The Food and Agricultural Policy Simulator

By Larry E. Salathe, J. Michael Price, and Kenneth E. Gadson*

Abstract

This article describes the structure and dynamic properties of the Food and Agricultural Policy Simulator (FAPSIM), an annual econometric model of the U S agricultural sector FAPSIM estimates a simultaneous price-quantity equilibrium solution for a set of individual commodity models developed for beef, pork, dairy, chickens, eggs, turkeys, corn, oats, barley, grain sorghum, wheat, soybeans, and cotton FAPSIM also endogenously determines farm production expenses, cash receipts, net farm income, Government deficiency and reserve storage payments, consumer price indexes for food products, and farmer participation in Government commodity programs The model estimates that each 100-million-bushel increase in corn exports increases the price of corn by $0 15 per bushel

Keywords

Agriculture, crops, econometric model, feed grains, livestock, policy analysis

The agricultural sector model described in this article is the outgrowth of research by numerous individuals over three decades [1] In the fifties and sixties, researchers in the Economic Research Service (ERS) began developing econometric models for selected commodities (*22*) [2] Such models were generally small (not exceeding 10 equations) and recursive, reflecting the lack of computational capability It was not until the midsixties that various researchers in ERS urged that resources be devoted to the development of a comprehensive model of the U S agricultural sector The motivation for development of such a model was twofold First, the model would enhance and support the Agency's intermediate-term economic intelligence and forecasting ability Second, the model would provide a means for evaluating and quantifying the impacts of alternative legislative proposals and policies on the agricultural sector

The seventies began with James Matthews as head of the Price Research and Methods Section, ERS Under his leadership, work began on a model that would reflect major components of the total U S agricultural industry Model development was to proceed in two steps First, models would be developed for individual commodities or commodity groups Once a model was operational, it would be linked to other commodity models via common variables

The first phase of the process built on previous research both within and outside of ERS This phase began with the development of an econometric model of the soy bean industry (*11*) This model underwent several revisions during the seventies (*2, 15, 16*) Annual econometric models for the major livestock commodities were also developed in the early and midseventies and updated and revised in the late seventies (*6, 7, 8, 12, 23*)

Researchers encountered several problems in linking the various models As a result, the process of linking the various models tended to lag behind that of developing the individual component models One problem researchers encountered in linking the various models was their difficulty in maintaining commonality in variable definitions across models Often, they had to reestimate portions of the various commodity models using common variables prior to including them in the linked system A more serious and difficult problem manifested itself as more models were added to the linked system As the size of the system grew, the dynamic properties of the linked system became unstable even though the individual commodity models displayed stable characterisitcs

Despite these problems, the initial version of the linked crops-livestock model, known as the Cross Commodity Forecasting System (CCFS), was made operational in the late

*Salathe, Price, and Gadson are agricultural economists with the National Economics Division (NED), ERS

[1] The authors thank Charlotte Tucker and Jim Tannehill for providing statistical assistance Numerous other individuals have made invaluable contributions towards the development of FAPSIM The range of contributions precludes identifying all individuals responsible for the model's development Unable to provide an exhaustive list of individuals contributing to the model's development, the authors simply wish to gratefully acknowledge the previous research efforts of such individuals

[2] Italicized numbers in parentheses refer to items in the References listed at the end of this article

seventies The CCFS consisted of approximately 160 equations for predicting prices, supplies, utilization, and ending stocks of beef, pork, milk, chickens, turkeys, eggs, corn, oats, barley, grain sorghum, wheat, soybeans, soybean meal, and soybean oil (*19*) Generally, the model's equations were based on annual data prior to 1977

After ERS's 1979 reorganization, work began on updating the CCFS Under the direction of Larry Salathe, the entire CCFS was updated in 1980-81 The model was also altered to enhance its policy analysis capability in preparation for the 1981 farm bill Respecification of numerous equations in the CCFS became necessary because the inclusion of data for the late seventies altered equation parameter signs Major modifications of the model in preparation for the 1981 farm bill included adding equations to predict cotton prices, supplies, and utilization, production, utilization, and Government purchases of butter, cheese, nonfat dry milk, fluid milk, frozen milk products, and condensed and evaporated milk, crop yields, consumer food price indexes for major food categories, and Government outlays for deficiency and reserve storage payments and dairy price support operations for major farm commodities In addition, a new approach for predicting crop acreage response was incorporated into the model

The new model was named the Food and Agricultural Policy Simulator (FAPSIM) to emphasize its policy analysis capability However, since it became operational in early 1981, the new model has demonstrated an ability to predict future events with reasonable accuracy Currently, it contains 360 endogenous and 265 exogenous variables (*18*) Because of the size of the model, an indepth discussion of its structure is deferred to succeeding articles Our purpose here is to provide an overview and to present a series of validation results In addition, the model is used to analyze the impacts of fluctuations in corn exports and beef imports on the agricultural sector These alternative scenarios provide information on the model's stability and on impact multipliers

Model Overview

Prior to solving for equilibrium commodity prices, production, and utilization (consumption, exports, and stock levels) in any particular year, all the exogenous variables are initialized A major subcategory of exogenous variables includes Government policy variables such as individual crop loan rates, target prices, national program yields and acreages, and diversion and set-aside rates Another major subcategory of exogenous variables includes macroeconomic variables such as population, disposable personal income, food processing wage rates, petroleum prices, and the nonfood consumer price index

The livestock and crop components of the model are solved simultaneously [3] Livestock slaughter, breeding herd size, and replacement numbers are functions of lagged crop year prices For example, the number of heifers added to the breeding herd during calendar year 1980 is specified as a function of the price of corn in crop year 1979 (Oct 1979 Sept 1980) [4] Crop prices are also affected by livestock prices and livestock numbers For example, corn feed demand in crop year 1979 is specified as a function of the number of grain-consuming animal units on farms and an index of livestock prices in calendar year 1980

Farm cash receipts, production expenses, and net farm income are calculated for calendar year 1980 based on crop year prices and production in 1979 and 1980 and on livestock prices and production and the prices of farm inputs in calendar year 1980 The consumer price indexes for food and all items (food and nonfood) are computed by weighting individual consumer price indexes for livestock and crop commodities by their relative importance as determined by the Bureau of Labor Statistics The consumer price index for all items is endogenously computed and is used as a general deflator in all retail demand equations

A set of general functional relationships is provided below for each major subsector These relationships are typical of those contained in the model

Livestock Subsector

Livestock commodities contained in FAPSIM include beef, pork, dairy, chickens, eggs, and turkeys Each individual livestock submodel consists of a set of equations used to estimate production (slaughter), market and retail prices, civilian consumption, and ending stocks In addition to these variables, the dairy submodel also contains a detailed milk processing component

Supply

Considerable detail is provided on the stock of breeding animals, additions to the breeding stock, slaughter of the breeding stock, and the size of the livestock crop The identity given below is used to track changes in the stock of breeding animals

[3] A Gauss-Seidel solution algorithm is used to solve the model's simultaneous system of equations An indepth discussion of this algorithm may be found in (*4*)

[4] A variety of regression formulations were specified to evaluate the appropriateness of alternative linkages between calendar year livestock and marketing (crop) year crop variables A comparison of the regression results indicated that models specifying livestock production as a function of lagged crop prices generally had more reasonable parameter values and lower mean square errors than alternative specifications

$$HERD_t = \lambda HERD_{t-1} + ADD_t - SLTR_t \quad (1)$$

where

$HERD_t$ = the ending stock of breeding animals on farms in year t,

λ = survival rate,

ADD_t = additions to the breeding herd in year t, and

$SLTR_t$ = slaughter of breeding animals in year t

Similar accounting identities are employed to track changes in the number of market animals on farms

Slaughter of breeding animals depends on the profitability of livestock feeding The number of breeding animals slaughtered is positively related to the stock of breeding animals and negatively related to the ratio of livestock price to feed price Additions to the breeding herd are a function of the ratio of livestock price to feed price and of the number of animals eligible to enter the breeding herd

