The Food and Agricultural Policy Simulator: The Dairy-Sector Submodel

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Abstract

This article presents the structure, parameters, and validation statistics for the dairy-sector submodel contained in the U S Department of Agriculture's (USDA's) Food and Agricultural Policy Simulator (FAPSIM) This submodel endogenously estimates dairy cow numbers, milk production, farm-level milk prices, fluid milk consumption, and the supply, utilization, and prices of butter, cheese, nonfat dry milk, condensed and evaporated milk, and frozen milk products It also endogenously estimates USDA purchases of manufactured dairy products and the costs of Government dairy product purchases under alternative dairy price-support options The annual model is used to examine the adjustment resulting from lowering dairy price-supports from 75 to 65 percent of parity

Keywords

Dairy products, econometric model, milk, policy analysis, simulation

Introduction

U S dairy policy has been under continuous debate since 1972 During the midseventies, debate focused on dairy import quotas (*1*) [1] Recently, large Federal budget outlays resulting from dairy price-support operations have raised questions concerning the Government's role in the U S dairy industry Because of Government involvement in the dairy sector through dairy price supports, dairy import quotas, and milk marketing orders and agreements, it is likely that dairy policies and programs will remain under considerable scrutiny

Researchers have developed a variety of economic models to examine and evaluate alternative dairy policies and programs (*2, 3, 6, 8, 9*) Such models have generally recognized interrelationships among the dairy, feed-grain, and beef and veal sectors, but they have treated such sectors as exogenous The failure to endogenize the beef and veal and the feed-grain sectors could result in substantial errors when researchers analyze dairy policies

The U.S Department of Agriculture's (USDA) Food and Agricultural Policy Simulator (FAPSIM) is an annual econometric model of the agricultural sector (*10*) FAPSIM consists of a set of individual commodity models for beef, pork, dairy, chickens, eggs, turkeys, corn, grain sorghum, barley, oats, wheat, soybeans, and cotton that are linked via common variables The model estimates a price-quantity equilibrium solution that is simultaneously consistent across all commodity sectors This report details the dairy sector of FAPSIM We present the dairy submodel's structure, equation parameter estimates, validation statistics, and linkages to other FAPSIM submodels We use the dairy submodel to explore the effects of lowering the price-support level on dairy products from 75 to 65 percent of parity

Structure of the Dairy-Sector Submodel

The dairy-sector submodel explicitly recognizes the role of the Federal Government in milk marketing and pricing [2] The Government supports the price of manufacturing milk (and of milk eligible for fluid consumption) by purchasing manufactured dairy products The support level for manufacturing milk is set at some fraction of parity as determined by the Congress This support level is then adjusted by a processing allowance to derive the price at which the Government will then purchase butter, cheese, and nonfat dry milk These purchases increase the demand for manufactured dairy products and the price of milk When prices of manufactured products reach 110 percent of designated purchase levels, the Government may release accumulations of manufactured

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

[2] The model presented draws upon earlier work by Novakovic and Thompson (*6*) and Salathe (*9*) Major structural differences between the model presented and previous studies are in the supply relationships for manufactured dairy products and Government stock specifications

dairy products Such releases increase supplies and lower milk prices Because the Government supports milk prices by purchasing butter, cheese, and nonfat dry milk, Government purchases of such products depend on the level of supply and demand for each product

The dairy submodel consists of four subcomponents (1) milk supply, (2) milk price, (3) milk manufacturing, and (4) commercial demand

Milk Supply

The milk supply component contains equations for dairy cow slaughter, additions to the dairy cow herd, dairy cow numbers, milk production, milk fed to calves, milk sold to plants and dealers, and the supply of milk eligible for fluid consumption An identity (equation) is used to determine the ending inventory of dairy cows on farms based on the beginning inventory of dairy cows, death loss, dairy cow slaughter, and additions to the dairy cow herd This identity is the following

$$COWSNMC(+1) = 0\ 98\ COWSNMC + COWSEMC - COWKSMC$$

where

COWSNMC = the number of dairy cows on farms on January 1,

COWSEMC = the number of additions to the dairy cow herd during the year, and

COWKSMC = the number of dairy cows slaughtered during the year

This identity assumes that 2 percent of all dairy cows die during each calendar year Data on the actual number of dairy cow additions are not available Therefore, we assume that 60 percent of all dairy cow replacements over 500 pounds on January 1 are added to the dairy herd during the calendar year Although both assumptions are open to debate, they were necessary if the dairy and beef and veal sector submodels were to be linked For example, data on dairy cow slaughter can be generated by use of the identity Such a data series is otherwise unavailable Yet, without such a data series, it would be impossible to estimate either the contribution of dairy cow slaugther to total beef production or the effects of beef and milk prices on dairy cow slaughter

Dairy cow slaughter and additions to the dairy cow herd are hypothesized to be influenced by the price of milk, the price of cattle, the price of feed, and the stock of dairy cows The ratio of the price of milk relative to the price of cattle and the ratio of the price of milk to the price of feed reflect the relative profitability of keeping rather than selling dairy heifer calves and dairy cows The price of feed is calculated as a weighted (reflecting average importance in dairy rations) average of the prices of corn, oats, grain sorghum, barley, wheat, and soybean meal This variable links the dairy sector to the crops submodels

Milk production per cow is a function of lagged milk production per cow, a time trend, and the ratio of milk price to the price of feed The time trend captures improvements in management practices over time such as improved culling and breeding practices We included the ratio of milk price to the price of feed on the assumption that farmers reduce feeding rates during periods when milk prices are low relative to feed costs

The fraction of milk eligible for fluid consumption has steadily increased over time Salathe (*9*) found that at least a portion of the increase could be explained by the lagged difference between the producer prices for fluid and manufacturing grades of milk Therefore, the supply of milk eligible for fluid consumption is hypothesized to be related to the lagged difference in producer prices for fluid and manufacturing grades of milk and to the quantity of milk sold to plants and dealers

Milk Price

The milk price component is consistent with the pricing mechanism for Federal milk marketing orders The Minnesota-Wisconsin manufacturing milk price series is the standard on which the Federal order system determines Class I and II milk prices The Minnesota-Wisconsin manufacturing milk price is related to the wholesale prices of butter, cheese, and nonfat dry milk We calculate the price of fluid-eligible milk by weighting Class I and II prices by the proportion of fluid-eligible milk utilized as Class I and II

