the coefficient associated with the lagged feeder calf or slaughter steer price is decreased if the price either falls below or exceeds its critical values. At low price levels, price response is reduced as producers attempt to maintain inventory levels. At high prices, the response to price is reduced as producers expect prices to return to lower levels. These critical turning points were established in the study by successive computer runs over the historical period. Each relationship has its own critical levels; lower levels are between $21 and $25 while upper levels are near $28 for slaughter price and $32 to $33 for feeder calf price.

Cow inventories (both beef and dairy) and steer and bull inventories account for a substantial part of commercial cattle slaughter. Inasmuch as commercial slaughter is considered on a liveweight basis in the model, the average weight of steers enters into its determination.

Initially, commercial cattle slaughter is estimated by a least-squares regression of the following form:

$$Y_t = a + b\Delta^2 X1_t + cX2_t + d\Delta^2 X3_{t-1}$$

where

X1 = January 1 beef cow numbers,

X2 = January 1 steer and bull numbers,

X3 = Annual feeder calf prices.

This relationship explained 93 percent of the variation in commercial slaughter. However, use of this relationship in the computer model led to an unstable, explosive system.

Several alternative relations were employed to improve the performance of the computer model. Since the bulk of commercial slaughter comes from slaughter of cattle on hand January 1, the following residual was calculated:

$$R = \text{Commercial slaughter} - aX1 - bX2 - cX3,$$

where

X1 = January 1 dairy cow numbers,

X2 = January 1 beef cow numbers,

X3 = January 1 steer and bull numbers.

The coefficients a, b, and c represent average cull or disposal rates over the cattle cycle. This residual still contains the year-to-year variation. It was fitted by least squares to the explanatory variables of the slaughter steer price lagged 2 years and the average weight of steers weighted by the proportion of January 1 steer inventories to cow inventories.

Computer experimentation with the model revealed that the 2-year lagged supply price enters into slaughter determination in addition to the 1-year lagged price effects already incorporated in the inventory variables. Although the 2-year lag seems somewhat long, it is logical in that the price before the summer breeding season influences the number of cows bred in year t-2. These calves are part of the calf crop of year t-1 and are ready for slaughter in both halves of year t.

The use of a weighted average inventory level introduces a nonlinear element in the independent variable. The negative coefficient supports the hypothesis that, under normal conditions, steers are fed to heavier weights when cattle numbers are relatively low. Allowance for the average disposal of inventories reduces the problem of multicolinearity among the inventory components and also allows more variation in the dependent variable. This form of the relationship stabilizes the model and yields more accurate estimates of commercial cattle slaughter.

The average weight of steers fluctuates with the change in steer numbers, the beef-corn price ratio the previous half year, and a trend term. A favorable beef-corn ratio encourages feeding to heavier weights while the trend term indicates a change in the ratio of fed to nonfed steers.

The components of the identity for determining the supply of beef available for consumption--beef stocks, beef production, and net foreign trade--are comparable with those in the pork consumption identity. The wholesale and live price relations are also similar to those of the pork sector.

Feeder price in the second half of the year changes with the direction of slaughter steer prices. If slaughter steer prices are steady or rising, the slaughter-feeder price margin of the previous 6 months, the slaughter steer price, and fall range conditions can be related to changes in the feeder price. However, if slaughter steer prices decline from the previous year, the current slaughter-feeder price margin is the more appropriate variable in explaining feeder price changes. Presumably, cattle feeders scrutinize the existing margin more closely during times of falling cattle prices. Thus, feeder calf prices in the spring are essentially set by the fall feeder price, but are also affected by the change in numbers of cattle on feed January 1.

Validation of the Model

Reported and predicted values of four key variables during 1955-64 are presented in figures 3 and 4. These variables are commercial slaughter, per capita consumption, wholesale price, and January 1 beef cows on hand.

The most serious error of the model was its inability to predict the large increases in commercial cattle slaughter in early 1964 with the corresponding increase in consumption and decrease in wholesale price. Estimates of pork price also were low during 1963-64. These low estimates of pork price could be attributed to the use of the trend term.

