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Economic Projections Using a Behavioral Model

By Richard J. Crom

A recently published model of the livestock-meat economy is used to illustrate modifications that permit us to obtain a reasonable and consistent set of projected values to 1980. Economic theory and an understanding of the industry were used to introduce a set of assumptions about institutional change and human behavior. The projected values serve as a basis for comparison with alternative projections resulting from changes made in the model to represent different policies or management decisions.

Key words: Beef; methodology; pork; projection; simulation models.

In recent years, economists have developed quantitative models of entire industries as more sophisticated computer software became available. The computer's ability to store and retrieve data generated from successive sequential solutions of relationships in the model provides means for projecting the model into the future. The projection can be made for a considerable length of time, since the model generates values of its own endogenous input variables, if projected values of exogenous variables are supplied.

Various methods of determining more precise and more reliable measures of behavioral and technical coefficients have been developed with the goal of achieving more reliable projections. But projections from all models necessarily based on historical relationships are fallible due to their common underlying assumptions and their mathematical derivation. The error term associated with functional derivations, usually regarded as a result of random forces in the historical period, may have profound effects on projections when the estimated value it affects is used as sequential input. Once an error is initiated, a cumulative error "buildup" is introduced

into the projection period. Furthermore, the constant term of the function will eventually be of insufficient magnitude to maintain proper relationships between the estimated and the explanatory variables. As a result, estimates will be too large (or too small).

While the former problem is serious, its consequences are not as unresolvable as other assumptions inherent in the model. Models which quantify the economic structure of a sector of the economy describe that economic structure which evolves from the institutional structure and human behavior of that period. Thus, any projection of such a model implies that the institutional structure and human behavior which existed in the past will be invariant in the future. Such an assumption is naive!

Projection of a model as developed from historical data does maintain scientific objectivity and is a useful first step. However, the probability of obtaining unrealistic values after several time periods is high, even if modifications were included in the original model to negate error buildup. Continued use of behavioral or technical relationships containing trend terms may soon yield very large or very small values of the variables they predict. In addition, unique situations which bring about expected changes in behavior may arise which were not encountered during the historical period. Since we have no specific observations from the past to indicate appropriate changes in the structure of the model, we are left with the choice either of accepting the projection as generated by the model or of modifying the model to yield projections in line with reasonable expectations. The latter projections may well be more useful as decision criteria if all assumptions about structural changes are clearly identified. While the latter approach involves informed judgment, the former may leave the economist with a set of projections no one believes.

Editor's Note: A technical bulletin published by USDA in September 1970 contained a simulation of the U.S. beef and pork economy for 1955-70. Recently, the model was used to evaluate the effect of several beef import levels on the domestic livestock industry (U.S. Dept. Agr., unpublished manuscript). This exercise required modification of the original model as published, to obtain the set of projected values used as a basis for comparison of the alternative import levels. The accuracy of the model for short-term prediction has not been tested. The present article shows the changes that were made in assumptions, the reasons for the changes, and the improvement that was obtained in results. This article is intended to stimulate thinking among researchers about some basic methodological issues that economic projections involve.

Modification of a formal economic model to obtain a set of projected values which are consistent and reasonable introduces an element of art. The economist's goal is to obtain a consistent and viable set of projected values with a minimum of structural change. It involves selection and implementation of a further set of assumptions about economic behavior and institutional change which constrain the model in order to produce an acceptable set of projected values. It involves the use of economic theory, an understanding of the industry, and a good bit of common sense. The projected values that result from an initial experiment on the model serve as a set of base values for comparison with sets of projected values obtained from further experimentation (simulation).

While developing a recursive model of the beef and pork sectors,¹ an attempt was made to take account specifically of error terms in functional relations usually regarded as random and to introduce modification in behavioral reactions to unusual economic situations in a very elementary sense. These modifications in the model, referred to as "operating rules," are discussed fully in the publication cited. They were made while developing the model over the historical period in anticipation of achieving a more precise and realistic set of variables in the projection period. Operating rules were of three general types. One type involved introducing a change into the relationship when one of the explanatory variables exceeded a certain value or fell below a value usually outside of the range of the data. Another type of rule included a change in a relationship when certain variables not in the function obtained extreme values. A third type of operating rule involved a change in a behavioral relation when a variable changed by an unusually large amount from its previous value. Examples of these operating rules are presented in the order described above.