The farm-level price of milk reflects both the relative proportion of milk produced as fluid and as manufacturing grades and their respective prices The producer price of manufacturing milk is related to the wholesale prices of butter, cheese, and nonfat dry milk We calculate the producer price of milk by weighting the prices of manufacturing and fluid-eligible milk by the proportion of milk produced as fluid-eligible and manufacturing grades

Milk Manufacturing

The dairy submodel contains equations to predict supply, utilization, and prices for butter, cheese, nonfat dry milk, frozen milk products, fluid milk, and condensed and evapo rated milk It is hypothesized that the demand for milk to be processed into fluid, condensed, and evaporated milk and into frozen desserts will be satisfied prior to the allocation of milk to butter, cheese, and nonfat dry milk production The volume of milk available for manufacturing (milk production less that processed into fluid, condensed, and evaporated milk, into frozen milk products, and into milk consumed by calves) explains production of butter, cheese, and nonfat dry milk Production of butter, cheese, and nonfat dry milk is also affected by their respective wholesale price-proxies reflecting the relative profitability of producing each of these products Production of evaporated and condensed milk is related to the prices of fluid and condensed and evaporated milk Imports and exports of dairy products are exogenous

Retail prices of the six dairy products are expressed as a function of their respective wholesale price and variables that reflect marketing costs Explicit econometric equations do not need to be specified either for the wholesale prices of cheese, nonfat dry milk, and butter or for the retail price of condensed and evaporated milk as these equations can be derived from specified production, demand, and stock relationships

Commercial Demand

Commercial demand for dairy products consists of exports, domestic consumption, stocks, and Government purchases Exports and military consumption are exogenous Civilian consumption of each dairy product is related to its own real price, the real price of competing products, real disposable income, and population growth Commercial stocks of butter, cheese, and nonfat dry milk are related to their respective wholesale prices and to production

Government purchases (placements) of dairy products have generally been specified as linear functions of the wholesale price and the Government support price (6) Such functional relationships ignore the discontinuity in Government purchases when market clearing prices are above the designated support price

We avoid this problem by computing Government purchases as the residual difference between supply and demand Initially, a free-market clearing price is computed This price is then compared with the price-support level, and if the free-market price is above the price-support level and below the release price, no action is taken However, if the free-market price is below the price-support level, the market price is set equal to the price-support level, and the level of Government purchases is computed as the difference between supply and demand at the support price A similar process is followed when the free-market price exceeds the release price for a particular dairy product

Empirical Equations

We estimated the equation parameters of the dairy submodel using ordinary least squares We selected three distinct time periods—1950-79, 1955-79, and 1960-79—for parameter estimation The final set of equations selected represents the best set based on hypothesized parameter signs, significance of the parameter estimates, and the standard error of regression We compared parameter estimates over the three estimation periods When parameter estimates did not vary substantially over the three estimation periods, we included the equation using the longest data series in the submodel

A few equations, while accurately predicting a particular variable over much of the estimation period, contained rather substantial errors for selected years The most notable errors were for dairy cow additions during the 1965-71 period and dairy cow slaughter during the 1965-69 period Dummy variables were included only after alternative specifications were explored and found inferior Table 1 defines the variables contained in the submodel Tables 2 through 8 report the parameter estimates

The dairy cow additions and slaughter equations indicate that increases in cattle (utility cow and calf) prices and in feed costs reduce the number of dairy cows An increase in feeding costs negatively affects milk production per cow The stock of dairy cows on farms 2 years earlier was included in the dairy cow additions equation as a proxy for the available supply of replacements

Production of butter and cheese was found to be significantly related to the wholesale prices of butter, cheese, and nonfat dry milk and to the quantity of milk available for manufacturing Producer milk prices were significantly related to the wholesale prices of butter, cheese, and nonfat dry milk Nonfat dry milk production was positively related to butter production, but negatively related to cheese production

Per capita civilian disappearance of fluid milk is a function of the ratio of the retail price of fluid milk relative to the consumer price index (CPI) for nonalcoholic beverages and is a function of the ratio of the retail price of fluid milk relative to the price of nonfat dry milk Increases in both variables significantly reduce civilian disappearance of fluid milk A time trend captures the decline in consumer preferences for fluid milk relative to nonalcoholic beverages during the estimation period Per capita disposable real income was dropped from the regression because it was not statistically significant

Per capita civilian disappearance of nonfat dry milk declines as the price of nonfat dry milk increases relative to the price of fluid milk Unlike per capita civilian disappearance of fluid milk, there is a fairly strong positive relationship between per capita consumption of nonfat dry milk and real per capita disposable income

Per capita civilian disappearance of butter declines significantly as the ratio of the retail price of butter increases