The large error in the cattle slaughter estimate could be attributed to a combination of factors. First, the estimate of January 1 steers on hand was low. Generally, cattle feeders retain steers on feed when they expect prices to rise, which may have been the case because of low prices in late 1963. The carryover increased average slaughter weights, thus adding to the error in the commercial slaughter estimate. If the coefficient associated with lagged price in the average slaughter weight equation were increased when price fell below a predetermined level, the cattle slaughter estimate would be improved. These two cases illustrate the type of adjustment made in the final stages of developing the model.

Summary and Conclusions

The recursive nature of the model allows the use of single equations in obtaining initial estimates of behavioral relations. The computer offers a means of observing the interaction of these individual equations as the model attempts to approximate the reported prices and outputs of the industry. In this type of model building, the researcher may interact with the computer in developing new behavioral relations or in modifying initial estimates of coefficients, until a model is obtained that will reproduce the historical period given only the value of prices and outputs at the beginning of the period. The unique feature of this type of model is its ability to use different coefficients, different variables, and different time lags depending on preassigned rules.

After validation, the model may be rerun on the computer under assumed changes in economic structure based on proposed Government programs, or shifts in any of the specified

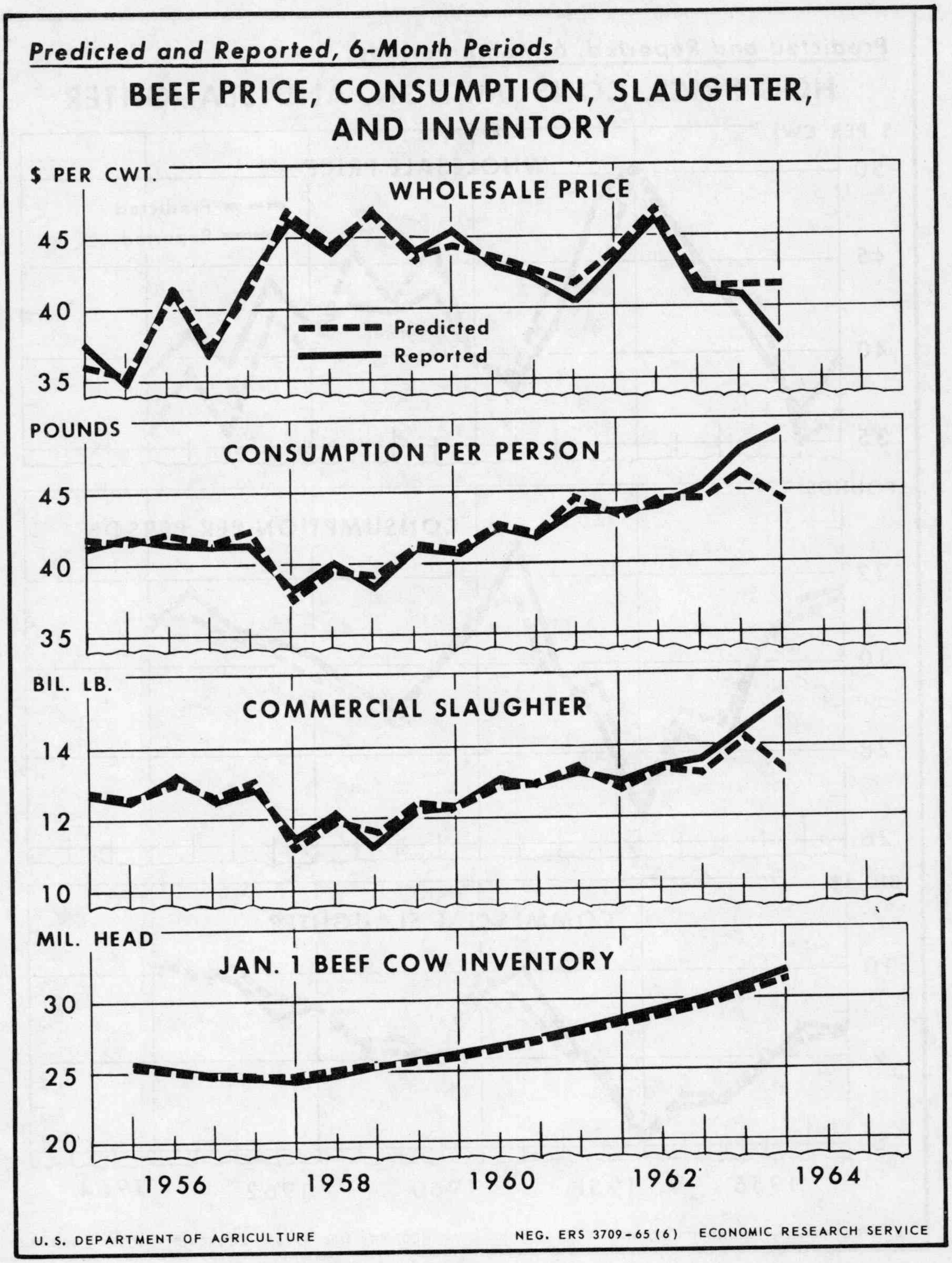

Predicted and Reported, 6-Month Periods
BEEF PRICE, CONSUMPTION, SLAUGHTER, AND INVENTORY
$ PER CWT.
WHOLESALE PRICE
45
40
35
Predicted
Reported
POUNDS
CONSUMPTION PER PERSON
45
40
35
BIL. LB.
COMMERCIAL SLAUGHTER
14
12
10
MIL. HEAD
JAN. 1 BEEF COW INVENTORY
30
25
20
1956
1958
1960
1962
1964
U. S. DEPARTMENT OF AGRICULTURE
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Figure 3

