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Documentation for the USDA, Economic Research Service Annual U.S. Dairy Sector Econometric Model

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Abstract

The U.S. Department of Agriculture, Economic Research Service (ERS) maintains and uses a dynamic dairy sector model for the United States. This model is a tool for the development of 10-year dairy projections, as published in the *USDA Agricultural Projections* annual report. The model is also used to analyze changes in market conditions and the impacts of changes in various Federal Government policies on the dairy sector. This report provides documentation on the specification and estimation employed by this model to obtain projections for the dairy sector.

Keywords: dairy industry, dairy model, dairy forecasts, dairy projections, dairy sector, USDA baseline

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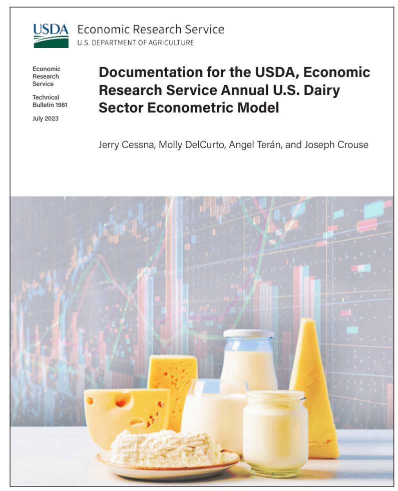


What Is the Issue?

This report provides documentation for the Annual U.S. Dairy Sector Model used by the USDA, Economic Research Service (ERS). Using econometric estimation, this dynamic model provides projections for supply, demand, and prices for U.S. milk and dairy products over a 10-year period. The model provides support for U.S. dairy projections published in the *USDA Agricultural Projections* report each year. The model is also used to analyze changes in market conditions and the impacts of changes in various Federal Government policies on the dairy sector.

The USDA, ERS Annual U.S. Dairy Sector Model is a comprehensive depiction of the dairy sector market, including the supply of milk; the allocation of milk fat and skim solids (also called nonfat solids) used in dairy products; various Federal Government policy variables; consumer demand quantities; imports and exports; stocks; and prices of milk and dairy products.

Dairy projections in the *USDA Agricultural Projections* report (also referred to as “baseline projections”) are determined each year through econometric work and judgment of the USDA Dairy Interagency Commodity Estimates Committee (Dairy ICEC). The Dairy ICEC includes representatives from four USDA agencies: Economic Research Service; Agricultural Marketing Service; Foreign Agricultural Service; and the Farm Production and Conservation Business Center. The chairperson for the Dairy ICEC is from the USDA, World Agricultural Outlook Board. While the Annual U.S. Dairy Sector Model assists the Dairy ICEC in its deliberations for the baseline projections, model results can be adjusted during the process based on committee judgement. The final baseline model results each year represent the consensus judgment of the committee.

This Technical Bulletin provides an in-depth discussion of how the model is specified, estimated, and calibrated in order to:

- provide transparency concerning much of the econometric work associated with USDA baseline projections for the dairy sector,
- explain how the model is used in combination with judgment of the USDA Dairy Interagency Commodity Estimates Committee, and

- explain how the model is used for scenario analyses concerning impacts of market conditions or various Federal Government policies on the U.S. dairy sector.

What Did the Study Find?

As stated in the *USDA Agricultural Projections* to 2031 report, "USDA's long-term agricultural projections…are a departmental consensus on a conditional long-run scenario for the agricultural sector. These projections provide a starting point for discussion of alternative outcomes for the sector." The Annual U.S. Dairy Sector Model, as calibrated to the baseline projections, is a tool to analyze alternative projected outcomes for the dairy sector due to impacts of changes in market conditions or impacts of changes to various Federal Government policies. Macroeconomic assumptions, feed prices, foreign export prices for dairy products, various Federal Government policy parameters, and other types of variables can be altered to analyze changes of supply, demand, and price variables for the dairy sector. The scenario model projections resulting from the altered inputs can be compared to the baseline projections in order to estimate impacts of the changes. An example is provided to demonstrate how the model can be used to analyze the effects of a change in feed prices on the dairy sector.

While scenario analyses from the model would be of interest to agricultural economists, policy makers, and private decision makers, the parameters used in the model would also be of interest. Prices and income are key signals of economic decision making. Prices are determined by the interaction of supply and demand, reflecting the willingness of producers to supply goods and consumers to buy these goods. Income changes affect the relative demand for these same goods. Key measures of producers' and consumers' responsiveness to changes in prices and income are price elasticities and income elasticities, respectively. Price and income elasticity estimates are provided in this report for many of the supply and demand variables included in the model.

The USDA, ERS Dairy Sector Model indicates that milk supply is very inelastic with respect to price changes. For the number of milk cows and average milk per cow, estimated elasticities for a 1-year lag of the milk-feed ratio are 0.031 and 0.016, respectively. Price and income demand elasticities for all dairy products included in the model are estimated to be inelastic, which is typical for food products. Price elasticities range from –0.035 for fluid milk to –0.868 for aggregated Class II products other than frozen products (mostly soft manufactured products such as yogurt, cottage cheese, sour cream, etc., that are in the Class II category of the Federal Milk Marketing Order system). Staple products, such as fluid milk, would be expected to be very price inelastic. Demand for products that are considered less essential, or luxury goods, are not as price inelastic. Some Class II products may fall in this category. Income elasticities estimates range from 0.069 for fluid milk to 0.604 for butter.