Table 1—Dairy submodel variables

Variable	Definition
Endogenous	
COWSNMC	Number of milk cows on farms, January 1, million head
COWKSMC	Number of milk cows slaughtered, million head
COWSEMC	Number of dairy cow replacements, million head
MILPF	Average price received by farmers for all milk sold to plants, dollars per cwt
MILECLOP	Effective Class I milk price paid by dealers, dollars per cwt
MILMWAT	Minnesota-Wisconsin manufacturing grade milk price, dollars per cwt
MILPPFEMAT	Average price received by farmers for fluid eligible milk, dollars per cwt
MILPPMAT	Average price received by farmers for manufacturing grade milk, dollars per cwt
MILBC	Quantity of milk fed to calves, billion pounds
MILAP	Total milk production, billion pounds
MILSPPLTS	Quantity of milk sold to plants and dealers, billion pounds
MILASFM	Quantity of milk produced eligible for fluid market, billion pounds
MILMFG	Quantity of milk available for manufacturing, billion pounds
MILSPFZ	Production of frozen dairy products, billion pounds of milk used
MILSPEC	Production of evaporated and condensed milk, billion pounds
MILSPECM	Production of evaporated and condensed milk, billion pounds of milk used
MILCCMC	Civilian disappearance of fluid milk plus cream, billion pounds
MILBUT	Wholesale price of Grade A butter, Chicago, cents per pound
MILAMCHEE	Wholesale price of American cheese at Wisconsin assembling points, 40-pound block, cents per pound
MILPWDR	Wholesale price index for nonfat dry milk, 1967 = 1 0
MILOMP	Minimum Federal order price for Class I milk, dollars per cwt
MILIR	Retail price index for fluid milk, 1967 = 1 0
MILIRIC	Retail price index for ice cream, 1967 = 1 0
MILCCFZ	Civilian disappearance of milk used in frozen dairy products, billion pounds
MILCCEC	Civilian disappearance of evaporated and condensed milk, billion pounds
MILIREV	Retail price index for evaporated milk, 1967 = 1 0
MILHTEV	Ending stocks of evaporated and condensed milk, billion pounds
MILSPND	Production of nonfat dry milk, billion pounds
MILCCND	Civilian disappearance of nonfat dry milk, billion pounds
MILHGND	Beginning USDA stocks of nonfat dry milk, billion pounds
MILHBND	Beginning commercial stocks of nonfat dry milk, billion pounds
MILGUND	USDA purchases of nonfat dry milk, billion pounds
CHESP	Production of cheese, billion pounds
CHECT	Civilian disappearance of cheese, billion pounds
CHEHB	Beginning commercial stocks of cheese, billion pounds
CHEHG	Beginning USDA stocks of American cheese, billion pounds
CHEGU	USDA purchases of American cheese, billion pounds
CHEIRAM	Retail price index of American cheese, 1967 = 1 0
BUTSP	Production of butter, billion pounds
BUTCC	Civilian disappearance of butter, billion pounds
BUTHB	Beginning commercial stocks of butter, billion pounds
BUTHG	Beginning USDA stocks of butter, billion pounds
BUTGU	USDA purchases of butter, billion pounds
BUTIR	Retail price index of butter, 1967 = 1 0
DARCPI	Retail price index of dairy products, 1967 = 1 0
DAIGP	Total cost of USDA dairy product purchases, million dollars
DAIFC	Cash receipts from milk sales, billion dollars
Exogenous	
CATPFNF*	Price of utility cows, Omaha, dollars per cwt
CORPF*	Price received by farmers for corn, Oct Sept , dollars per bushel
BARPF*	Price received by farmers for barley, June-May, dollars per bushel
OATPF*	Price received by farmers for oats, June-May, dollars per bushel
SORPF*	Price received by farmers for grain sorghum, Oct -Sept , dollars per bushel
WHEPF*	Price received by farmers for wheat, June-May, dollars per bushel
SOMPF*	Price of soybean meal, Decatur, 44 percent, dollars per cwt
CALPF*	Price received by farmers for calves, dollars per cwt
.TIME	Time trend 1950 = 50, 1951 = 51, and so forth
MILOOP	Federal order over order payments for Class I milk, dollars per cwt
BUTGG	USDA donations of butter, billion pounds
BUTDV	USDA unaccounted-for change in stocks of butter, billion pounds
.GASIR	Consumer price index for regular and premium gasoline, 1967 = 1 0
.YPD$	U S personal disposable income, billion dollars
MARIR*	Consumer price index for margarine, 1967 = 1 0
DUM_{ij}	Dummy variable, 19ij = 1 0
DUM_{ijkl}	Dummy variable, 19ij - 19kl = 1 0
MILMGND	USDA exports of nonfat dry milk, billion pounds
MILDVND	USDA unaccounted-for change in stocks of nonfat dry milk, billion pounds
CHEMX	Exports of cheese, billion pounds
CHEMI	Imports of cheese, billion pounds
CHECM	Military disappearance of cheese, billion pounds

Table 1—Dairy submodel variables (continued)

Variable	Definition
CHEGG	USDA donations of American cheese, billion pounds
CHEMG	USDA exports of cheese, billion pounds
CHEDV	USDA unaccounted-for change in stocks of American cheese, billion pounds
BUTMG	USDA exports of butter, billion pounds
BUTMX	Exports of butter, billion pounds
BUTMI	Imports of butter, billion pounds
BUTCM	Military disappearance of butter, billion pounds
MILCIDF	Historical difference between Federal order minimum Class I milk price and Minnesota-Wisconsin manufacturing grade price, dollars per cwt
MILPFDIF	Historical difference between average price received by farmers for fluid eligible milk and weighted Federal order price for fluid eligible milk, dollars per cwt
.WRHD	Dairy manufacturing industry wage rate, dollars per hour
.NPC	Total U S population, millions
.PCNAL*	Consumer price index for nonalcoholic beverages, 1967 = 1 0
.PC*	Consumer price index for all items, 1967 = 100
MILMIND	Imports of nonfat dry milk, billion pounds
MILMXND	Exports of nonfat dry milk, billion pounds
MILCMND	Military disappearance of nonfat dry milk, billion pounds
MILGGND	USDA donations of nonfat dry milk, billion pounds
MILSPPBUT	USDA purchase price of butter, dollars per cwt
MILNFDSPP	USDA purchase price of nonfat dry milk, dollars per cwt
MILCHCHSPP	USDA purchase price of American cheese, dollars per cwt
MILMIEC	Imports of evaporated and condensed milk, billion pounds
MILMXEC	Exports of evaporated and condensed milk, billion pounds
MILCMEC	Military disappearance of evaporated and condensed milk, billion pounds
MILMIFZ	Imports of frozen dairy products, billion pounds
MILCMFZ	Military disappearance of frozen dairy products, billion pounds
MILBCND	Nonfat dry milk fed to calves, billion pounds

*Denotes variables that are exogenous to the dairy submodel, but endogenously computed by other FAPSIM submodels

relative to the retail price of margarine, but the disappearance of butter does not appear to be significantly affected by the level of real per capita disposable income A time trend reflects reduced consumption of foods high in cholesterol Beginning in 1978, the downward trend in civilian disappearance of butter seems to have leveled off somewhat