The stock of breeding animals governs the size of the livestock crop The size of the livestock crop in turn determines future livestock slaughter as well as additions to the breeding herd Livestock slaughter depends on the ratio of livestock price to feed costs and on the number of market animals on farms Total production is expressed as a linear function of the number of animals slaughtered Total supply of livestock equals livestock production plus beginning stocks and imports Imports are treated as exogenous

Demand

Civilian consumption of livestock is determined by the identity

$$CDISAP_t = PROD_t - STOCKS_t + STOCKS_{t-1} + IMPORTS_t - MDISAP_t - EXPORTS_t \quad (2)$$

where

$CDISAP_t$ = civilian consumption in year t,

$PROD_t$ = production in year t,

$STOCKS_t$ = ending stocks in year t,

$MDISAP_t$ = military consumption in year t,

$EXPORTS_t$ = exports in year t, and

$IMPORTS_t$ = imports in year t

Military consumption and exports are treated as exogenous Ending stocks are expressed as a function of total supply and the ratio of current to lagged retail price

Price

The retail price index for each livestock commodity is determined by an econometric relationship expressing the real retail price as a function of own per capita consumption, real per capita disposable income, and the retail prices of competing livestock products These price-dependent demand equations are homogenous of degree zero in prices and income Competing livestock prices are included in each demand equation For example, the retail price index for pork is a function of the retail prices of beef and poultry (chicken and turkey)

Farm and market prices of each livestock commodity are estimated by use of the corresponding retail price index and variables reflecting meat processing and marketing costs The wage rate in each livestock processing industry and a general fuel price index are used as proxies for changes in meat processing and marketing costs

Each livestock submodel consists of a simultaneous system of equations and is linked to other livestock models through either production or retail demand Livestock production and prices in turn affect the crops subsector through the demand for feed

Crops Subsector

Crop commodities in FAPSIM include corn, oats, barley, grain sorghum, wheat, soybeans, and cotton Each crop submodel consists of a set of equations used to estimate production, total supply and demand, price, and ending stocks The soybean submodel also contains a soybean processing component

Supply

Total supply of each crop is computed as the sum of production, beginning stocks, and imports Imports are treated as exogenous Production is determined by multiplying acreage harvested by yield per harvested acre Both acreage harvested and yield are determined endogenously Acreage harvested is expressed as a linear function of acreage planted Yields are expressed as a linear function of acreage planted, acreage set aside and diverted, weather, and the ratio of lagged crop price to the price of fertilizer Time is included to reflect changes in technology, such as hybrid seed, drought-resistant seed varieties, and increases in seeding rates

A major shortcoming of previous research has been the failure to develop acreage response equations that explicitly predict the level of farmer participation in Government commodity programs For example, the acreage response equations developed by Houck and Ryan (*10*) contain Government policy variables such as the effective support price and the effective diversion payment rate These equations can be used to predict total acreage response, but they cannot predict the level of Government program participation

The acreage response relationships contained in FAPSIM reflect the relative profitability of either participating or not participating in a Government commodity program [5] The expected net return per acre for a program participant who produces crop i is

$$EPR_i = [(EPP_i * EY_i - VC_i)(1.0 - (SA_i + DIV_i))] + [SR_i * PY_i (1.0 - (SA_i + DIV_i))] ALLOC_i + [DR_i * PN_i * PY_i * DIV_i] \quad (3)$$

where

EPR_i = expected program return per acre for crop i,

EPP_i = the maximum of the loan rate and the expected market price,

EY_i = expected yield per acre,

VC_i = variable cost per acre,

SR_i = expected deficiency payment rate (announced target price minus the maximum of the expected market price and loan rate) per acre,

PY_i = national program yield,

SA_i = proportion of each acre required to be set aside,

DIV_i = proportion of each acre required to be diverted,

DR_i = diversion payment rate per bushel,

$ALLOC_i$ = minimum national program allocation factor, and

PN_i = proportion of acreage eligible for diversion payments

The expected net return per acre for a Government program nonparticipant who produces crop i is given by the identity

$$EMR_i = EMP_i * EY_i - VC_i \quad (4)$$

where

EMR_i = expected market net return per acre for crop i,

EMP_i = expected market price,

VC_i = variable cost per acre, and

EY_i = expected yield per acre

Central to the development of acreage response equations is the construction of variables that reflect farmers' perceptions of expected prices and yields There appear to be at least two alternative price mechanisms that farmers might use as the basis for their price expectations The first is actual market price prior to planting, and the second is the futures market price at harvest Given the problems in predicting futures market prices, especially in an annual simulation framework, a simple average of monthly crop prices 1-5 months prior to planting is assumed to represent farmers' price expectations [6] The expected price prior to planting is endogenously determined as a function of the season-average market price in the previous crop year

Crop yields are also unknown at the time of planting Again, there appear to be at least two alternative yield estimates that farmers may use as the basis for their planting decisions First, farmers can base future yield perceptions on past or experienced yield levels Or, alternatively, they can discount abnormal weather conditions in past years and base their expected yield perceptions on yields realized under "normal weather" conditions In FAPSIM, expected yields are generated by regressing actual yields on time, which assumes farmers base their expected yield perceptions on "normal weather" yield trends

The expected net return variables are used to estimate acreage response by participants and nonparticipants Total acreage in the program (planted plus diverted and set-aside acreage) for crop i is expressed as a behavioral relationship of the form

$$PA_i = f\left[\frac{EPR_i}{CPI}, \frac{EMR_i}{CPI}, \frac{APP_i}{CPI}, NP_i(1.0 - SD_i)\right] \quad (5)$$

[5] The acreage response equations contained in FAPSIM follow from previous research by Robert Bancroft of the University of Vermont, while he was employed by ERS (*1*) The authors wish to thank Dr Bancroft for his valuable assistance

[6] The average of monthly crop prices prior to planting is adjusted to reflect the historical movement in crop prices between planting and harvest

where

PA_i = program acreage for crop i,

APP_i = the average expected net return of competing crops,

NP_i = national program acreage for crop i,

SD_i = set-aside plus diversion rate for crop i, and

CPI = the all item consumer price index lagged one period,

and where EPR_i and EMR_i are defined as above Program acreage is positively related to the deflated, expected program return (EPR_i/CPI) because this variable represents the profitability of planting crop i and of participating in the Government program Total program acreage is negatively related to the real, expected, market net return for crop i (EMR_i/CPI), as it measures the attractiveness of nonparticipation, and is negatively related to the average real return for competing crops (APP_i/CPI) Because the announced national program acreage and diversion requirements place an upper limit on total program acreage, an expansion in national program acreage or a reduction in set-aside and diversion rates will expand total program acreage

Total acreage planted to a particular crop by program participants is a function of total program acreage multiplied by program set-aside and diversion rates Acreage set aside and diverted is calculated endogenously as total program acreage minus acreage planted by participants The participation rate is endogenously computed as acreage planted by participants divided by the sum of acreage planted by participants and nonparticipants

Acreage planted to crop i by nonparticipants is a function of acreage planted to crop i by program participants, acreage set aside and diverted, the real expected net return of competing crops, and the real expected market return for planting crop i Acreage planted in the program, acreage set aside and diverted, and the real, expected, net return of competing crops all represent the desirability of using land for alternative purposes Thus, acreage planted to crop i by nonparticipants is inversely related to each of these variables Acreage planted by nonparticipants is positively related to the real, expected, market net return

Demand

Total demand is the sum of export, seed, food, and feed demand Exports of corn, wheat, soybeans, soybean meal, soybean oil, grain sorghum, and cotton are endogenously determined Exports are generally expressed as a function of domestic price deflated by the exchange rate, the exchange holdings of major importing countries, and grain and livestock production in major grain importing countries Per capita food demand for crop i is a function of the real price of crop i, the real price of competing crops, and real disposable per capita income The real price of each crop is the farm price deflated by the all-item consumer price index The farm price is included in these relationships because retail prices for individual crops are not available