In the relationship estimating commercial hog slaughter, hog slaughter was reduced 54 million pounds for each \$1 increase in hog price the previous quarter. An increase (decrease) in the lag price induces producers to hold (sell) more breeding stock and thereby reduce (increase) their marketings of slaughter hogs. Observation of historical data indicated that less breeding stock than usual was marketed when the lag price fell below \$13 per hundredweight. This is plausible since it is reasonable for producers to expect more favorable prices to follow extremely low prices. Thus an operating rule was introduced to reduce the coefficient of lag hog price from (-54) to (-30) when the lag price fell below \$13.

¹R. J. Crom, *A Dynamic Price-Output Model of the Beef and Pork Sectors*, U.S. Dept. Agr., Tech. Bul. 1426, Sept. 1970.

Hog prices usually did not affect the number of cattle placed on feed. The latter are a function of the supply of feeders available (as indicated by the January 1 inventory) and the beef-corn ratio. However, extreme values of hog prices are likely to cause some "switchover" between cattle and hog feeding. In the second quarter, the estimate of placements of cattle on feed was reduced 4 percent when the second-quarter hog price exceeded \$23.50 per hundredweight. This operating rule was effective in 1966 and 1969 when high hog prices probably induced some farmer-feeders to increase hog production at the expense of cattle feeding.

Finally, a sharp increase in the value of a variable used in a behavioral relation may have more impact than an orderly change in the value of the variable over time. Sows farrowing usually were increased (decreased) for each \$1 rise (fall) in the price of hogs two quarters earlier. However, observation of the data indicated that a substantial drop (\$7) from the year-earlier price initiated an additional 14 percent cut in sows farrowing.

During the development of the model, a total of 126 operating rules were introduced over the 60 calendar quarters (1955-70) to obtain a more precise reproduction of the variables. They were employed 221 times to modify 1,620 values of variables simulated by the system. Behavioral relationships were used to simulate 1,125 values of variables during this period; identities were used to simulate 795 values of variables. Each behavioral relation which simulated quarterly values was used 60 times; relationships simulating annual values were used 15 times. The greatest combination of operating rules and explanatory variables used in any one behavioral relationship was 26 for the quarterly relationships and eight for the annual relationships.

Use of these modifications in initial situations improved the validation of the model substantially. In the case of the January 1 beef cow inventory, the prime determinant of growth in the cattle sector, the initial operation of the model was "on track" compared to the historical data for 2 years; but this was followed by four overestimates, two underestimates, and another expansion phase (see fig. 1).² The validation run reproduced the beef cow inventory with minor errors. The distribution of errors in per capita supplies and prices is shown for the initial run and validation run for the comparable 52-quarter period 1955-68 in tables 1 and 2. In general, the recursive system could tolerate an error in the estimation of per capita supply of about 0.5 pound or an error of \$1.50 to \$2 in the price of live steers.

²The initial run was made to June 30, 1968, while the validation run continued to June 30, 1970.