Per capita civilian disappearance of cheese is a function of the ratio of the retail price of cheese relative to the all-item CPI and to real per capita disposable income The retail price of meat was dropped from the equation because it was not statistically significant However, the demand for cheese seems to have shifted upward in 1973, immediately after the large increase in meat prices It appears that consumers significantly increased their demand for cheese following the large increase in meat prices in 1972-73 and did not reduce their demand for cheese after meat prices leveled off

Validation Statistics

Various procedures have been proposed for validating econometric models These procedures generally involve examining the statistical characteristics of individual equations, as well as examining the predictive ability of the entire system of equations The equations comprising the dairy submodel seem to contain parameters of appropriate sign and magnitude However, such characteristics do not ensure that the entire system of equations will accurately predict future events Since future events are unknown, researchers have proposed that model predictions for historical periods be used to examine a model's predictive ability

A variety of validation statistics have been proposed to determine the predictive adequacy of econometric models [3] The most widely used include the mean absolute relative error (MARE), Theil's U_1 and U_2 statistics, and turning point error (TPE) The MARE is widely used because of its ease in calculation and interpretation It can be interpreted as the mean error of the model's estimate for a particular variable If the MARE equals zero, the model's estimate for a particular variable exactly equals that variable's historical data The MARE is independent of measurement units

A drawback of the MARE is that it does not possess an upper limit Thus, Theil's U_1 statistic was proposed as an alternative measure of a model's predictive ability The value of this statistic equals zero if the model's estimates for a variable are exactly equal to that variable's historical data. The maximum value of Theil's U_1 statistic is 1, which will occur either when negative proportionality exists between the model's estimates and the historical data or the model always predicts a value of zero for nonzero historical values or when the model predicts nonzero values for historical values that are zero

[3] See (5) and (7) for indepth discussions on historical validation of econometric models

Table 2—Milk supply

Variable	Equation
COWSNMC(+1)	0 98 COWSNMC + COWSEMC - COWKSMC
COWKSMC	0 738171 + 0 326629 DUM6569 + 0 479213 DUM5758 - 0 149505 MILPF/FDD (2 41) (5 59) (6 21) (-3 50)
	+ 0 102808 COWSNMC + 0 501987 COWSEMC - 0 754813 MILPF/CATPFNF (2 85) (2 33) (-1 62)
	R^2 = 0 987
COWSEMC	0 203916 + 1 09718 MILPF(-1)/CALPF(-1) + 0 0841727 MILPF(-1)/FDD(-1) (0 52) (1 74) (1 41)
	+ 0 142653 COWSNMC(-2) - 0 318917 DUM6571 (18 82) (-6 02)
	R^2 = 0 961
MILAP / (COWSNMC(+1) + COWSNMC)/2	- 3 92481 + 0 135732 MILPF/FDD + 0 127848 • TIME (-2 61) (2 38) (2 83)
	+ 0 424017 MILAP(-1)/(COWSNMC + COWSNMC(-1))/2 (2 20)
	R^2 = 0 991
MILBC	- 0 381728 + 0 167949 COWSNMC (-5 87) (42 31)
	R^2 = 0 984
MILSPPLTS / (MILAP - MILBC)	- 1 73964 + 0 0717014 .TIME - 0 000473564 .TIME**2 (-17 00) (23 28) (-20 63)
	R^2 = 0 993
MILASFM / MILSPPLTS	- 0 0433665 + 1 02736 MILASFM(-1)/MILSPPLTS(-1) (-1 24) (38 61)
	+ 0 0236661 (MILPPFEMAT(-1) - MILPPMAT(-1)) (1 38)
	R^2 = 0 986
MILMFG	MILAP - MILBC - MILCCMC - MILSPFZ - MILSPECM
FDD	0 5563 CORPF(-1) + 0 0469 SORPF(-1) + 0 2565 OATPF(-1) + 0 0462 BARPF(-1)
	+ 0 0102 WHEPF(-1) + 0 0839 SOMPF(-1)

Note Numbers in parentheses are Student t values

A more stringent test of the predictive ability of an econometric model is Theil's U_2 statistic This statistic equals zero when the model's estimates for a particular variable exactly coincide with that variable's historical data It equals 1 if the forecast error generated by the model for a variable equals the error generated when we assume that variable remains unchanged from the previous year A value greater than 1 indicates that the model generates predictive errors exceeding those derived when we assume current-year values equal previous-year values

Another measure of the ability of a model to predict turning points is the TPE statistic Errors in predicting turning points stem from two sources First, the model may predict a turning point in a variable when one did not occur Second, the model may fail to predict a turning point when one did occur The TPE measures the relative frequency of the total number of turning point errors

The dairy-sector submodel was validated over the 1966-79 period [4] In the validation run, historical values were used for all nondairy-sector variables contained in FAPSIM The dairy-sector submodel generated values for lagged endogenous variables As a result, model errors over the historical period stem from two sources The first source is a result of

[4] A Gauss-Seidel algorithm is used to solve the model's system of simultaneous equations (4)

Table 3—Milk price

Variable	Equation
MILPPMAT	− 0 283616 + 0 0178284 MILBUT + 0 599078 MILPWDR (−1 31) (1 77) (3 15) + 0 0543683 MILAMCHEE (5 13) R^2 = 0 999
MILMWAT	− 0 226964 + 0 0114579 MILBUT + 0 449113 MILPWDR (−3 15) (3 34) (3 52) + 0 0663590 MILAMCHEE (9 31) R^2 = 0 999
MILOMP	MILCIDF + MILMWAT
MILECLOP	MILOOP + MILOMP
MILPPFEMAT	MILPFDIF + [(MILECLOP)(MILCCMC)(MILSPPLTS)/(MILAP − MILBC) + (MILMWAT)((MILASFM − MILCCMC)(MILSPPLTS))/(MILAP − MILBC)]/MILASFM
MILPF	[(MILPPFEMAT)(MILASFM) + (MILPPMAT)(MILSPPLTS − MILASFM)]/MILSPPLTS