Feed demand for each crop is a function of own crop price and the prices of competing crops, deflated by an index of livestock prices, and a livestock production index This formulation assumes that livestock producers increase feeding rates when crop prices decline relative to livestock prices The livestock production index is an average of the number of livestock on farms, weighted to reflect the relative amounts of grain fed to different types of livestock

Seed demand is a function of acreage planted in the following year, current crop price, and a time trend The time trend is included to reflect increases in seeding rates per acre Seed demand is positively related to crop price and acreage planted

Stocks and Price

A common approach to estimate stock levels is to calculate ending stocks as the residual difference between total supply and total demand The basic model framework using this approach is

$$S_t = S(P_{t-1}) \quad (7)$$

$$D_t = D(P_t) \quad (8)$$

$$ST_t = S_t - D_t + ST_{t-1} \quad (9)$$

$$P_t = P(ST_t/D_t) \quad (10)$$

where

S_t = total supply in period t,

D_t = total demand in period t,

P_t = price in period t, and

ST_t = total ending stocks in period t

Current year price is a function of the ratio of ending stocks to total demand This is commonly referred to as a "disequilibrium" model stemming from the failure of the price equation (10) to necessarily equate supply and demand This failure results from the estimation of equation (10) as a structural, rather than a reduced form, equation The FAPSIM model uses the alternative framework

$$S_t = S(P_{t-1}) \quad (7')$$

$$D_t = D(P_t) \quad (8')$$

$$ST_t = ST(P_t) \quad (9')$$

$$P_t = F^{-1}[S(P_{t-1}) + ST_{t-1} - D(P_t) - ST(P_t)] \quad (10')$$

where market price (equation (10')) is determined by substituting equations (7') through (9') into the supply-demand identity and by solving for price Comparison of equations (10) and (10') indicates that equation (10) will not necessarily provide a market clearing price consistent with specified demand and supply functions

Past theoretical research suggests that the demand for commercial stocks consists of two components (1) a speculative demand and (2) a transactions demand (*14*) Transactions demand for stocks is normally expressed as a function of sales whereas the speculative component is normally expressed as a function of expected price These two stock demand components suggest that commercial stock levels are a function of own (current) real price and of total crop demand The level of Government and reserve stocks are also included in the commercial stock equations as they may partially substitute for commercial stock holdings

Farmer-owned reserve (FOR) and Government stock levels are determined by the use of a set of decision rules It is assumed that Government and reserve stocks will accumulate up to the point where crop price equals the designated loan rate If the initial equilibrium price is above the designated reserve release level, reserve stocks are either released until the equilibrium price falls to the FOR release price or reserve stocks are depleted Similarly, if the initial equilibrium price is above the Commodity Credit Corporation (CCC) release price and reserve stocks are either zero or below their specified minimum, Government stocks are released until the equilibrium price falls to the CCC release price or until such holdings are depleted

Validation Tests

The ability to provide accurate forecasts depends on the relationships between the different variables included in the model These relationships fall into one of three categories definitional, institutional, and behavioral

Definitional relationships are included to insure that the model will supply a set of estimates that are internally consistent For example, the model generates estimates of yield per harvested acre and of acreage harvested based on behavioral relationships To maintain consistency among the estimates, we calculate total production by multiplying acreage harvested by yield per harvested acre

The institutional relationships include equations used to reflect the operation of farm commodity programs An example of this type of relationship is the calculation of deficiency payments, which depends on market price, loan rate, target price, and total production eligible for deficiency payments Once the policy instruments are assigned values and the estimates of market price and program acreage are obtained, deficiency payments can be calculated by use of the formula designated by law

The two types of relationships discussed above are unique in that the functional relationships among the variables are known, based on logic or rules This is not the case with behavioral relationships These relationships are formulated to satisfy economic theory and *a priori* beliefs concerning the interrelationships between variables There are numerous functional forms which are consistent with these requirements, and the exact functional relationship can never be known with certainty

The first stage in the model validation process involves selecting an appropriate functional form for each of these relationships We used ordinary least squares to estimate regression coefficients for many different equation specifications for each relationship [7] The equations forming the model were selected, based on subjective beliefs (based on actual observed behavior or previous research) regarding parameter signs and magnitudes, "goodness of fit," and the statistical significance of the individual regression coefficients The size of the model prevents our discussing individual equation characteristics Instead, we will focus on the dynamic properties of the entire system of equations

Two simulation methods have been proposed for validating a model consisting of a simultaneous system of equations The first method is static simulation in which historical values are used for all the lagged endogenous variables each year the model is solved The second method is dynamic simulation in which the lagged endogenous variables are assigned their historical values only in the initial year for which the model is solved In all successive years, previous-year model solutions are used for lagged endogenous variables Thus, the model feeds off itself to generate estimates over the validation period As FAPSIM was designed primarily for intermediate-term (policy and forecasting) analysis, we chose a dynamic simulation for model validation All the validation tests reported below are based on the dynamic type of simulation

A number of statistical measures have been proposed for evaluation of the historical performance of econometric

[7] Annual data for the 1950 79 period were used to estimate the model's coefficients

models[8] Each of these statistics provides different information on the model's ability to duplicate historical economic phenomena Three of these statistics are described below The first measure is the mean absolute relative error (MARE) It is defined as

$$\text{MARE} = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right| \tag{11}$$

where

y_t = the actual value in year t,

$\hat{y}_t$ = the model estimate in year t, and

n = the number of years simulated

This statistic is an increasing function of the absolute value of the model's prediction error and is independent of the units used to measure y If the MARE = 0, the model fits the historical data perfectly Thus, the MARE is bounded from below by zero and increases as the absolute value of the estimation error increases The main drawback with using this statistic is that it is not bounded from above

As an alternative, Theil (*20*) proposed the following statistic

$$U = \frac{\sqrt{\sum_{t=1}^{n} (y_t - \hat{y}_t)^2}}{\sqrt{\sum_{t=1}^{n} y_t^2} + \sqrt{\sum_{t=1}^{n} \hat{y}_t^2}} \tag{12}$$

It is bounded from above by a value of 1 which will occur when negative proportionality exists between the model's estimates and the historical data or when the model always predicts a zero (nonzero) value for historical values that are nonzero (zero)

Neither of the measures described above is totally adequate for evaluating the model because the model may track the historical values reasonably well in terms of these statistics, but it fails to pick up turning points in the data This situation gives rise to two types of error (1) the model may predict a turning point when one does not occur, or (2) the model may fail to predict a turning point when one is present The relative frequency of these two types of errors is defined as the turning point error (TPE) The closer this statistic is to zero, the better the model

The FAPSIM model was validated over the 1966-80 period Because of the size of the model, we will not present goodness-of-fit measures for each of the 360 endogenous variables Instead, we present statistical results for those variables regarded as crucial for the purpose of evaluating the performance of the model These variables include market price and production for each livestock category, farm-level price and planted acreage for each crop, cash receipts from farm marketings, farm production expenses, net farm income, and the consumer price indexes for food and for all items

The validation statistics for each variable are reported in table 1 The estimates of livestock and crop prices generally have higher MARE and U statistics than the corresponding production variables This situation occurs because the final demands for these products are quite inelastic, and any error in the production estimate will cause the equilibrium price to be estimated with even a larger relative error The TPE for corresponding price and production variables is approximately the same This similarity is to be expected, because if production is overestimated (underestimated), the equilibrium price will tend to be underestimated (overestimated)