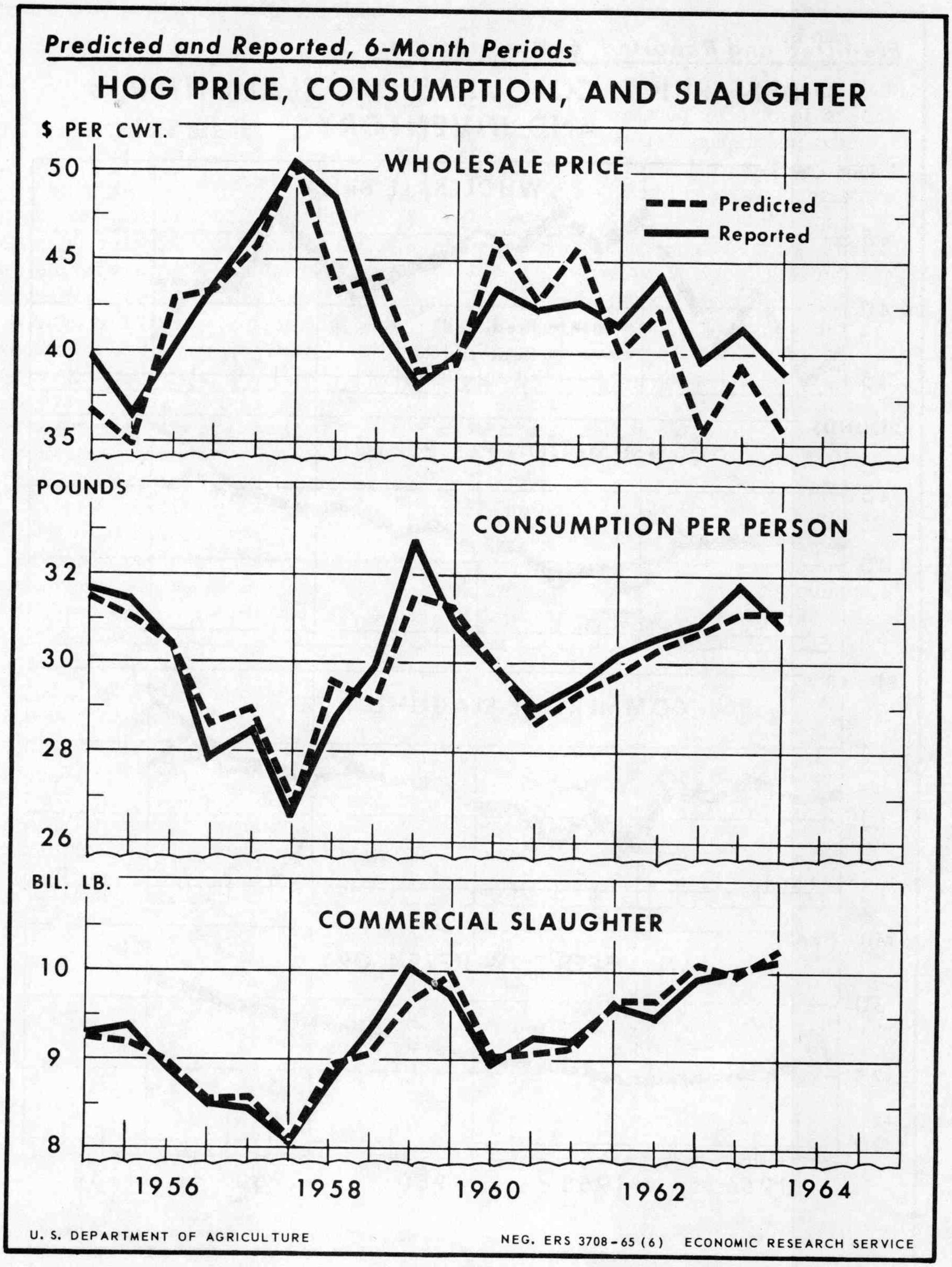
Predicted and Reported, 6-Month Periods
HOG PRICE, CONSUMPTION, AND SLAUGHTER
$ PER CWT.
WHOLESALE PRICE
Predicted
Reported
50
45
40
35
POUNDS
CONSUMPTION PER PERSON
32
30
28
26
BIL. LB.
COMMERCIAL SLAUGHTER
10
9
8
1956
1958
1960
1962
1964
U. S. DEPARTMENT OF AGRICULTURE
NEG. ERS 3708-65 (6)
ECONOMIC RESEARCH SERVICE

Figure 4

economic circumstances. Thus, years of economic activity can be simulated on the computer in a few minutes. Alternatively, the effects of new values of exogenous variables such as a different rate of income or population growth may be evaluated under the existing structure.

Several uses of the model for projection purposes are also possible. First, the existing model which represents the historical period may be simulated on the computer for as many years into the future as desired, provided independent projections of exogenous variables are available. At the beginning of the projection run, prices and output for the most recent year available are read into the computer as initial conditions. All of the assumed changes in the economic structure mentioned in the preceding paragraph also could be simulated as alternative projections. One of the desirable features of the recursive model is that the time paths of all prices, slaughter, year-end inventories, and imports are generated. In many cases, the evaluation of the projected time paths of these variables may be more important than their projected value for the end of the period. To be used in prediction, however, the model should contain a means of forming expectations of future prices and outputs and then use these expectations (as producers do) in adjusting current output and in making production plans.

Two areas of work are currently underway in further development of the model. One is conversion of the model from a semiannual to a quarterly basis. The second involves inclusion of regional components.

Appendix: Basic Relationships in the Model

The 30 behavioral relationships are presented in exhibits A and B for readers interested in the actual coefficients, the rules for their modification, and the values of the modified coefficients. The reader is referred to figures 1 and 2 for the causal ordering of the relationships. Standard errors of coefficients of equations estimated by regression techniques are omitted; however, one asterisk (*) denotes a t value significant at the 5 percent probability level while two asterisks (**) denote a t value significant at the 1 percent probability level.