Note Numbers in parentheses are Student-t values

Table 4—Butter sector

Variable	Equation
BUTSP	− 0 350572 + 1 22365 MILBUT/MILAMCHEE + 0 0116949 MILMFG (−1 30) (6 31) (2 40) − 0 152769 MILAMCHEE/MILPWDR + 0 153427 DUM74 (−2 42) (2 40) R^2 = 0 926
BUTCC/.NPC	0 0600122 − 0 00274512 BUTIR/MARIR + 0 00114400 DUM7879 − 0 00080432 DUM74 (9 17) (−2 46) (3 12) (−1 61) − 0 152247 .TIME/.NPC (−8 93) R^2 = 0 869
BUTIR	− 0 0858682 + 0 0130207 MILBUT + 0 0413876 .WRHD + 0 101378 .GASIR (−3 36) (16 24) (4 12) (2 95) R^2 = 0 996
BUTHB(+1)	0 0036095 + 0 0162062 BUTSP + 0 0156486 DUM7374 (0 32) (2 49) (2 49) R^2 = 0 203
MILBUT	$(-$ BUTSP + BUTCC + BUTHB(+1) − BUTHB + BUTMX + BUTCM − BUTMI + BUTHG(+1) − BUTHG$)^{-1}$
BUTHG(+1)	BUTSP − BUTCC + BUTHG − BUTHB(+1) + BUTHB − BUTMX − BUTCM + BUTMI
BUTGU	BUTHG(+1) − BUTHG − BUTGG + BUTMG − BUTDV

Note Numbers in parentheses are Student-t values

Table 5—Cheese sector

Variable	Equation
CHESP	– 6 07091 + 0 111475 MILMFG + 3 12002 MILAMCHEE/MILBUT (-3 74) (10 79) (3 74) + 0 0101392 MILAMCHEE/MILPWDR – 0 517856 DUM74 + 0 288983 DUM68 (0 60) (-3 22) (2 15) R^2 = 0 966
CHECT / .NPC	0 00307155 – 0 955747 CHEIRAM/.PC + 0 609481 .YPD$/(.NPC)(.PC) (1 11) (-2 02) (7 68) + 0 00368518 DUM7480 (6 90) R^2 = 0 990
CHEIRAM	0 0391632 + 0 0138097 MILAMCHEE + 0 0832134 .WRHD + 0 0832052 .GASIR (1 00) (4 20) (1 59) (1 13) R^2 = 0 995
CHEHB(+1)	– 0 139726 + 0 260058 CHEHB + 0 556479 CHESP (-3 23) (1 48) (3 06) R^2 = 0 581
MILAMCHEE	(– CHESP + CHECT + CHEHB(+1) – CHEHB + CHEMX + CHECM – CHEMI + CHEHG(+1) – CHEHG)$^{-1}$
CHEHG(+1)	CHESP – CHEHB(+1) – CHECT – CHEMX – CHECM + CHEMI + CHEHB + CHEHG
CHEGU	CHEHG(+1) – CHEHG + CHEGG + CHEMG – CHEDV

Note Numbers in parentheses are Student-t values

Table 6—Nonfat dry milk sector

Variable	Equation
MILSPND	0 220950 + 1 50162 BUTSP – 0 225588 CHESP (0 71) (8 62) (-4 44) R^2 = 0 961
MILCCND / .NPC	0 00667157 + 0 00140079 DUM73 – 0 00243915 MILPWDR/MILIR + 0 0515417 .YPD$/(.NPC)(.PC) (14 99) (5 07) (-10 95) (2 08) R^2 = 0 937
MILHBND(+1)	0 0420496 + 0 276756 MILSPND + 0 0647213 DUM74 (2 27) (2 35) (2 65) R^2 = 0 301
MILPWDR	(– MILSPND + MILCCND + MILHGND(+1) – MILHGND – MILMIND – MILHBND + MILMXND + MILBCND + MILHBND(+1) + MILCMND)$^{-1}$
MILHGND(+1)	MILCCND + MILSPND + MILHGND – MILBCND + MILHBND – MILMXND + MILMIND – MILHBND(+1) – MILCMND
MILGUND	MILHGND(+1) – MILHGND + MILGGND + MILMGND – MILDVND

Note Numbers in parentheses are Student-t values

Table 7—Evaporated and condensed mılk sector

Varıable	Equatıon
MILSPEC	8 54493 − 0 112500 .TIME + 0 939724 MILIREV/MILIR (33 12) (−16 89) (3 40) R^2 = 0 975
MILCCEC .NPC	0 0230599 + 0 00121912 DUM6568 − 0 00241843 MILIREV/MILIR − 0 459281 .YPD$/(.NPC)(.PC) (13 12) (4 06) (−2 15) (−5 37) R^2 = 0 980
MILHTEV(+1)	− 0 0291461 + 0 0546571 DUM6667 + 0 0862268 MILSPEC (−1 82) (3 35) (9 68) R^2 = 0 862
MILIREV	(− MILSPEC + MILCCEC + MILHTEV(+1) − MILMIEC + MILMXEC + MILCMEC − MILHTEV)$^{-1}$
MILSPECM	0 313912 + 1 96209 MILSPEC (6 63) (75 60) R^2 = 0 997

Note Numbers ın parentheses are Student-t values

Table 8—Frozen desserts and fluıd mılk sector

Varıable	Equatıon
MILCCFZ .NPC	0 0730505 − 1 90300 MILIRIC/.PC − 0 093076 .YPD$/(.NPC)(.PC) (7 28) (−3 46) (−0 61) R^2 = 0 740
MILIRIC	2 35231 + 0 335003 .WRHD + 0 0423319 MILECLOP − 0 0382222 .TIME (9 32) (5 50) (1 79) (−8 44) R^2 = 0 982
MILSPFZ	MILCMFZ − MILMIFZ + MILCCFZ
MILCCMC .NPC	2 45628 − 0 0915642 MILIR/.PCNAL − 0 0470187 MILIR/MILPWDR − 6 02686 .TIME (10 67) (−7 86) (−2 54) (−9 75) R^2 = 0 960
MILIR	0 221189 + 0 0491676 .WRHD + 0 105076 MILECLOP (14 85) (3 37) (13 24) R^2 = 0 997
DARCPI	− 0 039374 + 0 671257 MILIR + 0 102841 BUTIR + 0 190153 CHEIRAM + 0 0775998 MILIRIC (−4 80) (39 59) (11 69) (14 60) (10 26) R^2 = 0 999
DAIGP	((BUTGU)(MILSPPBUT) + (CHEGU)(MILCHCHSPP) + (MILGUND) (MILNFDSPP)) .10
DAIFC	290 148 + 9 97787 (MILPF)(MILSPPLTS) (10 42)(282 07) R^2 = 0 999