The MARE and Theil's U statistic for the production variables are generally less than 0 07 and 0 05, respectively A notable exception is the acreage planted to sorghum The error in this variable is attributable to a large error (53 percent) in the model's estimate of sorghum price in 1972 that caused the sorghum acreage estimates to be off by 41 percent in 1973 and by 39 percent in 1974 If that 2-year period were excluded, the MARE of sorghum acreage would fall to 0 064 In terms of the TPE, the model predicts turning points correctly for each production variable more than 60 percent of the time

With the exception of barley, the MARE is less than 0 13 and the U statistic is less than 0 09 for each commodity price As both these statistics indicate that the price estimates exhibit more variability about their actual values than do the corresponding production estimates, we will examine these variables in greater detail

Figures 1-14 depict the simulated and the historical values for each commodity price Examination of figures 1-7 reveals that the model appears to track livestock prices reasonably well over the 1966-80 period The figures suggest that even though the model feeds on itself in a dynamic simulation, errors do not tend to accumulate over the simulation period In addition, the model performed well for 1980, even though 1980 data were not used in estimation of the model's equations

Figures 8-14 show the model's estimates of crop year prices over the validation period The model appears to perform well for all crops A substantial portion of the prediction

[8] See (*13*) and (*17*) for indepth discussions on historical validation of econometric models

Table 1—Validation statistics, 1966-80

Variable description	MARE	Theil's U	TPE[1]
Pork production	0 039	0 024	0 400
Beef production	032	019	200
Broiler production	019	014	133
Turkey production	038	021	333
Egg production	022	013	400
Milk production	009	006	200
Price of barrows and gilts	097	048	267
Price of slaughter steers	084	042	267
Price of utility cows	107	058	133
Price of broilers	057	036	200
Farm price of turkeys	088	046	400
Farm price of eggs	095	052	400
Farm price of milk	052	025	133
Acreage planted of wheat	045	030	133
Acreage planted of corn	019	011	133
Acreage planted of barley	061	037	200
Acreage planted of sorghum	109	085	200
Acreage planted of oats	053	035	467
Acreage planted of soybeans	061	042	400
Acreage planted of cotton	074	047	400
Farm price of wheat	118	062	333
Farm price of corn	083	063	333
Farm price of barley	143	083	333
Farm price of sorghum	111	082	667
Farm price of oats	059	036	333
Farm price of soybeans	077	060	133
Farm price of cotton	121	062	400
Total cash receipts from farm marketings	033	016	000
Total farm production expenses	020	010	000
Net farm income	093	077	467
Consumer price index, all food	029	019	000
Consumer price index, all items	005	003	000

[1] The number of turning point errors divided by 15, the total number of possible turning point errors

error for each crop can generally be attributed to a poor model estimate for one particular year For example, the price of wheat was overestimated by 46 percent in 1972 because of an overestimate of wheat exports and an underestimate of total supply If that particular year were ignored, the MARE for the price of wheat would fall below 10 percent

As indicated in table 1, the FAPSIM model predicts receipts from farm marketings, farm production expenses, net farm income, and the consumer prices indexes for food and all items fairly accurately Both the MARE and Theil's U statistic are relatively low for each of these variables In addition, the model correctly predicts the turning points in those variables correctly in almost every year

Overall, the model seems to perform quite well considering its size and the length of the validation period Of the 32 variables presented in table 1, only 4 were predicted with a mean absolute relative error exceeding 11 percent Only three variables had turning point errors in more than 6 of the 15 years during the 1966-80 period, which was characterized by unprecedented volatility in the agricultural sector

Scenario Analysis

Although a model may be capable of predicting past historical events with reasonable accuracy, this does not guarantee that the model will generate reasonable predictions or impacts To provide an indication of the model's sensitivity and stability, we use the model to analyze two alternative scenarios (1) a 1-year (1980) increase in corn exports of 500 million bushels and (2) a 1-year (1981) increase in beef imports of 500 million pounds The impacts associated with both these scenarios are defined relative to a base solution for the 1980-90 period. Thus, for each scenario, the impacts of the initial shock are traced annually through to 1990

Increase in Corn Exports

Table 2 presents the impacts generated by the model resulting from a 500-million-bushel increase in corn exports in

Figure 1

Price of Barrows and Gilts

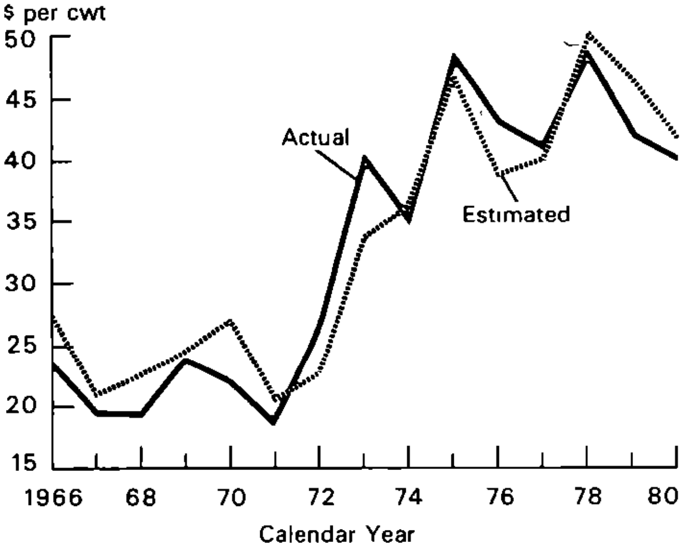


Figure 2

Price of Slaughter Steers

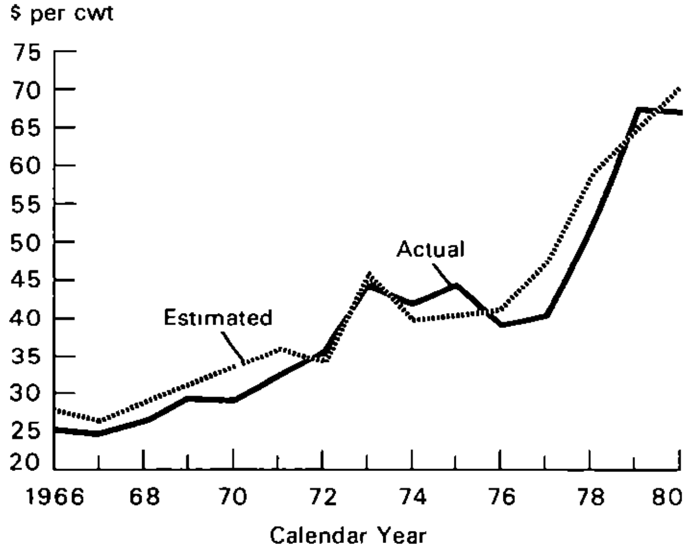


Figure 3

Price of Utility Cows

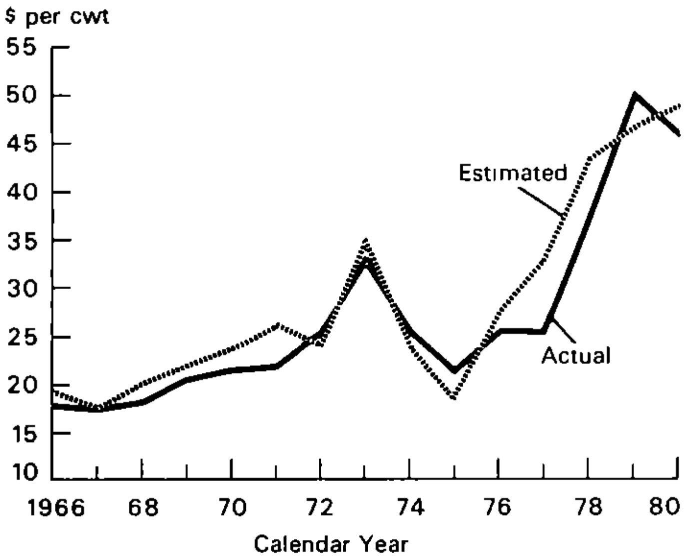
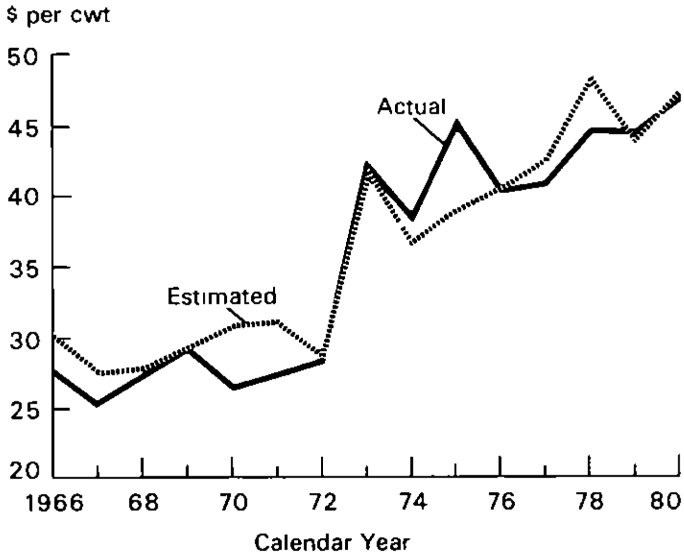