JANUARY 1 BEEF COW INVENTORY

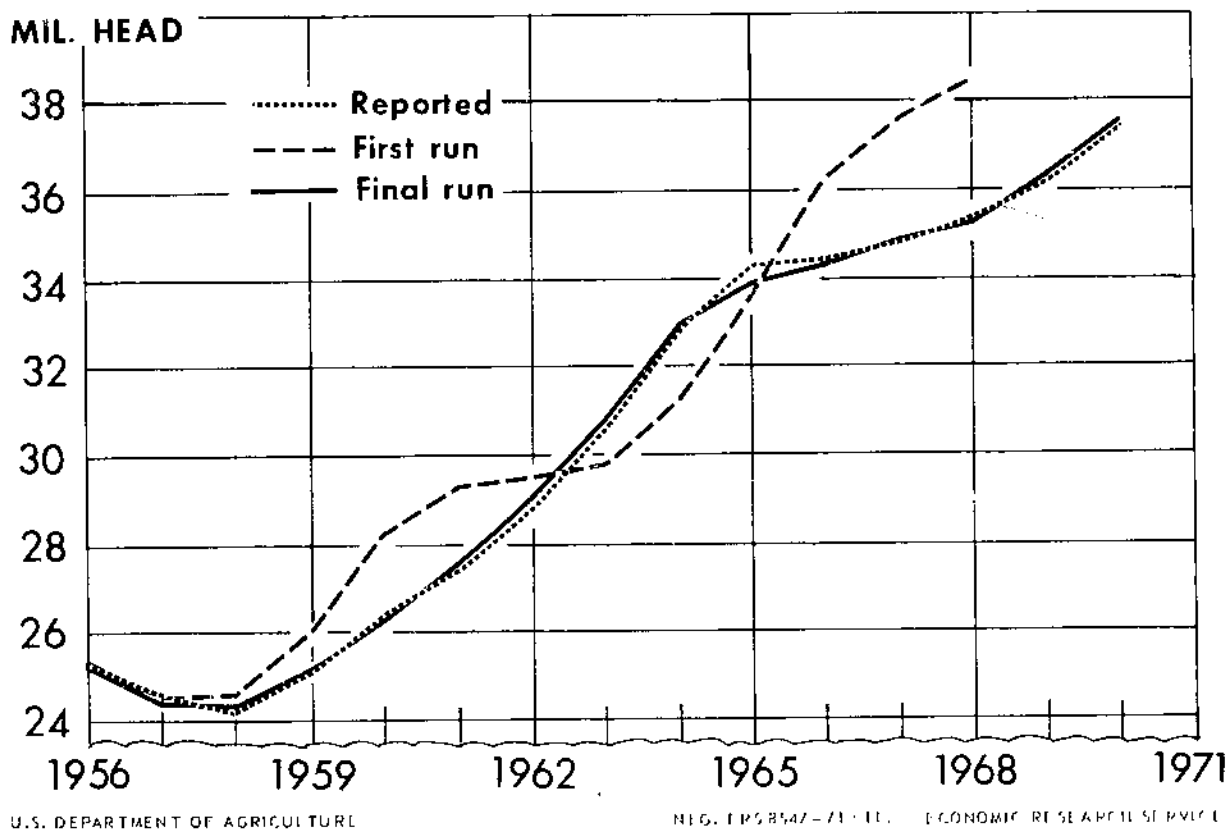


Figure 1

Table 1.—Distribution of per capita supply errors in validation period, July 1955 to June 1968

Item	Range in errors (lbs.)							
	0.0	0.1-0.4	0.5-0.8	0.9-1.2	1.3-1.6	1.7-2.0	2.1-3.0	3.1-7.0
Per capita fed beef consumption:								
First run	1	17	12	16	3	3	0	0
Validation run . . .	9	40	3	0	0	0	0	0
Per capita nonfed beef supply:								
First run	3	17	14	7	5	1	2	3
Validation run . . .	9	44	9	0	0	0	0	0
Per capita pork supply:								
First run	1	15	6	9	9	5	7	0
Validation run . . .	8	36	7	1	0	0	0	0

Table 2.—Distribution of pricing errors in validation period, July 1955 to June 1968

Item	Range in errors (\$/cwt.)					
	0-.50	.51-1.00	1.01-2.00	2.01-3.00	3.01-4.00	4.01-5.00
Choice Steer Price:						
First run	12	10	12	5	7	6
Validation run	31	14	7	0	0	0
Hog price:						
First run	3	13	10	9	11	6
Validation run	30	15	7	0	0	0

When making a prognosis of economic activity, projection with a dynamic behavioral model provides useful information, since it portrays the temporal interactions among the many variables of the industry. Hypotheses about the results of a change in the structure portrayed by the model, in the exogenous variables, or in the initial conditions can be tested by initiating these changes, simulating their results, and comparing these results with the base projection of the model (i.e., a projection without the hypothesized change).

Recently, the quarterly price-output model of the beef and pork sectors was projected to 1980 based on data and conditions known for July 1, 1970. The modifying assumptions introduced into this model to obtain the base projection are used as examples of further modification of a model to obtain a more useful set of projected values.³

Initial projection to 1980 of the model as validated through July 1, 1970, yielded a set of quantity values indicating a growth rate considerably greater than would be expected by knowledgeable people in the industry. Prices remained correspondingly low. The broken lines in figure 2 indicate initial values simulated by the model for three selected variables. (Recall values of 26 variables are simulated each quarter with an additional four simulated as of each January 1.) Careful examination of the model indicated the need for replacing four basic functions and their 28 associated operating rules. Critical values were adjusted upward in another 18 operating rules to keep up with the general increase in price levels.

In two cases, the functional estimates were replaced with constant values. The average weight of nonfed cattle at marketing was considered a function of time and a seasonal factor in the original model. The average

weights of nonfed cattle were held constant during the projection period at their 1970 levels, since continued operation of the trend term would have yielded nonfed weights heavier than those of fed cattle.