How Was the Study Conducted?

Historical data from various sources are used in the model. Data are drawn from USDA's Economic Research Service (ERS), National Agricultural Statistics Service (NASS), Agricultural Marketing Service (AMS), and Foreign Agricultural Service (FAS). The main data sources outside of USDA include the U.S. Department of Labor, Bureau of Labor Statistics (BLS) and the U.S. Department of Commerce, Bureau of the Census and Bureau of Economic Analysis. The model includes equations related to demand for dairy products; milk components of dairy products (milk fat and skim solids); manufacturing allocation of milk and milk components; imports and exports; stocks of dairy products; various Federal Government policies; and prices of milk and dairy products. Model equations include regressions, estimates based on conversion factors for milk components, and identities (straightforward calculations that are always true, such as milk production = number of milk cows x milk per cow). Regression statistics provided in this Technical Bulletin are used to assess how well regression equations reflect historical data relationships.

Documentation for the USDA, Economic Research Service Annual U.S. Dairy Sector Econometric Model

Introduction

Each year, USDA publishes 10-year annual conditional supply, use, and price projections for major agricultural commodities (including projections for the dairy industry), in the *USDA Annual Projections* report. These projections are also referred to as "baseline projections," and the baseline projections as a whole are often referred to as the "baseline scenario." According to the *USDA Agricultural Projections to 2031* report, the baseline scenario "…is not a USDA forecast about the future. Instead, it is a conditional, long-run scenario about what would be expected under the continuation of current farm legislation and other specific assumptions." The USDA Dairy Interagency Commodity Estimates Committee (Dairy ICEC) determines the projections for the dairy sector through a combination of econometric modeling and judgment of the committee members. The Dairy ICEC is represented by several USDA agencies including the Economic Research Service; Agricultural Marketing Service; Foreign Agricultural Service; and the Farm Production and Conservation Business Center. The chairperson for the Dairy ICEC is from the USDA, World Agricultural Outlook Board. For information on the USDA official baseline, see the *USDA Agricultural Projections to 2031* report (U.S. Department of Agriculture, 2022).

The USDA, Economic Research Service (ERS) maintains and uses a dynamic econometric model of the U.S. dairy industry to support USDA baseline projections. The model is comprehensive, simultaneously projecting milk production, fluid milk sales volume, manufactured dairy product consumption, dairy manufacturing allocation,[1] dairy product prices, and milk prices received by dairy farmers sequentially along a 10-year projection period. The model's predecessor is a regulatory analysis model formerly used by USDA, Agricultural Marketing Service Dairy Programs (U.S. Department of Agriculture, 2007).

While the Annual U.S. Dairy Sector Model assists the Dairy ICEC in its deliberations for the baseline projections, model results are adjusted during the process based on committee judgment. The final baseline model results each year represent the consensus judgment of the committee. The model is also a tool for analyzing scenarios involving changing market conditions and various Federal Government policies. Model input variables, including those related to market conditions and certain Federal Government policies, can be adjusted to analyze alternative scenarios compared with the baseline.

Model Variables and How Projections Are Derived

There are two broad categories of variables in most statistical models: exogenous and endogenous. The value for an exogenous variable is determined outside of the model in which it is used. The value for an endogenous variable is determined by its relationship with the other variables in the model.

[1] Dairy manufacturing allocation refers to the distribution of milk components among manufacturers, through market-based economic incentives, for the production of dairy products.

There are 381 variables in the model, including 202 exogenous variables and 179 endogenous variables. The exogenous variables include 127 historical data series, 34 dummy variables, and 41 intercept adjusters for altering baseline projections (based upon USDA, ICEC expert judgment). Descriptive statistics for variables are in appendix A. There are 179 equations in the model, equal to the number of endogenous variables. A complete list of model equations is in appendix B.

Some of the exogenous variables in the USDA, ERS Annual Dairy Sector Model are projected by USDA committees or analysts that are not part of the Dairy ICEC. The projected values are taken as assumptions by the Dairy ICEC. Examples of these exogenous variables include population, per capita disposable income, the Consumer Price Index (CPI) for all products, feed prices (corn, soybean meal, and alfalfa hay), and a cull cow price proxy.[2] The projections of some exogenous variables are determined by the judgment of the Dairy ICEC or the modeler. These projections include Oceania export prices for butter, skim milk powder (SMP), and Cheddar cheese;[3] the Western Europe export price for dry whey; the milk-fat tests and skim-solids[4] tests for producer milk; shipments of products to U.S. territories; exports and imports of minor dairy products; stocks of minor dairy products; production of minor dairy products; animal use of nonfat dry milk (NDM) and dry whey; conversion factors; and the weighted average Federal Milk Marketing Order Class I differential.[5]

Dummy variables (also called indicator variables) covering 1 or more years are included among the exogenous variables. For example, “dummy for 2009” indicates that the observation is 1 for the year 2009 but 0 for other years. Other dummy variables cover multiple years. For example, “dummy for years after 2010” indicates that the value is 0 for any year up to 2010 but 1 for years following 2010. Dummy variables are used in the regression equations to account for outliers and to obtain coefficients that are consistent with economic theory and fit historical data.