Figure 4

Price of Broilers



crop year 1980 With the exception of cotton, all crop prices are affected immediately by the increase in corn exports. The price of corn increases by $0 75 per bushel in crop year 1980, this is equivalent to a $0 15 per bushel price increase for each 100-million-bushel increase in corn exports As sorghum, barley, oats, and wheat all substitute for corn as animal feed and human food, their prices also increase The price of soybeans increases because higher corn prices lead to increased demand for soybean meal as an animal feed The price of cotton is unaffected by the change in corn exports in the first year because the demand of cotton does not depend on the price of any other crop included in the model

Because calendar year livestock production is a function of lagged crop year crop prices, initial adjustments in livestock production and prices do not occur until 1981 The increase in corn exports in the 1980 crop year causes 1981 livestock prices to increase Biological differences between cattle, hog, and poultry production result in differences in shortrun pro-

Figure 5

Farm Price of Turkeys

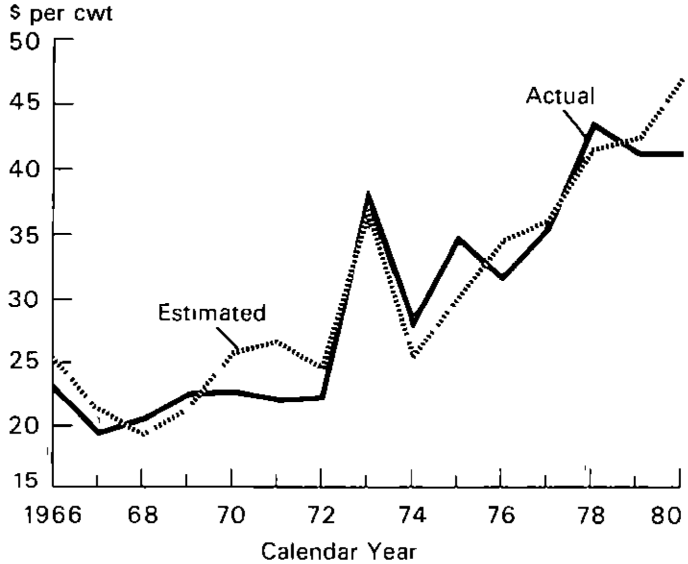


Figure 6

Farm Price of Eggs

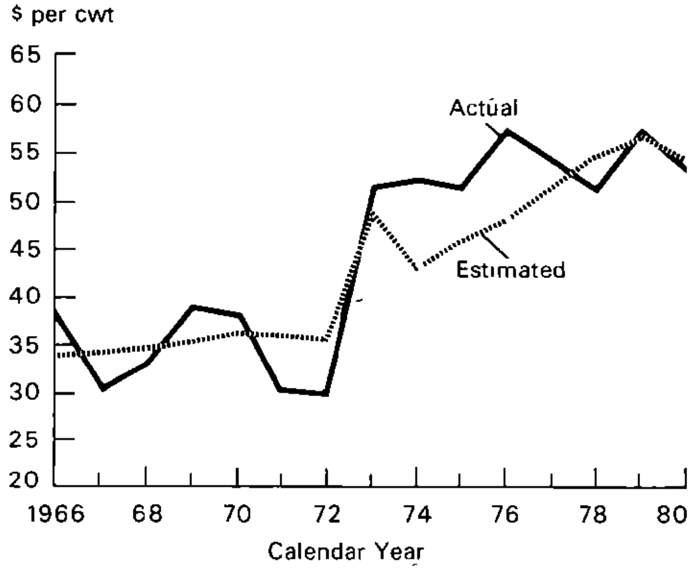


Figure 7

Farm Price of Milk

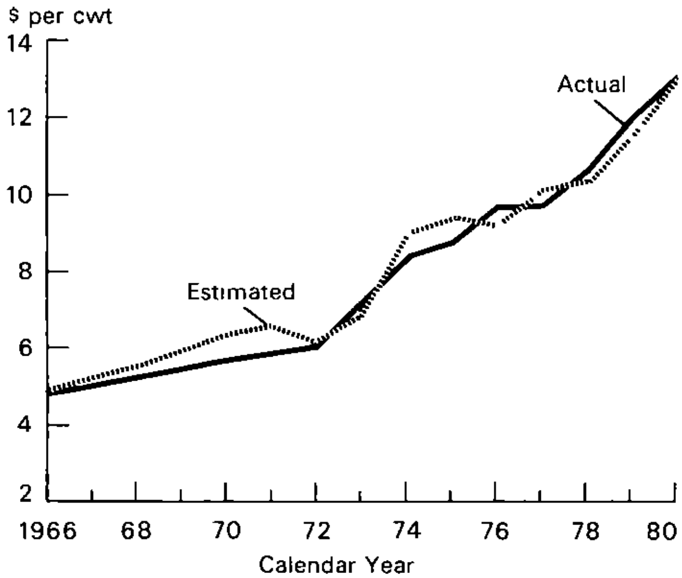
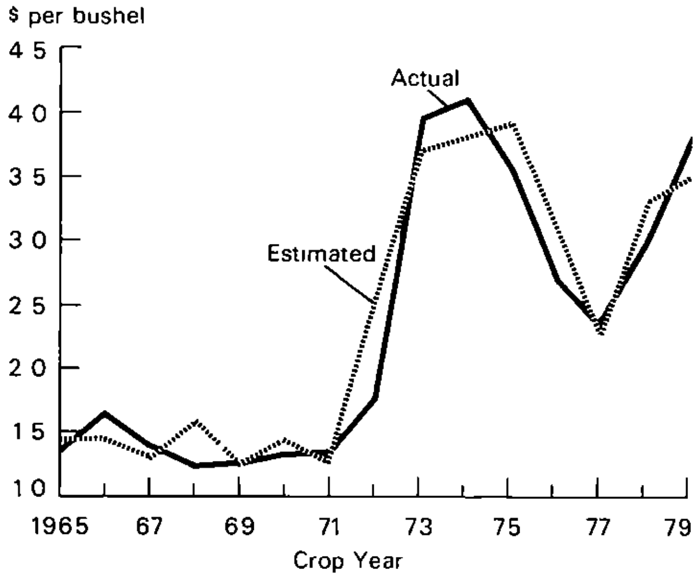


Figure 8

Farm Price of Wheat



duction and price response Because chicken and turkey producers can respond quickly (relative to hog and cattle producers) to changes in feed-grain prices by reducing production, the 1981 prices of chickens and turkeys increase relatively more than do the prices of hogs and cattle The price of turkeys increases relatively more in 1981 than does the price of broilers because the price of chickens increases relative to the price of eggs, thereby reducing egg production but in turn increasing chicken (broiler plus nonbroiler) production The price of milk remains essentially unaffected by the change in feed costs, because the Government's dairy price-support program tended to insulate milk prices in 1981