Beef exports, a relatively minor item, were held constant during the projection period near the modal values of the late 1960's. Thus, they became an exogenous variable since exports are now essentially used to satisfy demands of U.S. citizens abroad. The original function did not perform satisfactorily and the relative unimportance of the variable did not warrant development of a new relationship.

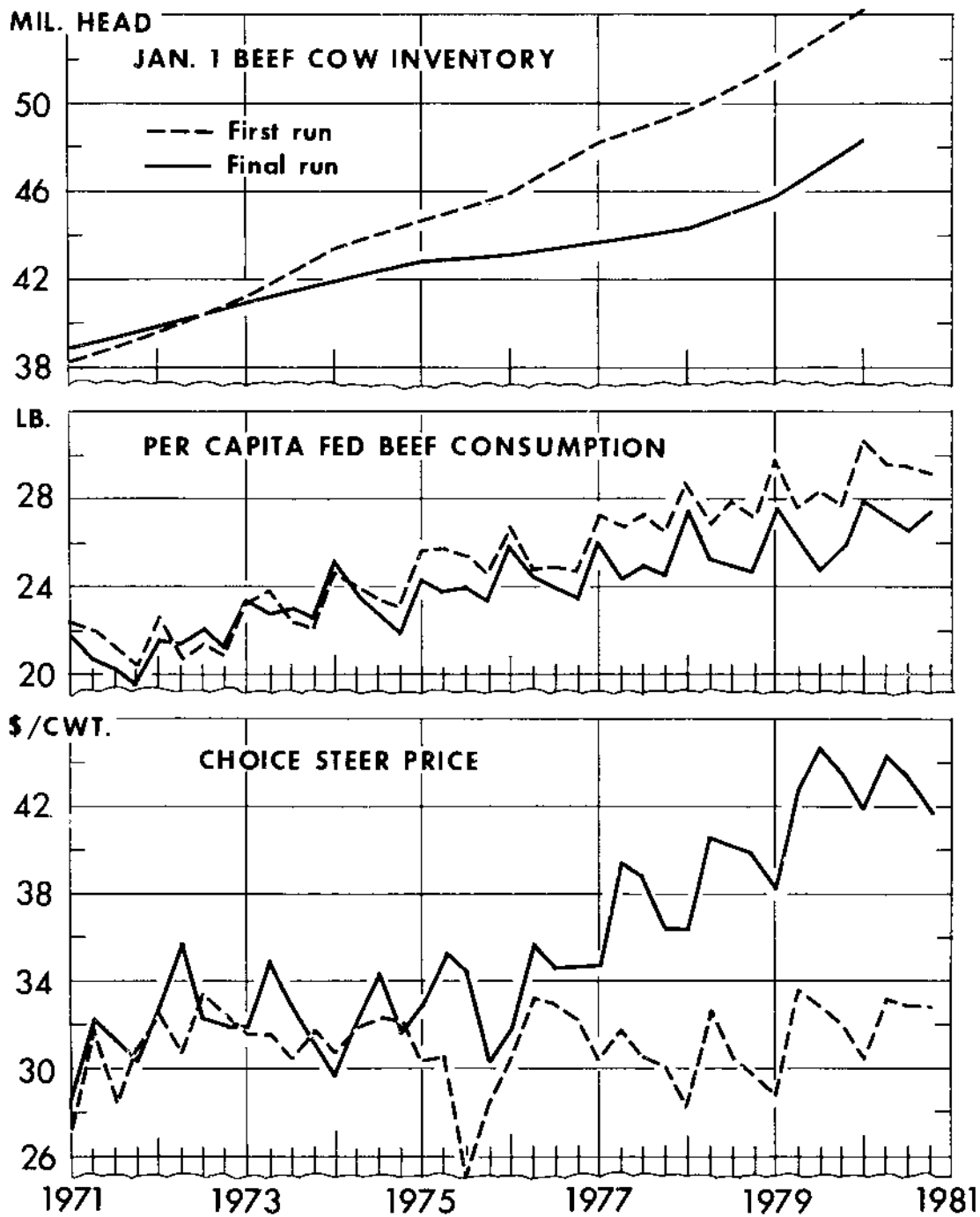
One important type of change in the model for the projection period was the modification or reestimation of behavioral relationships. Since many of the operating rules developed over the historical period were specifically associated with a particular function, introduction of a replacement function necessitated removal of some operating rules. And the need for new operating rules to further modify the replacement functions became apparent as the projection progressed.