For the USDA baseline, model results are adjusted based on the consensus judgment of the Dairy ICEC. Intercept adjusters for regression equations, also known as add factors, are used for this purpose. While intercepts may be adjusted, gradient coefficients remain intact. This allows changes of endogenous variables in response to changes in other variables to remain the same for scenario analyses. Note that while dummy variables are used in regression equations for historical data, intercept adjusters, as described in this documentation, are used to adjust results in the projection period.

Projections of endogenous variables in the model depend upon the values of exogenous variables and simultaneous projections of other endogenous variables. Many of the supply and use endogenous variables are projected using regression equations, including those for milk cows, milk per cow, demand for dairy products, manufacturing allocation, stocks, imports, and exports. Most market-clearing dairy product prices are estimated with balance equations that set supply equal to demand. A few dairy product prices are calculated using regression equations that link to other prices in the model; these include the wholesale price of mozzarella, the CPI for fresh milk, the retail price for whole milk, and the retail price of ice cream. Projections of some endogenous variables are calculated using identity equations based on projections of other endogenous variables. For example, while the annual average number of milk cows and average milk per cow are endogenous variables projected through regression equations, milk production is an endogenous variable calculated by an identity: Milk production = number of milk cows x milk per cow. Other projections that are calculated through identities include milk marketings (milk production minus farm use), Federal Milk Marketing Order class prices, and beginning stocks (equal to ending stocks of the previous period). Projections of fluid use and

[2] A cull cow price proxy is used because national price data are not available for milk cows sold for slaughter. The cull cow price proxy currently used by the Dairy ICEC is the national price of 90-percent lean cutter cows (500 pounds and up) in dollars per hundredweight on a live equivalent basis.

[3] Oceania export prices are average prices for Australia and New Zealand combined.

[4] Skim solids are also called nonfat solids. They include protein, lactose, and minerals found in milk.

[5] In the FMMO system, fluid milk processors usually pay higher prices for milk than dairy product manufacturers. This is accomplished through Class I differentials, which vary geographically throughout the United States.

commercial use of dairy products are calculated by multiplying per-capita use projections (determined by regression analysis) by population projections.

The model regression equations are estimated using the ordinary least squares method. Given the size of the model, there are insufficient degrees of freedom to employ simultaneous-equation estimators such as two-stage least squares or three-stage least squares. Regression equations are tested for first-order serial autocorrelation using the Godfrey test (Godfrey 1978a, 1978b).[6] Projections are simulated using the SAS statistical software PROC MODEL procedure (SAS Institute, Inc., Version 9.4).

Milk fat and skim solids quantities associated with supply and demand elements are computed by using conversion factors. For most products, production quantities are multiplied by the conversion factors to compute milk fat and skim solids quantities. Exceptions are milk fat and skim solids used for butter production and skim solids used for production of dry skim milk products. Butter and dry skim milk products are produced from residual milk fat and skim solids that are available after production of all other dairy products. Conversion factors are used to compute production quantities of butter and dry skim milk products from available milk fat and skim solids (also called nonfat solids).

Milk fat and skim solids are allocated using conversion factors consistent with milk and dairy products. Prices for dairy products, fluid milk, and milk prices received by dairy farmers are solved within the model to achieve equilibrium conditions for supply and demand. Most dairy product prices included in the model are wholesale prices, and dairy product prices discussed in this report are wholesale prices unless otherwise specified.

The model includes variables and equations from the Federal Milk Marketing Order system. Many details concerning the Federal Milk Marketing Order system are not covered in this Technical Bulletin. For more information, see the Federal Milk Marketing Orders website, maintained by USDA, Agricultural Marketing Service (AMS), and *Federal Milk Marketing Orders: An Overview* (Greene, 2022).

Historical data and conversion factors are used for estimating quantities of milk fat and skim solids required for producing dairy products. These milk and component uses are classified on a basis consistent with the Federal Milk Marketing Order (FMMO) system as follows:

Class I – fluid uses

Class II – soft manufactured products (ice cream, cottage cheese, yogurt, etc.)

Class III – cheese

Class IV – butter, dry skim milk products,[7] whole dry milk, and canned milk.[8]

In 2020, about 62 percent of the U.S. milk sales volume was pooled in the FMMO system. Even though there is some U.S. milk that is not included in FMMO pools, the model includes class utilization for the United States as a whole and applies FMMO class prices to all U.S. milk to compute a U.S. "blend price." This simplifying assumption is based on the premise that prices for milk not pooled through the FMMO system are usually similar to prices of milk pooled in the FMMO system due to competitive factors.[9] The all-

[6] The Godfrey test p-values for first order correlation are displayed in the regression tables of this report. The null hypothesis of the test is that there is no serial correlation. If the p-value is below a critical value (perhaps 0.1 or 0.05), the null hypothesis that there is no serial autocorrelation is rejected.

[7] Dry skim milk products include nonfat dry milk, skim milk powder, and dry skim milk for animal use.

[8] The term "canned milk" in this documentation refers to evaporated or sweetened condensed milk in consumer-type packages.