With the exception of pork, production of all livestock commodities declined in 1981 as a direct result of the increase in 1980 crop year exports of corn Pork production increased even though the price of pork fell relative to the price of corn In FAPSIM, pork producers respond to a decline in the

Figure 9

Farm Price of Corn

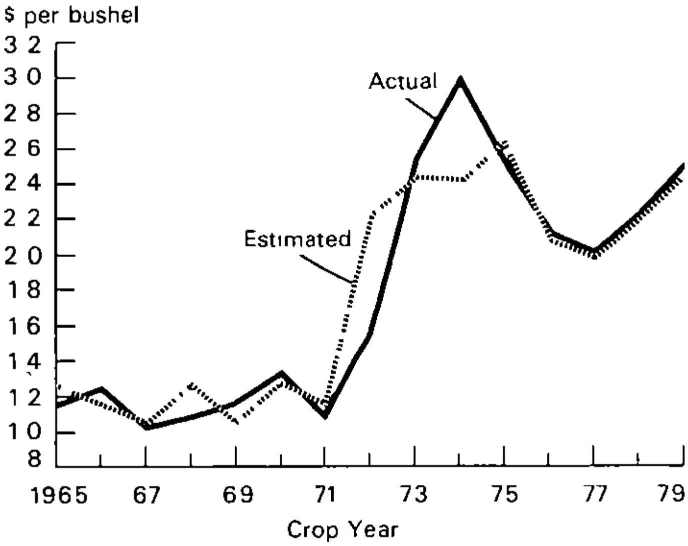


Figure 10

Farm Price of Barley

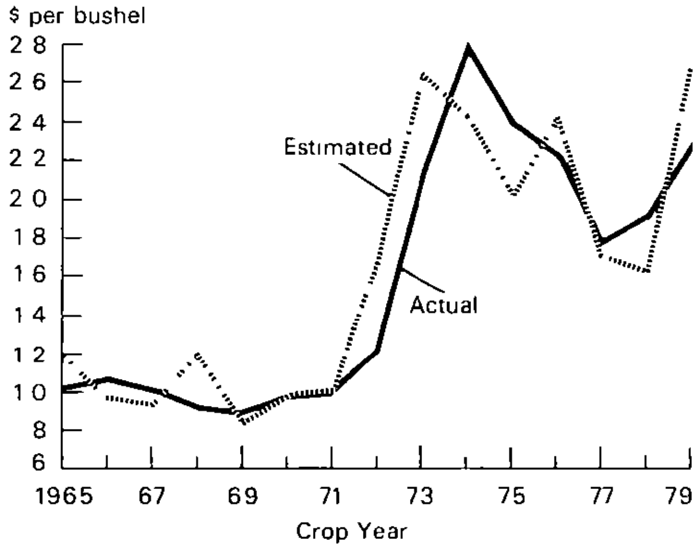


Figure 11

Farm Price of Sorghum

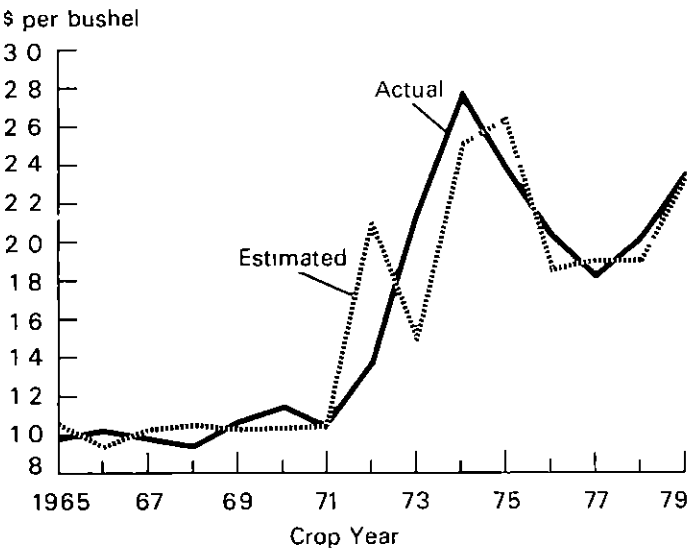
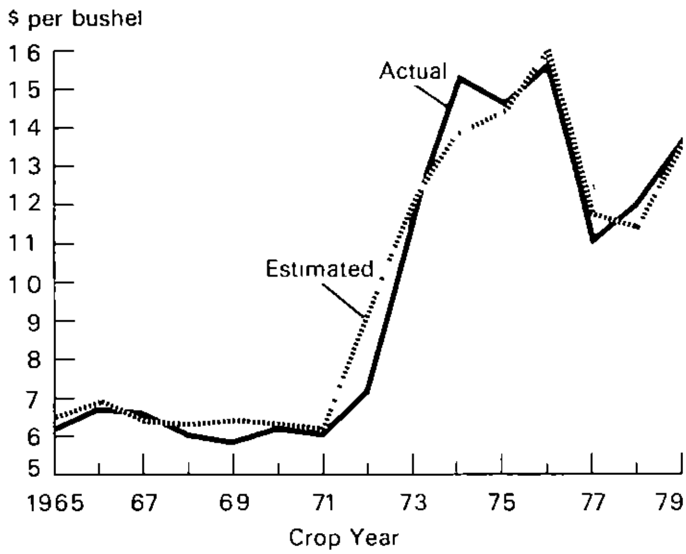


Figure 12

Farm Price of Oats



price of hogs relative to the price of corn by increasing sow slaughter and reducing the number of hogs added to the breeding herd Both responses increase current year hog production, but also decrease the size of the pig crop Thus, the model predicts that the increase in hog production resulting from expanding sow slaughter and reducing the number of hogs added to the breeding herd will outweigh the decrease in current year hog marketings resulting from a smaller pig crop However, succeeding year hog production will decline in response to a smaller inventory of market hogs on farms and a smaller pig crop Thus, FAPSIM predicts that any large adjustment in hog production will not occur until 1982

In FAPSIM, acreage planted is a function of the expected return from planting competing crops at planting time We compute the expected returns using lagged crop year prices Based on the changes in relative prices in 1980 resulting from the 500-million-bushel increase in 1981 corn exports, acreage of barley, sorghum, wheat, corn, and oats increase