The notation used to identify variables is shown beside each group of relationships. When the same relationship is used to estimate a variable for both halves of the year, the subscript j is used, with j = 1 for the January-June period and j = 2 for the July-December period. Trend terms are used having both annual and semiannual increments. "T" equals 1 in 1949 on an annual increment basis in relationships where the dependent variable is denoted as X_t; however, "T" equals 1 in the first half of 1949 on a semiannual increment basis in relationships where the dependent variable is denoted as X_{jt}.

EXHIBIT A

I. Inventory Relationships

$H21_t = -11,990.0 + 1.077^{**}\ H23_{t-1} + 166.2^{**}\ P2FC_{t-1}$ $\quad R^2 = 0.97$
If $P2FC_{t-1} < 22.0$ or > 35.0, reduce coeff. to 155.0

$H22_t = -3,418.0 + 0.3361^{**}\ H21_{t-1} + 142.4^{*}\ P2L_{t-1}$ $\quad R^2 = 0.90$
If $P2L_{t-1} < 23.0$ or > 28.5 reduce coeff. to 135.0

$H23_t = H23_{t-1} + H22_{t-1} - 3,197.0 + 1.036^{**}\ FIBCN_{t-1} - 1,103.0^{**}\ W$ $\quad R^2 = 0.99$
R^2 for portion fitted as residual. W=1 for 1959 & later years.

$H24_t = -4,017.0 + 0.7061^{**}\ H21_{t-1} + 81.26^{**}\ P2FC_{t-1}$ $\quad R^2 = 0.99$
If $P2FC_{t-1} < 22.0$ reduce coeff. to 70.0; if $P2FC_{t-1} > 35.0$, increase coeff. to 95.0

$H26_t = -6,132.0 + 0.5735^{**}\ H21_{t-1} + 70.96^{**}\ P2FC_{t-1}$ $\quad R^2 = 0.96$
If $P2FC_{t-1} < 24.5$, reduce coeff. to 65.0; if $P2FC_{t-1} > 35.0$ reduce coeff. to 60.0

$\Delta H32_t = -3,360.0 + 252.9^{**}\ (P3L/P6)_{t-1} - 2.68^{**}\ \Delta HF6_t$ $\quad R^2 = 0.88$
If $(P3L/P6)_{t-1} < 11.0$ or > 20.0, reduce coeff. to 240.0

$SF31_t = -165.0 + 0.9206^{**}\ H32_t$ $\quad R^2 = 0.97$

$SF32_t = -3,200.0 + 0.7329^{**}\ SF31_t + 82.0\ (P3L/P6)_t + 210.4\ T$ $\quad R^2 = 0.88$
T = 1 in 53, annual basis; if $(P31L/P21L)_t < 0.50$ change intercept to - 3,000;
if $(P31L/P21L) > 0.75$, change intercept to - 3,400

II. Slaughter, Meat Production, and Average Weight Relationships

$CS31_t = 284.0 + 1.334^{**}\ SF32_{t-1} - 57.57^{*}\ P32L_{t-1} + 1198.0^{*}\ P62_{t-1} + 72.90^{*}\ T$ $\quad R^2 = 0.96$

$CS32_t = 99.0 + 0.7764^{**}\ SF31_{t-1} - 16.10\ P31L_t + 861.4^{*}\ P61_t + 238.6^{**}\ T$ $\quad R^2 = 0.94$

$CS21_t = 0.1125\ H13_t + 0.0663\ H23_t + 0.55\ H24_t - 3,460.0 + 295.9^{**}\ P2LFS_{t-2} - 0.8592\ \Delta H13_{t+1} - 1.51^{**}\ NW21_t$ $\quad R^2 = 0.89^a$

$CS22_t = 0.1125\ H13_t + 0.077\ H23_t + 0.50\ H24_t - 2,645.0 + 236.5^{**}\ P2LFS_{t-2} - 1.005^{**}\ \Delta H13_{t+1} - 0.84^{**}\ NW22_t$ $\quad R^2 = 0.97^a$