[9] There are certainly unusual circumstances when prices for milk pooled on FMMOs are substantially different from prices for milk that is not pooled. For example, in 2020, market disruptions from COVID-19 and the Federal Government response to the pandemic resulted in substantial differences. Shocks such as these cannot be anticipated in model projections.

milk price projections are based on a correlation between the historical U.S. blend price calculated for model purposes and the actual all-milk price.[10]

Fluid use data are obtained from USDA, ERS. Milk fat and skim solids content for fluid milk are estimated from FMMO data.[11] Modeled manufactured products include American-type cheese (hereafter referred to as American cheese),[12] other-than-American cheese (hereafter referred to as other cheese),[13] butter, canned milk, dry whole milk, dry skim milk products, total frozen products, and other Class II products (hereafter referred to as Other Class II). Data for manufactured products, as reported by the USDA, National Agricultural Statistics Service (NASS), are used for all modeled dairy products except for Other Class II. Other Class II is treated as a composite solids-equivalent product, calculated for historical data purposes as the residual milk fat and skim solids, after meeting all other modeled product requirements.

The parameter estimates in this report were determined in October 2021. Most of the model's supply and demand equations are estimated using data from years 1990 through 2020. In some cases, the starting years for parameter estimates are more recent due to data limitations or substantially changing circumstances. Regression parameters are usually updated each year based upon the most recent complete annual data. Equations may be re-specified using a different structure if changes in the data warrant such re-specification or if the modeler finds a way to improve upon the previous model structure.

Accounting for Milk Fat and Skim Solids

Dairy markets are, in a sense, markets for milk components, which include milk fat and skim solids (protein, lactose, and minerals). The USDA Annual Dairy Sector Model includes extensive accounting of milk fat and skim solids. The milk fat and skim solids pounds required to produce each type of product are established by multiplying the production quantities of each of the products listed in table 1 by the appropriate conversion factors, as listed in the table. (For example, the quantities of milk fat and skim solid associated with butter production are 80.50 percent and 1.85 percent, respectively, of the product weight of butter produced.) The production quantity of all frozen dairy products combined is treated as though it is an aggregate composite product, including all regular ice cream, ice cream varieties with lower fat, frozen yogurt, sherbet, and other frozen dairy products. The milk fat and skim solids conversion factors for the aggregate frozen product are recent-year weighted averages across all frozen products. The production quantity of milk solids in all Other Class II products (mostly soft products other than frozen, such as yogurt, cottage cheese, etc.) is treated as though it is an aggregate composite product. Since historical data are not available for production of all Class II products, the U.S. Other Class II milk solids requirements are estimated for the historical period as the residual milk fat and skim solids left after accounting for all solids in Class I, III, IV, and total frozen

[10] According to the USDA, NASS website, the all-milk price "represents the gross price farmers…received in the given month per hundredweight (cwt) of milk sold at average fat test. The gross price is before deductions for items such as hauling and stop charges, advertising and promotion costs, and coop dues. It does not include hauling subsidies, but does include premiums and discounts for quality, quantity, or other reasons. The price per hundredweight equals total gross receipts divided by pounds of milk sold and multiplied by 100."

[11] A California FMMO was established in November 2018. Fluid milk data for California prior to this are from the California Department of Food and Agriculture.

[12] American cheese includes Cheddar, Colby, Monterey, Jack, washed curd, and stirred curd.

[13] Other-than-American cheese includes all natural cheeses other than those included for the American cheese category. The most prominent types are mozzarella, other Italian types, cream cheese, and Swiss cheese. According to the U.S. Dairy Export Council, more than 600 varieties of cheese are manufactured in the United States (U.S. Dairy Export Council, 2023). The other-than-American cheese category in the model does not include cottage cheese, which is a Class II product.

products. The proportions of the solids (milk fat versus skim solids) in Other Class II for the projection period are estimated based on recent trends.

Note that in table 1, the percentages of milk fat and skim solids add up to greater than 100 percent for American cheese and other cheese categories. The reason is that the weighted averages listed reflect the milk solids required for production, not the milk solids in the final product. Some of the milk solids used in cheese production go into the whey stream instead of the cheese, and some of the milk solids are lost in the process.

Table 1
Dairy product conversion factors (percentages)

Products	Milk fat and skim solids required per product unit	
	Milk fat	Skim solids
Producer milk	Increases gradually from 4.01 in 2021 to 4.23 in 2031	Increases gradually from 8.97 in 2021 to 9.08 in 2031
Fluid milk	Increases gradually from 2.19 in 2021 to 2.38 in 2031	Increases gradually from 9.13 in 2021 to 9.17 in 2031
Butter	80.50	1.85
American cheese [1]	32.82	85.10
Other cheese [2]	24.88	85.90
Nonfat dry milk	0.80	95.20
Canned milk	9.75	22.75
Dry whey	1.00	94.00
Dry whole milk	26.71	70.82
Frozen products [3]	9.14	9.96
Other Class II milk solids [4]	Increases gradually from 61.3 in 2021 to 62.1 in 2031	Decreases gradually from 38.7 in 2021 to 37.9 in 2031

[1] Based on Van Slyke Formula for Cheddar cheese. Milk-fat and skim-solids percentages for both American cheese and other cheese add to greater than 100 percent because the factors reflect solids required for production, not actual percentage in final product.
[2] Based on weighted average conversion factors of other cheeses.
[3] Composite frozen product category that includes ice cream, sherbet, and frozen yogurt.
[4] Other Class II composite solids equivalent product.