Figure 13

Farm Price of Soybeans

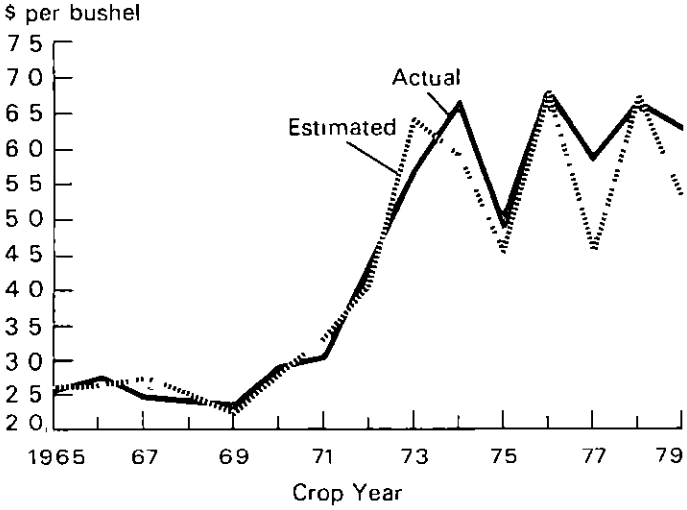


Figure 14

Farm Price of Cotton

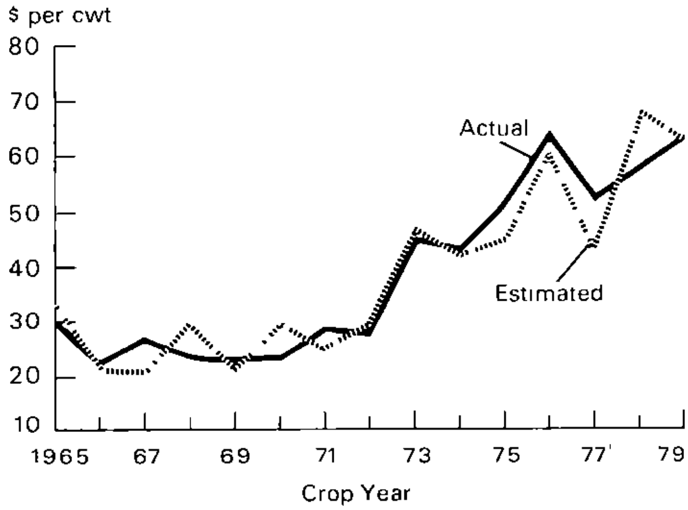


Table 2—Impact of a 500-million-bushel increase in 1980 corn exports

Variable description	Unit	Impact				
		1980	1981	1982	1985	1990
Pork production	Mil lbs	0 0	32 6	-345 6	89 2	2 8
Beef production	Mil lbs	0	-237 3	586 2	-695 0	136 9
Broiler production	Mil lbs	0	-64 8	-124 3	81 3	1 0
Turkey production	Mil lbs	0	-14 3	-22 6	16 4	-1 3
Egg production	Mil doz	0	-22 2	-34 8	7 1	- 6
Milk production	Bil lbs	0	-1 3	- 9	- 3	-1 0
Price of barrows and gilts	Dol /cwt	000	698	788	1 162	- 342
Price of slaughter steers	Dol /cwt	000	1 058	-4 286	4 137	- 476
Price of utility cows	Dol /cwt	000	142	-3 254	3 069	- 349
Price of broilers	Dol /cwt	000	1 305	- 229	899	- 276
Farm price of turkeys	Dol /cwt	000	1 389	- 503	1 107	- 260
Farm price of eggs	Dol /doz	000	680	980	- 003	029
Farm price of milk	Dol /cwt	000	009	005	067	005
Acreage planted of wheat	Mil acres	000	1 071	- 425	050	- 009
Acreage planted of corn	Mil acres	000	2 477	-1 237	096	092
Acreage planted of barley	Mil acres	000	265	136	- 005	004
Acreage planted of sorghum	Mil acres	000	2 086	- 981	000	096
Acreage planted of oats	Mil acres	000	024	032	- 014	- 010
Acreage planted of soybeans	Mil acres	000	-3 630	2 904	- 173	- 334
Acreage planted of cotton	Mil acres	000	- 178	- 413	051	159
Farm price of wheat	Dol /bu	196	- 127	014	014	- 003
Farm price of corn	Dol /bu	748	- 218	094	- 030	005
Farm price of barley	Dol /bu	551	- 185	006	- 029	003
Farm price of sorghum	Dol /bu	627	- 421	163	- 048	001
Farm price of oats	Dol /bu	177	- 032	- 001	- 003	- 016
Farm price of soybeans	Dol /bu	377	953	- 527	- 024	103
Farm price of cotton	Dol /cwt	000	1 635	2 880	279	-1 549
Total cash receipts from farm marketings	Bil dol	1 504	1 999	-1 968	1 986	- 361
Total farm production expenses	Bil dol	1 313	728	- 607	493	139
Net farm income	Bil dol	190	1 271	- 901	1 492	- 499
Consumer price index, all food	1967=1	000	010	- 015	022	- 003
Consumer price index, all items	1967=1	000	002	- 003	004	- 001

However, soybean and cotton acreage declines because the expected returns of competing crops increase by a larger amount These acreage adjustments in turn cause crop price adjustments in the 1981 crop year, leading to lower wheat and feed-grain prices but to higher soybean and cotton prices

Total cash receipts and farm production expenses increase in 1981 Higher livestock prices in 1981, coupled with higher crop prices in the 1980 crop year, result in a $2 0-billion increase in 1981 farm cash receipts Farm production expenses also increase by $0 7 billion in 1981, resulting in an increase in net farm income of $1 3 billion

As indicated by table 2, beef producers increase beef production in 1982 This reflects increased culling of cows in response to lower returns in 1981 This increase in cow slaughter does not have its maximum impact on production until 1985 After 1985, beef producers begin rebuilding their herds, leading to increased production and lower prices in 1990 These adjustments characterize the dynamic nature of livestock production The initial increase in corn exports causes the price of corn to increase, signalling producers to reduce production But it takes time for producers to adjust fully For the hog producer, this adjustment period is much shorter than for the cattle raiser (but much longer than for broiler producers who can turn around in 3 months) Hog producers may have already made decisions to expand output and have their gilts or sows bred But the time from breeding until their pigs reach slaughter weight is no more than 10 months The time from when the cattle producers' heifers are bred until their offspring reach slaughter weight can be about 27 months Furthermore, if the first offspring are retained to further increase the herd rather than sent to slaughter, it could be about 5-1/2 years from the time the first calf is retained to increase output, until that heifer's offspring reaches slaughter Because significant lags exist in production adjustment, future livestock production may expand (decline) despite lower (higher) livestock prices

The dynamic nature of livestock and crop production suggests that any shock to the agricultural sector will have repercussions for many years But, it is likely that the effect of the shock would dissipate over time The results presented in table 2 suggest that the impacts on the agricultural sector from an initial shock decline over time For all variables, with the exception of milk production and the price of cotton, the estimated adjustment in the 1990 estimates are only a fraction of the maximum adjustment occurring during the 1980-90 period

Decrease in Beef Imports

Table 3 presents the impacts generated by the model resulting from a 500-million-pound decrease in 1981 beef imports The price of slaughter steers increases by $1 66 per hundredweight or by $0 33 per hundredweight for each 100-million-pound decrease in beef imports Because beef, pork, chicken, and turkey substitute for beef at the retail level, the prices of these commodities also increase in 1981 The price of milk is virtually unaffected because of the Government dairy price-support program

Production of beef, broilers, and turkeys increases moderately in 1981 However, pork, egg, and milk production declines slightly in response to higher prices for hogs, cattle, and layers The maximum response in hog production occurs in 1982, which reflects farmers' response in 1981 to reduce sow slaughter and to add additional hogs to the breeding herd

Adjustments in livestock prices and production in the 1981 calendar year affect 1980 crop year prices However, the overall adjustment in crop prices resulting from a 500-million-pound decrease in beef imports appears to be minor The prices of corn, soybeans, and sorghum increase between 2 and 3 cents per bushel in 1980 The price of sorghum exhibited the largest adjustment in 1980, reflecting the relatively large proportion fed to cattle The adjustment in crop prices in 1980 in turn influences 1981 acreage planted Only acreage planted to sorghum appears to respond significantly (-0 10 million acres) in 1981

Overall, the maximum adjustment in commodity prices resulting from a 1-year decrease in beef imports generally occurs during the initial year of the decline in imports Maximum impact on crop production occurs 1 year after the adjustment (current crop year) in imports, reflecting the lagged response of crop producers to price After these initial adjustments, the price and production estimates gradually approach their baseline levels, providing another indication of the model's stability

Conclusions

We have presented an overview, validation statistics, and dynamic properties of FAPSIM This model is an annual national econometric model of the U S agricultural sector The model estimates a simultaneous price-quantity equilibrium solution for a set of commodity models developed for beef, dairy, pork, chickens, turkeys, eggs, corn, oats, barley, grain sorghum, wheat, soybeans, and cotton