Note Numbers ın parentheses are Student-t values the inability of the model's equations to exactly predict economic events in the dairy sector in any particular year The second source stems from the model's inability to exactly predict past (lagged) values for dairy-sector variables

Table 9 presents the validation statistics computed for the dairy-sector variables for the 1966-79 period [5] Overall, the dairy-sector equations appear to predict with reasonable accuracy Total cow numbers (COWSNMC) were predicted with an average error of less than 1 percent and with no turning point errors Total milk production (MILAP) was predicted within about 1 percent Over the 14-year (1966-79) period, the model predicted three turning points in milk production that did not occur Two of those errors occurred in 1974 and 1975 when milk prices were increasing rapidly However, as indicated by the MARE and by Theil's U statistics, the failure to predict such turning points did not lead to substantial prediction errors

Milk prices are predicted with reasonable accuracy, as well as production, utilization, and prices of manufactured dairy products Of the 44 variables, 27 are predicted within a 5-percent error on average over the 1966-79 period, and 26 have fewer than four turning point errors (table 9) Only seven variables have average errors exceeding 10 percent, and only five variables have Theil's U_2 statistics exceeding 1 0

Commercial stocks of evaporated and condensed milk, nonfat dry milk, and butter were all predicted with an average

[5] The validation statistics presented in table 9 for milk production and price are similar to those obtained when the entire FAPSIM model was validated (*10*)

Table 9—Validation statistics, 1966-79

Variable	Mean absolute relative error	Theil U_1 statistic	Theil U_2 statistic	Turning point error[1]
	Percent			
COWSNMC	0 87	0 174	0 329	0 000
COWKSMC	2 58	215	445	429
COWSEMC	3 17	668	1 296	286
MILPF	5 34	332	673	143
MILECLOP	4 68	311	615	214
MILMWAT	6 39	344	703	143
MILPPFEMAT	5 31	340	697	143
MILPPMAT	6 04	327	668	143
MILBC	2 18	394	867	143
MILAP	1 03	320	619	214
MILSPPLTS	1 18	315	620	214
MILASFM	1 86	516	819	214
MILMFG	3 33	203	407	286
MILSPFZ	1 45	167	319	357
MILSPEC	3 08	231	424	214
MILSPECM	3 12	233	426	214
MILCCMC	1 95	531	1 394	429
MILBUT	6 64	379	942	429
MILAMCHEE	7 36	382	790	214
MILPWDR	4 56	277	497	143
MILOMP	4 93	327	644	286
MILIR	2 83	217	420	143
MILIRIC	2 92	180	367	143
MILCCFZ	1 45	449	862	214
MILCCEC	2 64	217	437	143
MILIREV	4 32	221	459	214
MILHTEV	14 26	241	445	286
MILSPND	9 08	424	743	571
MILCCND	4 63	238	513	286
MILHBND	27 33	282	486	500
MILGUND	54 33	304	552	357
CHESP	3 39	268	572	071
CHECT	2 72	250	542	071
CHEHB	9 17	355	598	357
CHEGU	101 34	569	1 420	143
CHEIRAM	3 83	247	505	143
BUTSP	6 28	520	951	500
BUTCC	4 55	505	1 113	357
BUTHB	43 77	315	540	500
BUTGU	50 86	403	790	286
BUTIR	6 06	382	885	071
DARCPI	3 06	221	450	143
DAIFC	4 98	336	735	214
DAIGP	47 69	580	1 393	214

[1] The number of turning point errors divided by 14, the total number of possible turning point errors

error exceeding 10 percent Such errors were not unexpected as commercial stocks of these dairy products are small relative to total production (generally less than 0 5 percent) and tend to be quite volatile Because such stocks comprise only a small portion of the demand for these dairy products, sizable prediction errors in these variables do not generally result in substantial errors in other variables

The three additional variables with MARE exceeding 10 percent were USDA purchases of cheese (CHEGU), butter (BUTGU), and nonfat dry milk (MILGUND) However, if 1979 is ignored, the MARE of USDA purchases of cheese declines from 101 to 34 percent and the MARE of USDA purchases of butter declines from 50 to 22 percent The large overestimates of Government purchases of butter and cheese in 1979 stem from an overestimate of milk production coupled with an underestimate of fluid milk consumption Both those prediction errors caused the model to overestimate butter and cheese production, which in turn caused substantial overestimates of USDA purchases of butter and cheese

The Theil U_2 statistic and the TPE statistic suggest that the large errors predicted for USDA purchases of butter, cheese, and nonfat dry milk are somewhat misleading First, the number of turning point errors are not substantial Second, for both butter and nonfat dry milk, the model outperforms a no-change-from-previous-year forecast Furthermore, such purchases were extremely volatile over the validation period and in many years were negligible For example, USDA purchases of cheese ranged from less than 3 0 million pounds in 1973 to 148 0 million pounds in 1977 The MARE statistic will tend to be large in such circumstances as a 3 0-million-pound error in 1973 is treated as equivalent to a 148 0-million-pound error in 1977

An additional validation test is to compare model predictions with actual data for periods not included in the estimation of model equations Therefore, we performed a 1-year simulation for 1980 The model estimated milk prices and production with less than a 1-percent error The only substantial error occurred in the model's estimate of USDA cheese purchases, it exceeded its actual value by 106 0 percent Again, the residual nature of this variable was the cause of the large error In 1980, the model overestimated cheese production by 5 0 percent, and it underestimated civilian consumption of cheese by 6 8 percent Together, these two errors caused the large overestimate of USDA cheese purchases This finding suggests that although the supply and utilization of dairy products may be estimated with reasonable error, the residual nature of dairy product purchases may still result in rather substantial errors in predictions for USDA purchases

Overall, the model seemed to perform adequately over the 1966-79 validation period and in 1980 The model demonstrated an ability to generate reasonable and accurate forecasts for a period characterized by rapidly changing milk prices