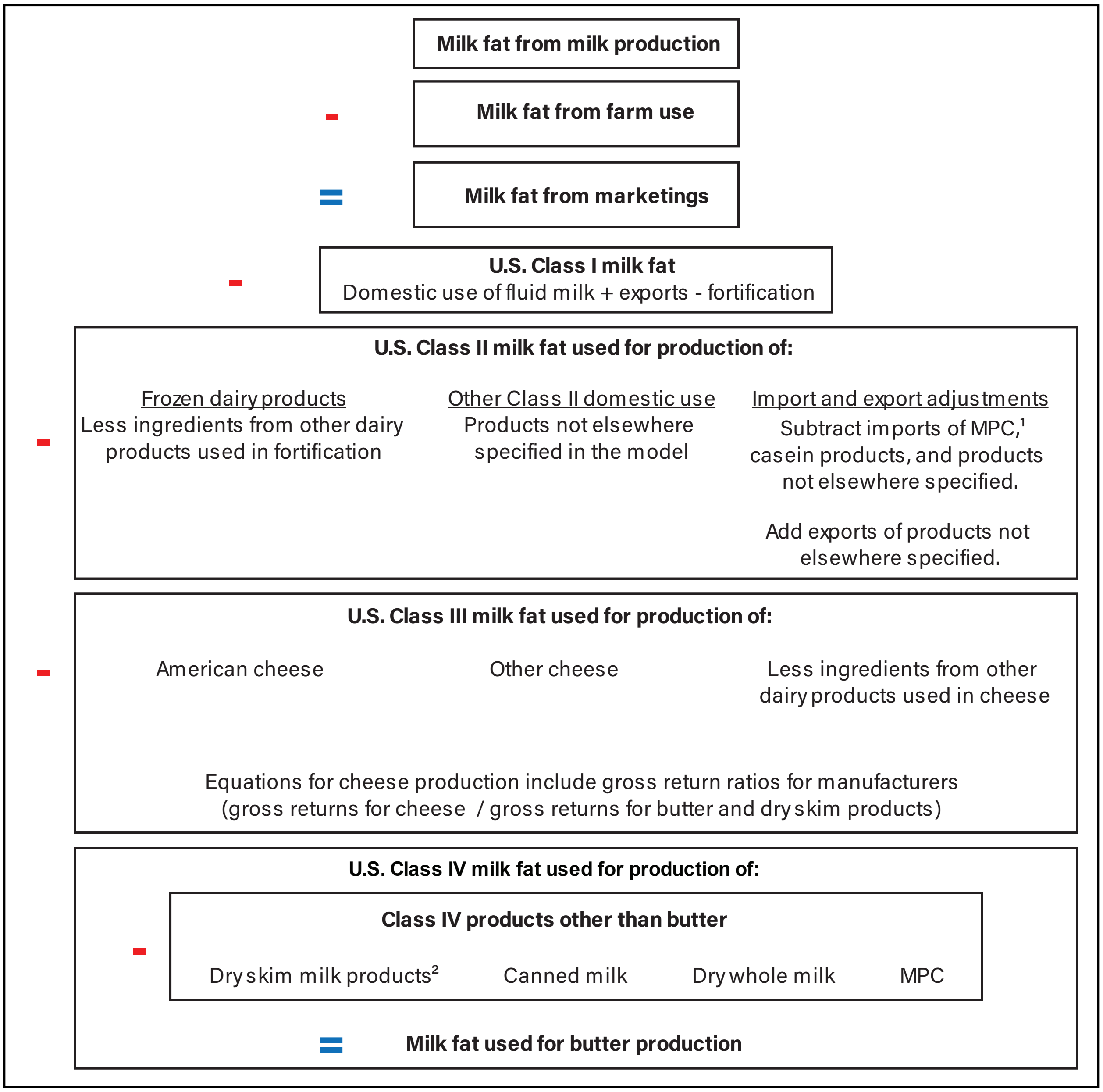
Source: USDA, Economic Research Service, Dairy Data (Supply and Utilization of Milk Fat and Skim Solids by Product); and USDA, Agricultural Marketing Service, *National Econometric Model Documentation, for Model Calibrated to USDA Agricultural Baseline Projections to 2016*.

The allocation of milk fat among dairy products is illustrated in figure 1. The same type of diagram could be made for skim solids by substituting the words "skim solids" for "milk fat" and interchanging the words "dry skim milk products" and "butter." For the projection period, milk fat and skim solids (milk components) are estimated for milk marketings (milk production minus farm use). Milk components are allocated for Class I products based upon domestic use of fluid milk, with adjustments for exports and fortification. Class II milk components are allocated based upon the projected production of Class II products (frozen dairy products and Other Class II), with some adjustments for projected ingredient imports and exports not elsewhere specified in the model. Class III milk components are allocated based on the projections of cheese production, minus dairy ingredients used in cheese. Milk components available for Class IV products are determined by subtracting Class I, II, and III components from milk marketings. Within the Class IV category, production quantities for butter and dry skim milk products are projected from residual milk fat and skim solids available. Note that even though butter and dry skim milk product production quantities are calculated from residual components, prices play a vital role, as cheese production equations include ratios of gross returns for cheese manufacturers to gross returns for manufacturers of butter and dry skim milk products.

Price Transmission

Price-transmission relationships in the model are displayed in figure 2. Market-clearing prices for major dairy products in the model are projected using balance equations that equate supply and demand variables. Given the simultaneous structure of the model, major dairy product supply and use quantities are functions of prices (along with other variables), while at the same time, prices are determined by supply and use.