The beef import function was reestimated from 1963-70 data using the same explanatory variables. The coefficients of this new function were not biased by the low values of observations in the 1950's and early 1960's. Thus, operating rules initiated during the latter part of the validation period in the original model were deleted. They were replaced with operating rules which held the resulting annual average beef imports between 6.5 and 7.5 percent of domestic beef production after allowing for seasonal variation. These constraints approximated the current levels of imports under existing quotas. While the quota limits imports, exporting countries hold their shipments near this maximum. Unless the existing regulations are repealed, it appears reasonable to expect similar behavior throughout the projection period as long as the United States maintains a favorable market for foreign suppliers.

The revised function for estimating beef imports based on 1963-70 data is:

³The model was programmed to start as of July 1, 1955, and no other date. Therefore, to commence operating the model as of any other July 1, several technical programming changes were necessary. Specific details of these technical changes will be furnished interested readers upon request along with all other modifications deemed necessary for the projection period.

PROJECTIONS OF SELECTED VARIABLES



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Figure 2

$$Y_{jt} = 1450.76 + 4.194 X_1 - 123.54 X_2 + 83.5 W_1 \\
\begin{matrix} (2.92) & (2.92) & (28.8) & (33.1) \\ -40.5 W_2 + 45.8 W_3 \\ (26.6) & (40.4) \end{matrix}$$

$$R_2 = 0.88 \quad d = 1.99$$

Y_{jt} = quarterly imports of beef in millions of pounds, carcass weight,

$$X_1 = (PR_{j-1,t} + PR_{j,2,t})/2.0,$$

$$X_2 = (PN_{j-1,t} + PN_{j,2,t})/2.0,$$

W_{jt} = quarterly 0-1 variables,

PR_{jt} = wholesale price of cow beef at New York,

PN_{jt} = per capita supply of nonfed beef.

Thus, beef imports increase when lagged domestic wholesale prices increase, decrease when lagged per capita supplies increase, and vary seasonally. These explanatory variables are the same variables used in the earlier model. However, each quarter's estimate is constrained by two tests:

$$\text{if } (\hat{Y}_{jt}) \geq U, \hat{Y}_{jt} \equiv U,$$

$$\text{if } (\hat{Y}_{jt}) \leq L, \hat{Y}_{jt} \equiv L,$$

$$\text{if } (\hat{Y}_{jt}) \leq \frac{U}{L}, \hat{Y}_{jt} \equiv \hat{Y}_{jt}.$$

Y_{jt} = quarterly estimate of beef imports,

$U = (B_j) \times (\text{all domestic beef production}) = \text{upper limit,}$

$L = (C_j) \times (\text{all domestic beef production}) = \text{lower limit.}$

The quarterly values of B_j and C_j are:⁴

Quarter	B_j	C_j
First	0.063	0.050
Second069	.055
Third099	.080
Fourth069	.055

⁴These coefficients of seasonal adjustment were derived through multiplication of the annual coefficient by the historical seasonal index. For example, $B_1 = (0.075) \times (0.84) = 0.063$.

They allow usual seasonal variation around the 7.5 percent annual maximum or the 6.5 percent annual minimum limits. The functional estimate is used if it falls within these seasonally adjusted limits.

The demand equations in the original model used to obtain wholesale prices for Choice grade carcass beef, utility cow beef, and wholesale pork products contained a per capita personal disposal income variable (fitted in deviation from trend form) and a trend term. The trend term represented long-run shifts in consumer tastes and other secular factors including the trend in personal income. This statistical separation of the two variables overcame the multicollinearity problem of the historical period. But it introduces a fixed relationship between income and trend in the future. The projected income series showed a substantial sharper increase in income from 1964 through 1980 than in the base period. This new trend was removed from the income variable, and the coefficients in the three demand equations were adjusted correspondingly.

In the model developed from historical data, the estimates for the wholesale price of Choice 600-700-pound steer carcasses was:

$$PW_{jt} = A + BZ_{jt} + 0.02253 Y_{jt} + 0.1106 T$$

where

PW = wholesale price of Choice beef carcasses,

A = constant (= 71.36 in 3d quarter).

Z = quantity variables,

B = coefficients of quantity variables,

Y = per capita disposable income,

T = time.