Analysis of Dairy Price Supports

In the remainder of this article, we use the dairy submodel and other submodels contained in FAPSIM to examine the effects of alternative dairy price-support options on the dairy sector and on other livestock and crops sectors We explore these impacts by comparing FAPSIM model forecasts under two alternative assumptions of price-support levels An initial FAPSIM model baseline for the 1981-85 period was generated under the assumption that manufactured milk would be supported at 75 percent of parity without semiannual adjustment A second set of model forecasts for the 1981-85 period were generated under the assumption that manufactured milk would be supported at 65 percent of parity without semiannual adjustment For this latter alternative, however, the price-support level was held at the April 1, 1981 level until it fell below 65 percent of parity Table 10 presents the changes in dairy-sector variables forecasted by FAPSIM

The results suggest that the farm price of milk (MILPF) would fall by about $0 11 per cwt in 1981 and by $0 83 per cwt in 1982 However, because of the assumption that the support level will not fall below the April 1, 1981 level, the full impact of the decline in support to 65 percent of parity does not occur until 1983 In 1983, the farm price of milk falls by $1 26 per cwt

Farmers respond to the decline in support by increasing cow slaughter and by reducing the number of dairy cow replacements By 1985, the model estimates that dairy cow numbers would fall by 0 22 million head Total milk production would be about 3 0 billion pounds lower in 1985, resulting from the decline in support to 65 percent of parity

The model indicates that civilian consumption of cheese (CHECT), butter (BUTCC), frozen milk products (MILCCFZ), and nonfat dry milk (MILCCND) would increase after the decline in support Such increases coupled with reduced supplies would decrease USDA dairy product purchases Consumption of evaporated and condensed milk declines slightly after the decline in support This adjustment occurs because the retail price of fluid milk (MILIR) declines relative to the price of evaporated and condensed milk, thus reducing demand for evaporated and condensed milk

USDA purchases of butter, cheese, and nonfat dry milk decline considerably In 1983, the cost of USDA purchases of butter, cheese, and nonfat dry milk were estimated to fall by $870 million Cash receipts to dairy farmers were estimated to fall by $1 8 billion in 1983

Table 10—Impact on dairy-sector variables of changing from 75 to 65 percent of parity, 1981-85[1]

Variable	1981	1982	1983	1984	1985
COWSNMC	-0 006	-0 049	-0 114	-0 172	-0 219
COWKSMC	006	039	040	022	011
COWSEMC	000	- 003	- 026	- 038	- 040
MILPF	- 106	- 834	-1 258	-1 226	-1 234
MILECLOP	- 106	- 843	-1 253	-1 221	-1 227
MILMWAT	- 106	- 843	-1 253	-1 220	-1 227
MILPPFEMAT	- 104	- 832	-1 247	-1 205	-1 222
MILPPMAT	- 112	- 848	-1 374	-1 380	-1 432
MILBC	000	- 001	- 008	- 020	- 029
MILAP	- 074	- 650	-1 563	-2 381	-3 034
MILSPPLTS	- 072	- 593	-1 476	-2 225	-2 838
MILASFM	- 060	- 505	-1 191	-1 447	-1 478
MILMFG	- 114	- 967	-1 777	-2 521	-3 130
MILSPFZ	007	048	067	062	059
MILSPEC	000	- 001	- 003	- 003	- 002
MILSPECM	000	- 002	- 006	- 006	- 004
MILCCMC	034	273	1 60	103	034
MILBUT	-1 690	-10 790	-23 190	-25 380	-28 630
MILAMCCHEE	-1 000	-8 880	-10 415	-9 170	-8 139
MILPWDR	- 045	- 228	- 660	- 716	799
MILOMP	- 106	- 843	-1 253	-1 221	-1 227
MILIR	- 011	- 089	- 131	- 128	- 129
MILIRIC	- 004	- 036	- 053	- 051	- 052
MILCCFZ	007	048	067	062	059
MILCCEC	000	- 002	- 002	- 002	- 002
MILIREV	- 019	- 156	- 241	- 239	- 244
MILHTEV	000	000	000	000	000
MILSPND	- 012	- 011	- 228	- 264	- 302
MILCCND	005	023	088	095	104
MILHBND	000	- 001	- 008	- 009	- 011
MILGUND	- 016	- 035	- 315	- 365	- 411
CHESP	000	- 085	045	004	- 023
CHECT	011	093	101	083	070
CHEHB	000	- 004	001	000	- 002
CHEGU	- 012	- 173	- 061	- 079	- 072
CHEIRAM	- 014	- 123	- 144	- 127	- 113
BUTSP	- 008	- 021	- 144	- 157	- 205
BUTCC	005	030	058	058	060
BUTHB	000	000	- 004	- 005	- 006
BUTGU	- 013	- 051	- 200	- 233	- 264
BUTIR	- 022	- 140	- 302	- 330	- 373
DARCPI	- 013	- 100	- 151	- 148	- 150
DAIFC	- 143	-1 141	-1 819	-1 937	-2 127
DAIGP	-66 21	-440 22	-869 66	-1,097 19	-1,359 91

[1] Change in respective variable predicted by FAPSIM after the price-support level was reduced to 65 percent of parity

The multicommodity nature of FAPSIM enables one to examine the impacts of a policy change on all agricultural commodity sectors Because the above policy change affects livestock production and the demand for feed, sizable adjustments may occur in both the beef and veal and the feed-grain sectors FAPSIM predicts that the price of corn would fall by 3 0 cents per bushel in 1985 Similar declines were estimated for sorghum and barley The price of oats and soybeans declined by 8 0 cents per bushel in 1985 The larger decline in the price of oats is expected because of the high proportion consumed by dairy animals The model predicts that the price of beef cattle would change by less than $1 00 per cwt as a result of changing the price-support level to 65 percent of parity

Although not large, these predicted changes in crop prices suggest that if researchers fail to allow for feedback among the crops, livestock, and dairy sectors when analyzing changes in dairy policies, sizable errors may occur To quantify the potential magnitudes of such errors, we simulated the 65-percent-of-parity scenario under the assumption that nondairy-sector variables remained at the levels predicted under the 75-percent-of-parity option Table 11 contains the percentage errors in adjustment resulting from assuming no feedback among the crops, livestock, and dairy sectors