Figure 1
Allocation of milk fat among dairy products in ERS Annual U.S. Dairy Sector Model



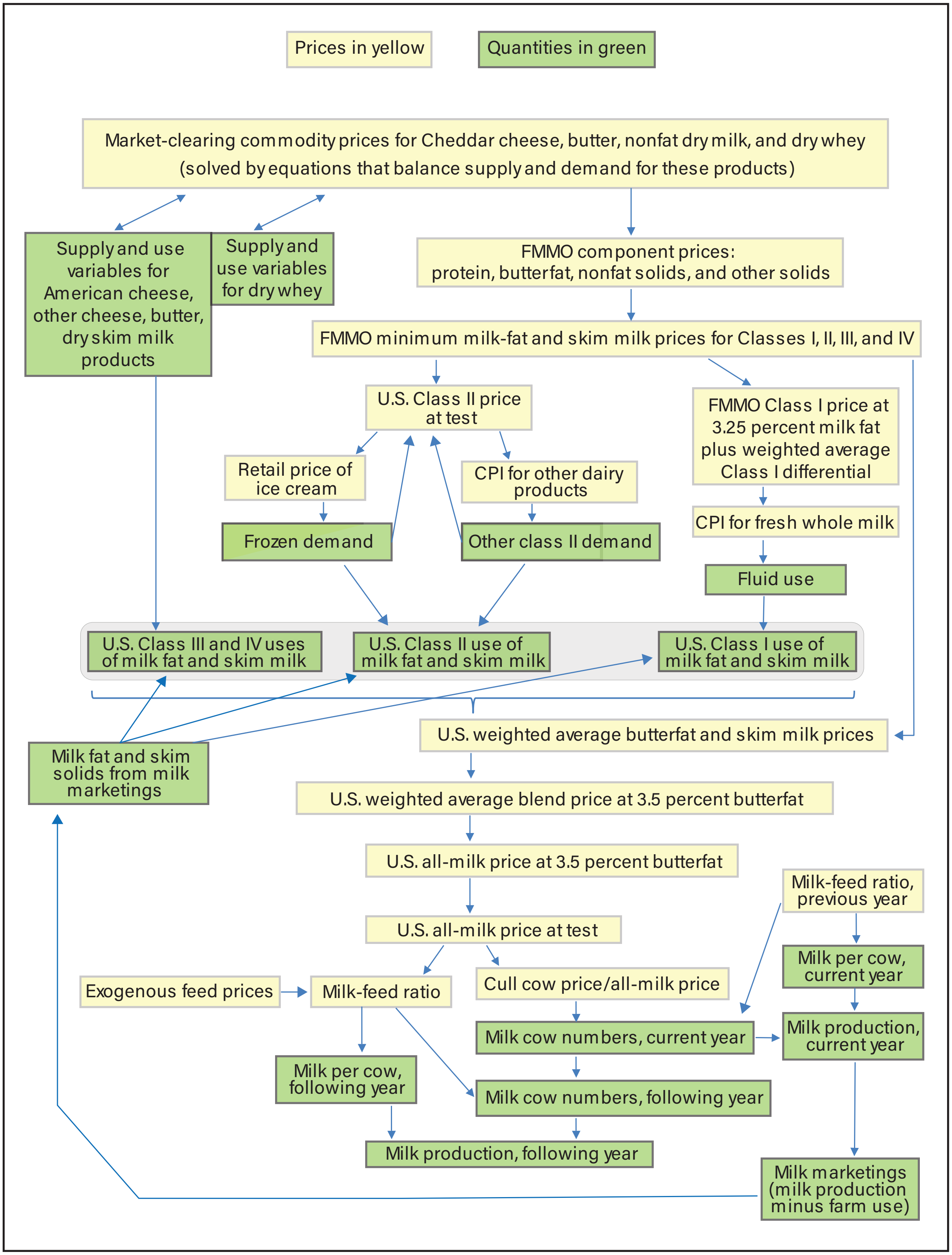
[1] MPC = milk protein concentrate.

[2] Dry skim milk products include nonfat dry milk, skim milk powder, and dry skim milk for animal use.

Note: The same type of diagram could be made for skim solids by substituting the words "skim solids" for "milk fat" and interchanging the words "dry skim milk products" and "butter."

Source: USDA, Economic Research Service (ERS).

Figure 2
Price transmission in ERS Annual U.S. Dairy Sector Econometric Model



FMMO = Federal Milk Marketing Order. CPI = consumer price index.

Source: USDA, Economic Research Service (ERS).

FMMO component and milk class price projections are computed from dairy product prices based on FMMO formulas (see appendix C). Since actual FMMO class prices are calculated from monthly and weekly dairy product pricing factors, but model class price projections are calculated from annual dairy product pricing factor projections, some simplification is necessary for modeling purposes. Advanced pricing and pricing factors are not included in the model.[14] The model FMMO formulas are the same as actual FMMO formulas, with the word "advanced" stricken in each place that it appears. The formulas applied to monthly prices for FMMOs are applied to annual average prices for model projections.

In the model, the FMMO Class I price is calculated for milk at 3.25 percent milk fat, with the weighted-average Class I differential for all FMMOs combined for the most recent historical year in the data. The FDA[15] minimum milk fat requirement for packaged milk sold to consumers as whole milk is 3.25 percent. The CPI for fresh whole milk is projected using the historical relationship of the CPI and the Class I price at 3.25 percent milk fat. This CPI for fresh whole milk is used in the regression equation for fluid milk demand.