The trend in income, which has been removed for 1955-66, was

$$Y_{jt} = 1613.0 + 17.94 T.$$

The upward trend in per capita disposable income changed in 1964. The trend in income, an exogenous variable, for 1964-80 is

$$Y_{jt} = 300 + 49.46 T.$$

This new trend was incorporated into the demand equation. Accordingly, the estimator for the wholesale price of Choice grade beef now becomes

$$PW_{jt} = 71.36 + BZ_{jt} + 0.02253 [Y - (300 + 49.46 T)] + 0.1106 T.$$

This reduces to

$$PW_{jt} = 64.6 + BZ_{jt} + 0.02253 Y_{jt} - 1.0037 T.$$

Since the trend component of income is much greater, both the constant of the function and the trend coefficient are lowered to reduce the effects of the new trend in income and thereby maintain the same relationship between the income and trend variables that existed in 1955-66.

Initial projections of the model indicated the need for reduction in the slope of the own price-quantity coefficient, as the sum of per capita supplies of all beef and pork exceeded 45.0 pounds per quarter (seasonally adjusted). Accordingly, the own price-quantity coefficients were reduced 10 percent when the sum of per capita supplies exceeded the turning point indicated by the initial projections. These operating rules introduce a "kink" into the own price-quantity linear demand plane, thereby serving as an approximation of the curvilinear relation suggested by inspection of initial projected values. The adjustment in the original slope coefficient in the demand equation for wholesale pork serves as an example. The form of the original wholesale price estimator was:

$$PW_{jt} = A - 3.3264 PCPS_{jt} + bZ_{jt}$$

where

PW_{jt} = wholesale price of pork,

$PCPS$ = per capita pork supply,

Z_{jt} = all other variables.

In the projection model, the following addition was made in the second quarter:

$$\text{If } (PCFBC_{jt} + PNFBS_{jt} + PCPS_{jt}) > 43.0$$

$$PW_{jt} = A - 3.0 PCPS_{jt} + bZ_{jt}$$

when $PCFBC + PNFBS$ = total per capita beef supply.

The values of coefficients specifying producer response to the lagged feeder cattle prices in the relationships specifying January 1 inventories of beef calves and beef heifers, and annual commercial slaughter of beef cows, were reduced when the feeder price exceeded \$36 per hundredweight. This level of feeder cattle prices was

not attained in the historical period, therefore this modification was not needed when developing and validating the model. As initial projections indicated a rather rapid increase in beef cow inventories when average feeder prices exceeded \$36, such a limit appeared necessary. This modification is similar to the demand adjustment; it involved reduction of supply response at extreme values of price variables. For example, the original supply coefficient associated with feeder price (+121.2) in the estimation of January 1 beef calf inventories was reduced to (+111.2) when the feeder price exceeded \$36.

A final type of adjustment was necessary because the model was developed using current-dollar prices. While use of constant dollars has substantial merit, no single index is appropriate as a deflator of livestock and meat prices. As the projection of the model progressed, critical values of variables signaling use of operating rules changed with the inflation built into this current-dollar system. For example, the original model contained an operating rule which specified an increase in placements of cattle on feed in the summer quarter if the Choice steer price exceeded \$30 in both the second and third quarters. While attainment of this value for two consecutive quarters was rather unusual in 1955-70, it became a more usual level of price during the projection period. Initial projections of the model indicated that an increase in this critical test value to \$33 would correct for this change in the price level. Seventeen similar increases in critical values were introduced for the projection period.

Modification of the model resulted in a final set of projected values (see solid lines in fig. 2) where the per capita supply of beef was 20.6 pounds below the initial estimate, and the January 1 beef cow inventory was 6 million head below the initial estimate. Obviously, prices were substantially higher in the latter years. However, Choice steer prices above \$40 in current dollars cannot be deemed unlikely by 1980.

These final values achieved through modification of the behavioral model portray a reasonable rate of growth in the domestic livestock industry over the next decade. They are now useful as a basis of comparison for values of the same variables which portray simulated changes in the structure of the industry, changes in policy, or changes in exogenous influence.

⁵After obtaining a reasonable set of projected values, the model was used to simulate prices and production of cattle and hogs under five alternative policies for regulating beef imports coming into the United States (A. A. Duymovic, R. J. Cron, and J. D. Sullivan, Effects of Alternative Beef Import Policies on the Beef and Pork Sectors, U.S. Dept. Agr., unpublished manuscript).