$BP2_{jt} = 103.0 + 0.501^{**}\ CS2_{jt} + 31.5^{**}\ T$ $\quad R^2 = 0.98$

$PP3_{jt} = 256.0 + 0.5258^{**}\ CS3_{jt} + 9.576^{**}\ T$ $\quad R^2 = 0.99$

$FIC21_t = 2,257 - 0.3084^{*}\ \Delta^2\ H23_t + 21.84^{*}\ \Delta^2\ P21FC_t$ $\quad R^2 = 0.80$

$FIC22_t = 4,874 + 0.905^{**}\ FIC21_t - 53.10\ RANGE_t$ $\quad R^2 = 0.79$

$FIBCN_t = 0.08410\ H23_t + 4,316.0 - 125.9^{**}\ P2FC_t - 210.6^{**}\ T$ $\quad R^2 = 0.98^a$

$AWFS2_{jt} = 928.0 + 5.296^{**} \left(\frac{P2_jL}{P6_j}\right)_{t-1} + 3.047^{**}\ T + 0.01652^{*}\ H24_t$ $\quad R^2 = 0.90$

[a] Refers to percentage of variation explained in that portion of the relationship estimated by least squares.

Description of Variables

January 1 Inventory (1,000 hd.)

H13 = Dairy cows.
H21 = Beef calves less than 1 yr. old.
H22 = Beef heifers 1-2 yr. old.
H23 = Beef cows.
H24 = Steers and bulls over 1 yr. old.
H26 = Cattle on feed, 26 States.
H32 = Sows and gilts over 6 mo. old.
HF6 = Stocks of corn on farms (1,000 bu.)

- -

Sows Farrowing (1,000 hd.)

SF31 = December-May.
SF32 = June-November.

- -

Slaughter (mil. lb., live wt.)

$CS3_j$ = Hogs, commercial.
$CS2_j$ = Cattle, commercial.
$FIC2_j$ = Cows, federally inspected.
FIBCN = Cows, federally inspected. (1,000 hd., annual basis)

- -

Meat Production (mil. lb., carcass wt.)

$BP2_j$ = Beef, commercial.
$PP3_j$ = Pork, commercial.

Prices, (annual average, dol./cwt.)

P2L = Choice steers, Chicago.
P3L = No. 1-3, 200-220 lb. hogs, Chicago.
P2LFS = July-June average, Choice steers, Chicago.
P2FC = G&C, 300-500 lb. feeder calves, Kansas City.
P6 = No. 3 corn, Chicago (per bu.)
(Pi_j notation indicates semiannual average)

- -

$AWFS2_j$ = Av. steer wt., federally inspected.
$NW21 = ((0.50\ H24_t) / (0.1125\ H13_t + 0.063\ H23))\ AWFS21$
$NW22 = ((0.55\ H24_t) / (0.1125\ H13_t + 0.077\ H23_t))\ AWFS22$
RANGE = Oct. 1 range conditions, 17 States.

EXHIBIT B

III. Foreign Trade and Ending Stocks Relationships

$FTR2_{jt} = -142.0 + 8.66^{*}\ PWB2_{jt-1} - 0.988^{**}\ FIC2_{jt-1} + 16.45^{**}\ T + 250.0\ W$ $\quad R^2 = 0.74$

W = 1 for 1959 and later years. If $PWB22_{t-1} < 35.0$, reduce coeff. to 6.0;
If $PWB21_{t-1} < 38.0$, reduce coeff. to 6.0

$FTR3_{jt} = -156.0 + 2.321^{*}\ PWP3_{jt-1} + 3.93^{*}\ T$ $\quad R^2 = 0.68$

$ES31_t = -134.0 + 0.477^{*}\ ES31_{t-1} + 0.1152^{**}\ \Delta PP31_{t-1}$ $\quad R^2 = 0.68$

$ES32_t = 68.0 + 0.6245^{**}\ ES32_{t-1} + 0.1020\ \Delta PP32_{t-1}$ $\quad R^2 = 0.80$