The U.S. Class II price at test[16] plays a role in projecting production quantities of Class II products, while at the same time, production quantities of Class II products play a role in projecting the U.S. Class II price at test. Historical relationships are used to project the average retail price of ice cream and the CPI for "other dairy products," i.e., dairy products not covered by other dairy-related CPIs. These retail proxies are used in regressions to project demand for frozen products and Other Class II. Projected quantities for these products determine the weights of milk fat and skim solids that are used to project the Class II price at test.

Conversion factors are used to estimate corresponding U.S. classified milk quantities for milk fat and skim milk from the projected dairy product quantities.[17] The U.S. classified milk quantities are combined with FMMO minimum milk prices to calculate U.S. weighted-average butterfat and skim milk prices. The classified milk quantities for milk fat and skim solids are used, along with FMMO minimum classified prices, to estimate U.S. weighted-average butterfat and skim milk prices. These butterfat and skim milk prices are then used to estimate a weighted-average U.S. "blend price" at 3.5 percent butterfat. A regression using this U.S. blend price projects an all-milk price at 3.5 percent butterfat. The all-milk price at 3.5 percent butterfat is then converted to an all-milk price at test.

The projected all-milk price at test is used as the numerator in the milk-feed ratio[18] and the denominator in the cull cow price/milk price ratio. A modeled regression for the average annual number of milk cows includes the milk-feed ratio of the previous year and the cull cow price/milk price ratio for the current year. A modeled regression equation for average milk per cow includes the milk-feed ratio of the previous year. Milk produc-

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[14] Actual component prices used to compute the Class I milk price and the Class II skim milk price are announced by USDA, AMS in advance of a specific pricing month (no later than the 23rd of the previous month) using 2-week weighted-average wholesale product prices. Component prices used to compute the Class III and IV milk prices (and the milk fat component price used to calculate the Class II milk price) are announced by USDA, AMS after a specific pricing month (no later than the 5th of the following month) using 4- or 5-week wholesale product price weighted averages. For more information, see the Milk Marketing Order Statistics webpage, maintained by USDA, Agricultural Marketing Service.

[15] FDA = U.S. Department of Health, Food and Drug Administration.

[16] Reference to a milk price "at test" designates that the price is based on the milk fat and skim solids percentages of the milk. Milk fat and skim solids percentages of producer milk are determined through laboratory tests.

[17] Dry whey is a special case. While the dry whey price is one of the prices used in calculating the FMMO Class III price, dry whey production quantities are not directly used in determining Class III milk fat and skim milk quantities. The model does not include a full accounting of all the products made from whey. The model conversion factors for cheese are based on milk "used to produce" cheese, including milk that goes into the whey stream. This accounting is similar to accounting for Class III milk pooled in the FMMO system.

[18] The milk-feed ratio is an estimate of the number of pounds of 16-percent protein mixed dairy feed equal to 1 pound of whole milk from the farm. The ratio is calculated as the all-milk price divided by a feed-proxy value. USDA, National Agricultural Statistics Service calculates the feed-proxy value using prices for corn, soybeans, and alfalfa hay. For modeling purposes, USDA, ERS has substituted the soybean meal price in place of the soybean price in the feed proxy value as follows: feed value = 0.991 × corn price per bushel + 0.133 × ((soybean meal price per short ton/ 0.9)/2000) × 60 + 0.0205 × alfalfa hay price per short ton.

tion is determined by multiplying milk cows by milk per cow. Milk marketings are calculated by subtracting farm use from milk production. The milk marketings, along with milk fat and skim-solids tests (exogenous variables in the model), determine milk fat and skim solids available for milk to be used in all four classes of dairy products, which in turn affects all the dairy products and milk prices in the model.

Milk Supply

The model estimates milk production via average milk per cow and average annual number of cows (table 2). The year-over-year difference in average number of cows is estimated as a function of the milk-feed price ratio of the previous year,[19] the ratio of a cull cow price proxy to the all-milk price, and trend variables. The cull cow price proxy currently used is the live equivalent of 90-percent lean cutter cows, 500 pounds and up, as reported in the *Livestock, Dairy, and Poultry Outlook* report published by USDA, ERS. The change in the number of cows is then calculated as the sum of the year-over-year difference in the number of cows in the current year and the number of cows in the previous year. Milk production per cow is estimated as a function of the previous year's milk-feed price ratio and trend variables. A term that includes a dummy for years after 2014 times the trend has a negative coefficient, reflecting a decrease in the upward movement of the trend in milk per cow in recent years. There is a tradeoff between milk components and milk production of cows. Perhaps the slower growth in milk per cow in recent years reflects the higher growth in milk components.

The regressions indicate a very inelastic response of the milk supply to prices in the previous year. For both equations, point price elasticities were calculated at means of the variables over the historical period. For the number of milk cows and average milk per cow, estimated point price elasticities for a 1-year lag of milk-feed ratio of the previous year are 0.031 and 0.016, respectively. For the number of milk cows, the point price elasticity for the ratio of the cull-cow price to all-milk price of the current year is –0.013.