Table 11 suggests that treating the dairy sector in isolation would result in moderate errors For example, failure to allow for feedback among the crops, livestock, and dairy sectors would result in about a 10-percent error in predicting the adjustment in milk production during the 1981-85 period Milk production would have been estimated to decline by an additional 0 4 billion pounds in 1985 under the assumption that the change in price-support policy would

Table 11—Estimated error in adjustment resulting from assumption of no feedback among the crops, beef and veal, and dairy sectors, 1981-85[1]

Variable	1981	1982	1983	1984	1985
	Percent				
COWSNMC	-7 50	-8 16	-9 65	-9 88	-11 87
COWKSMC	00	10 26	12 50	13 64	45 45
COWSEMC	00	-7 50	-7 69	-7 89	-10 00
MILPF	00	00	2 15	4 40	24
MILECLOP	00	00	2 23	4 34	00
MILMWAT	00	00	2 23	4 34	00
MILPPFEMAT	00	00	2 25	4 56	25
MILPPMAT	00	00	1 60	3.19	00
MILBC	00	00	-12 50	-5 00	-10 34
MILAP	-9 46	-7 85	-9 60	-10 92	-13 12
MILSPPLTS	-8 33	-8 26	-9 62	-10 92	-13 00
MILASFM	-10 00	-8 12	-9 99	-13 20	-18 24
MILMFG	-7 02	-6 41	-8 16	-9 36	-12 97
MILSPFZ	00	8 33	5 97	1 61	6 78
MILSPEC	00	100 00	150 00	100 00	100 00
MILSPECM	00	100 00	150 00	100 00	100 00
MILCCMC	-2 94	1 47	-8 13	-27 18	11 76
MILBUT	00	00	00	00	00
MILAMCHEE	00	00	3 98	8 83	00
MILPWDR	00	00	00	00	00
MILOMP	00	00	2 23	4 34	00
MILIR	00	00	2 29	4 69	00
MILIRIC	00	00	1 89	3 92	00
MILCCFZ	00	8 33	5 97	1 61	6 78
MILCCEC	00	100 00	150 00	100 00	100 00
MILIREV	00	1 92	3 73	6 69	2 46
MILHTEV	00	00	00	00	00
MILSPND	00	00	-3 51	-5 68	1 32
MILCCND	00	00	1 14	2 11	00
MILHBNC	00	00	-12 50	-11 11	00
MILGUND	00	2 86	-2 86	-4 38	73
CHESP	00	-8 24	-15 56	-250 00	-195 65
CHECT	00	-3 23	-6 93	-10 84	-2 86
CHEHB	00	-25 00	00	00	-100 00
CHEGU	00	-2 31	00	00	-56 94
CHEIRAM	00	00	4 17	8 66	00
BUTSP	00	-4 76	-4 86	-6 29	-1 95
BUTCC	00	-6 67	-1 72	-1 72	-1 67
BUTHB	00	00	00	00	00
BUTGU	00	00	-2 50	-4 29	-1 52
BUTIR	00	00	00	00	00
DARCPI	00	00	1 99	2 70	00
DAIFC	00	- 61	71	1 34	-3 10
DAIGP	- 77	-1 16	-1 83	-3 10	-5 52

[1] Estimated percentage error in respective variable resulting from assumption of no feedback

not have affected crop and livestock prices This additional adjustment compares with an estimated total adjustment in milk production of 3 0 billion pounds

The level of milk prices does not seem substantially affected by assuming no feedback among the crops, livestock, and dairy sectors The maximum error in estimated adjustment was 4 4 percent However, the Government's price-support operations through purchases of dairy products largely ensure that large errors in predicting the adjustment in milk prices will not occur

However, USDA purchases of dairy products could differ substantially because of the error in predicting the adjustment in milk production In 1985, failure to allow for feedback would result in a 5 5-percent underestimate of the adjustment in USDA outlays for purchases of dairy products, which amounts to an underestimate of $75 million

Conclusions

Mounting Government surpluses of manufactured dairy products and recent substantial Federal budget outlays for dairy price supports have renewed debate on the Government's role in the U S dairy industry A variety of proposals have been formulated by policymakers, farmer groups, and the dairy industry to reduce the Government's role in milk pricing and marketing The complexity of the dairy industry requires that a formal analytical framework be developed so that the potential impacts of alternative proposals on dairy farmers, milk processing firms, and consumers can be ana lyzed and quantified

The dairy submodel described here explicitly recognizes the role of the Government in supporting milk prices and marketing Furthermore, the model captures the interrelationships among dairy products at both processing and consumer levels

The dairy-sector submodel has been integrated into USDA's FAPSIM. FAPSIM estimates a simultaneous price-quantity equilibrium solution for a set of individual commodity models for beef, pork, dairy, chickens, eggs, turkeys, corn, oats, barley, grain sorghum, wheat, soybeans, and cotton FAPSIM can be used to explore the impacts of changes in dairy policies on crop and livestock producers as well as the impacts of changes in nondairy-sector variables (for example crop exports) on milk prices and production and on Government purchases of dairy products

The model suggests that reducing the price-support level on manufacturing milk from 75 to 65 percent of parity would cause the farm-level price of milk to fall $0 83 per cwt in 1982 and $1 26 per cwt in 1983 Total milk production would be about 3 0 billion pounds lower in 1985, and USDA outlays for purchases of dairy products would be about $1 4 billion lower in 1985

Failure to allow for feedback among the dairy, beef, and crops sectors results in an overestimate of the production adjustment that would occur as a result of reducing the support level to 65 percent of parity The magnitude of error is below 10 percent for most major dairy-sector variables such as milk production, prices, and Government outlays Failure to allow for feedback (solving a dairy submodel in isolation) among the dairy, beef, and crops sectors appears not to cause sizable errors in predicted adjustment Nevertheless, integrating a dairy-sector submodel with other commodity models increases the level of precision in predicting adjustment within the dairy sector Also, an integrated model permits us to examine the impacts of dairy-sector adjustment on other agricultural commodity sectors as well as to examine the effects of shocks in nondairy-sector variables on milk prices and production and on Government outlays

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