$\Delta ES2_{jt} = 0.04829^{**}\ \Delta^2\ CS2_{jt}$ $\quad R^2 = 0.80$

If est. $ES2_{jt} < 100.0$, $ES2_{jt} = 100.0$

IV. Demand and Margins Relationships

$PWB2_{jt} = 123.57 - 2.0467^{**}\ QPH2_{jt} - 0.5389^{*}\ QPH3_{jt} - 1.194^{**}\ RM2_{jt}$ $\quad R^2 = 0.99$

$- 0.9591^{*}\ RM3_{jt} + 0.0101\ YPH_{jt} + 0.9772^{**}\ T - 2.84^{**}\ W$

If $(FIC2_j / CS2_j) > 0.25$ add 1.00; if $(FIC2_j / CS2_j) < 0.16$, subtract 1.00; W = 1 for j = 1.

$PWP3_{jt} = 49.44 - 3.1218^{**}\ QPH3_{jt} - 0.55\ RM3_{jt} + 0.4073^{**}\ PWB2_{jt}$ $\quad R^2 = 0.92$

$+ 0.0612^{**}\ YPH_{jt} - 1.7515\ T - 4.30^{**}\ W$

W = 1 for j = 1.

Both demand equations were fitted quantity dependent. R^2 and t tests based on original equations.

$P2_jL_t = -1.50 + 0.6397^{**}\ PWB2_{jt} - 0.0145^{**}\ OM_{jt}$ $\quad R^2 = 0.99$

$P3_jL_t = -2.97 + 0.5749^{**}\ PWP3_{jt} - 0.0284^{**}\ OM_{jt}$ $\quad R^2 = 0.95$

$P21FC_t = -19.55 + 1.10\ P22FC_{t-1} - 0.004\ \Delta H26_t + 0.25\ AMRGE$

$P22FC_t = -33.50 + 1.25\ P22L_t + 0.20\ RANGE_t + 0.50\ PM_t$

Use this relation when $\Delta P22L_t \geq -1.25$
and $PM_t = 1.615\ P21L_t - 0.615\ P21FC_{t-1}$

$P22FC_t = -37.00 + 1.5\ P22L_t + 0.2\ RANGE + 0.4\ PM_t$

Use this relation when $\Delta P22L_t < -1.25$
and $PM_t = 1.615\ P22L_t - 0.615\ P22FC_{t-1}$

Description of Variables

Million lb., carcass wt.

$FTR2_j$ = Beef, imports minus exports.
$FTR3_j$ = Pork, imports minus exports.
$ES2_j$ = Ending stocks, beef.
ES31 = June 30 stocks, pork.
ES32 = Dec. 31 stocks, pork.
PP31 = Pork, prod., Jan.-June.
PP32 = Pork prod., July-Dec.

Million lb., live wt.

$FIC2_j$ = Fed. inspected cow slaughter.
$CS2_j$ = Commercial cattle slaughter.

Per Capita Consumption, lb.

$QPH2_j$ = Beef, carcass wt.
$QPH3_j$ = Pork, carcass wt.

Prices, dol./cwt., live wt.

$P2_jL$ = Choice steers, Chicago.
$P3_jL$ = No. 1-3 hogs, 200-220 lb., Chicago.
P21FC = G&C, 300-500 lb. calves, Kansas City, Jan.-July.
P22FC = G&C, 300-500 lb. calves, Kansas City, July-Dec.

Prices and values, dol./cwt., carcass wt.

$PWB2_j$ = Wholesale, Choice beef, Chicago.
$PWB3_j$ = Wholesale value 100 lb. pork, Chicago.
$RM2_j$ = Wholesale-retail spread, Choice beef, Chicago.
$RM3_j$ = Wholesale-retail spread, pork, Chicago.

H26 = Cattle on feed, Jan. 1 (1,000 hd.)
YPH_j = Per capita disposable income.
OM_j = Output/man, meatpacking, lb./hr.
RANGE = Oct. 1 range conditions, 17 States.
AMRGE = Apr.-May av., range conditions, 17 States.