The model was validated over the 1966-80 period and was found to perform extremely well given the volatility of the agricultural sector, the length of the validation period, and the size of the model Of the 32 variables for which validation statistics were computed, only 4 were predicted with a mean absolute relative error exceeding 11 percent Only three variables had turning point errors in more than 6 of the 15 years of the validation period In succeeding articles, validation statistics will be presented for the individual submodels contained in FAPSIM Such statistics will

Table 3—Impact of a 500-million-pound decrease in 1981 beef imports

Variable description	Unit	Impacts				
		1980	1981	1982	1985	1990
Pork production	Mil lbs	0 0	-2 5	23 9	-8 6	-0 3
Beef production	Mil lbs	0	34 3	-32 6	59 8	-4 1
Broiler production	Mil lbs	0	7 3	9 5	-3 0	2
Turkey production	Mil lbs	0	2 3	3 1	-1 0	2
Egg production	Mil doz	0	-2 5	-4 6	0	0
Milk production	Bil lbs	0	- 1	- 2	- 2	- 1
Price of barrows and gilts	Dol /cwt	000	995	047	- 052	040
Price of slaughter steers	Dol /cwt	000	1 658	431	- 254	059
Price of utility cows	Dol /cwt	000	1 184	334	- 189	043
Price of broilers	Dol /cwt	000	841	133	- 084	030
Farm price of turkeys	Dol /cwt	000	888	232	- 103	030
Farm price of eggs	Dol /doz	000	150	215	- 007	001
Farm price of milk	Dol /cwt	000	001	001	038	000
Acreage planted of wheat	Mil acres	000	037	111	- 004	001
Acreage planted of corn	Mil acres	000	024	- 061	008	002
Acreage planted of barley	Mil acres	000	009	- 023	002	000
Acreage planted of sorghum	Mil acres	000	104	- 029	010	001
Acreage planted of oats	Mil acres	000	001	- 008	- 001	- 002
Acreage planted of soybeans	Mil acres	000	- 078	075	- 012	- 007
Acreage planted of cotton	Mil acres	000	- 013	- 012	000	004
Farm price of wheat	Dol /bu	007	020	- 001	- 001	000
Farm price of corn	Dol /bu	026	009	006	000	000
Farm price of barley	Dol /bu	019	011	012	000	000
Farm price of sorghum	Dol /bu	034	001	007	001	- 001
Farm price of oats	Dol /bu	006	003	001	000	- 002
Farm price of soybeans	Dol /bu	026	027	- 015	003	002
Farm price of cotton	Dol /cwt	000	093	063	017	- 037
Total cash receipts from farm marketings	Bil dol	066	1 551	335	- 093	017
Total farm production expenses	Bil dol	051	606	210	003	031
Net farm income	Bil dol	015	945	057	- 096	- 014
Consumer price index, all food	1967=1	000	010	002	- 001	000
Consumer price index, all items	1967=1	000	002	000	000	000

provide insight into whether the source of validation error stems from a particular commodity submodel and whether such errors tend to be cumulative across submodels

We analyzed two shocks to provide information on the model's dynamic properties The shocks consisted of a 500-million-bushel increase in corn exports and a 500-million-pound decline in beef imports The initial increase in corn exports caused the price of corn to increase by $0 75 per bushel Somewhat smaller increases occurred in the price of other feed grains, wheat, and soybeans The size of the impacts generally declined after the first year for crop variables and after the fifth year for livestock variables for a one-period increase in corn exports The maximum adjustment resulting from a 500-million-pound decrease in beef imports occurred within 2 years for crop variables and within 1 year for livestock variables The size of the impacts generated by the model appear reasonable, both in terms of direction of change and magnitude In addition, the impacts decline after a reasonable adjustment period, suggesting that the FAPSIM model possesses stability

References

(1) Bancroft, Robert L "An Econometric Analysis of Aggregate Acreage Response, Program Participation and Land Retirement " Unpublished PH D dissertation Purdue Univ , 1981

(2) Baumes, Harry S , and William H Meyers *The Crops Model Structural Equations Definitions, and Selected Impact Multipliers* NED Staff Report U S Dept Agr , Econ Stat Coop Serv , Mar 1980

(3) Collins, Keith J "The Effects of Selected Supply and Demand Factors on the U S Cotton Market," *Cotton and Wool Situation*, CWS-23, U S Dept Agr , May 1980, pp 22-24

(4) Dahlquist, Germund, and Ake Bjorck *Numerical Methods* Englewood Cliffs, N J Prentice-Hall, Inc , 1969, pp 188-196

(5) Green, Robert C , and Roger L Hoskin *The Crops Model Feedgrains, Wheat, and Soybeans Submodels* NED Staff Report U S Dept Agr , Econ Res Serv , forthcoming

(6) Heien, Dale "An Econometric Model of the U S Pork Economy," *Review of Economics and Statistics*, Vol. 57, 1975, pp 370-75

(7) ———— "An Economic Analysis of the U S Poultry Sector," *American Journal of Agricultural Economics*, Vol 58, 1976, pp 184-91

(8) ————, and Jimmy L Matthews "An Econometric Model of the U S Beef Cattle Industry " Price Research and Methods Section Working Paper U S Dept Agr , Econ Res Serv , 1973

(9) Haidacher, R C , C E Overton, and R C Kite "An Econometric Approach to Developing a Cross-Commodity Forecasting System with Emphasis on Beef and Dairy " CED Forecast Support Group Working Paper U S Dept Agr , Econ Res Serv , Mar 1977

(10) Houck, J P , and Mary E Ryan "Supply Analysis for Corn in the United States The Impact of Changing Government Programs," *American Journal of Agricultural Economics*, Vol 54, 1972, pp 124-91

(11) ————, and Abraham Subotnik *Soybeans and Their Products* St Paul Univ of Minnesota Press, 1972

(12) Kite, Rodney C. "Six Models for the Livestock Economy Pork, Beef, Chicken, Turkey, Eggs, and Dairy " CED Forecast Support Group Working Paper U S Dept Agr., Econ Res Serv , Mar 1976.

(13) Kost, William E "Model Validation and the Net Trade Model," *Agricultural Economics Research*, Vol 32, No 2, Apr 1980, pp 1-16

(14) Lovell, M "Manufacturers Inventories, Sales Expectations, and the Acceleration Principle," *Econometrica*, Vol 29, 1960, pp 293-314

(15) Matthews, Jimmy L "Conditional Market Forecasts and Implications for the U S Soybean Economy," *Fats and Oil Situation* FOS-268 U S Dept Agr , July 1973

(16) ————, A W Womack, and Robert G Hoffman "Formulation of Market Forecasts for the U S Soybean Economy with an Econometric Model," *Fats and Oil Situation* FOS-260 U S Dept Agr , Dec. 1971

(17) Pindyck, Robert S , and Daniel L Rubinfeld *Econometric Models and Econometric Forecasts* New York McGraw-Hill, 1976

(18) Salathe, Larry E , Kenneth E Gadson, and J Michael Price *The Food and Agricultural Policy Simulator (FAPSIM) Structural Equations and Variable Definitions* NED Staff Report U S Dept Agr , Econ Res Serv , Apr 1982

(19) Teigen, Lloyd D , and Abner W Womack "An Econometric Model of the Livestock and Feed Sector " Paper presented at the First Annual Seminar on Livestock Futures Market Research, Chicago, Ill , June 1981

(20) Theil, H *Economic Forecasts and Policy* Amsterdam North-Holland Publishing Co , 1961

(21) Todd, Richard M *A Revised Farm Income Model* NED Staff Report U S Dept Agr , Econ Stat Coop Serv , Jan 1980

(22) Womack, Abner W "USDA Models—A Review of Research Conducted by the Price Research Section, 1950 79 " Presented at the Symposium on Econometric Modeling and Forecasting for Agriculture, Ottawa, Canada, May 22-23, 1980

(23) Yanagida, John F , and Roger K Conway *Annual Livestock Model of the United States* NED Staff Report U S Dept Agr , Econ Stat Coop Serv , Jan 1980