Table 2
Milk supply equations (using annual data from 1990 to 2020)

Dependent variable	Parameter [1 2]	Estimate	t Value	Pr > |t|	Elasticities [3]	R-Square	Godfrey test 1st order (P-value)
Year-over-year change in average number of milk cows	Intercept	–363.800	–4.93	<.0001		0.6981	0.3003
	lag (All milk price / feed value)	121.056	5.23	<.0001	0.031		
	Cull cow price proxy / all milk price	–15.263	–1.04	0.3087	–0.013		
	Dummy for years after 2004	121.963	5.13	<.0001			
	Dummy for years after 2010	79.544	2.74	0.011			
Average milk per cow	Intercept	14,091.050	81.61	<.0001		0.998	0.8915
	lag (All milk price / feed value)	133.218	2.55	0.0171	0.016		
	Trend [year – 1989]	315.654	78.61	<.0001			
	Dummy for years after 2014 × trend	–11.316	–4.37	0.0002			

[1] For years when the Milk Income Loss Contract (MILC) program was in operation, adjustments have been to the all-milk price to account for payments received by dairy operations that produced less than the annual production cap. For more information, see appendix D.
[2] The cull cow price proxy currently used is the live equivalent of 90-percent lean cutter cows, 500 pounds and up, as reported in the *Livestock, Dairy, and Poultry Outlook* report published by USDA, Economic Research Service.
[3] Point elasticities at the means of the variables are displayed. Although the dependent variable in the first equation is the year-over-year change in milk cows, the elasticities displayed reflect the percentage changes in milk cows relative to the explanatory variables.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and USDA, Farm Service Agency.

[19] Milk production variables, both the number of milk cows and milk per cow, tend to respond to milk prices and input prices with lags of several months. Sometimes the responses occur within the same calendar year, but at other times, the responses span from 1 calendar year to the next. Moreover, while changes in prices have effects on the milk supply, changes in the milk supply also have effects on prices. For these reasons, it would be difficult for an annual model to capture a same-year supply response to the milk-feed ratio.

Bozic et al. (2012), using data from 2006 to 2010, also found that the price responses of the milk supply were very inelastic with a 1-year lag. In that study, the effects of milk and feed prices were examined as separate terms, and results were reported for both milk production and milk cow numbers. Price elasticities for milk production, with respect to the milk price and feed value of the previous year, were estimated to be 0.094 and –0.031, respectively. Price elasticities for milk cow numbers, with respect to the milk price and feed value of the previous year, were estimated to be 0.070 and –0.034, respectively.

For years when the Milk Income Loss Contract (MILC) program was active (2002–13), the milk-feed ratio was adjusted in the model to account for estimated payments to relatively small dairy operations that did not exceed the production cap for the program. A dairy operation in this category would have received higher revenue for each additional pound of milk produced, providing an incentive to increase production. Adjustments to the milk-feed ratio to account for historical MILC payments to small producers help to improve the regression coefficients used in projecting milk cow numbers and milk per cow. See appendix D for more information concerning adjustments that were made. Considerable difficulties exist in attempting to model possible supply responses to more recent Government risk management programs and direct payments to dairy farmers. Thus, this model does not account for such possible supply responses. See appendix E for more information concerning these issues.

Leap-year adjustments for milk production and milk per cow are made for applicable years in the projection period. Milk marketings are calculated as milk production minus farm use (an exogenous variable in the model). Projections of milk fat and skim solids from marketings are calculated using exogenous milk fat and skim-solids tests, as determined by judgment of the Dairy ICEC.

Demand for Fluid Milk and Dairy Products

Per capita demand quantities for fluid milk and manufactured dairy products are estimated as functions of product prices, real per capita income, and other factors (table 3). For the most part, dairy product prices are deflated by the CPI for all products.[20] For the butter demand equation, deflating the butter price by the CPI for food results in a regression that more closely fits the data. Real per capita income is reported by the U.S. Department of Commerce, Bureau of Economic Analysis. Total consumption for each specific product or product aggregate is specified as per capita demand times the projected population for each year. Leap year adjustments are made for applicable years in the projection period.

Fluid milk demand responds to the CPI for fresh whole milk and real per capita disposable income. While most of the demand equations are in log-log form, a year-over-year specification better fits the data for per capita milk consumption. A dummy for years after 2009 accounts for the greater decline in fluid milk consumption in recent years. A recent USDA, ERS study found that per capita milk consumption in the 2010s fell significantly for children, teenagers, and adults (Stewart et al., 2021).

[20] The calculation to adjust for inflation to obtain a real price is: nominal price/(CPI for all products/100); or equivalently: (nominal price/CPI for all products) × 100.

Table 3

Per capita demand equations (using annual data)

Dependent variable	Period	Parameter [1,2]	Estimate	t-Value	Pr > |t|	Elasticities [3]	R-Square	Godfrey test 1st order (P-value)
Year-over-year change for per capita fluid milk consumption	1990–2020	Intercept	–116.574	–2.58	0.0161		0.9981	0.4623
		ln ((CPI fresh whole milk / CPI all) × 100)	–6.375	–1.64	0.1133	–0.035		
		ln (Real per capita disposable income)	12.530	3.46	0.0020	0.069		
		ln (Food away from home expenditures / total food expenditures)	–16.94	–2.17	0.0394			
		Dummy for years after 2009	–3.399	–4.72	<.0001			
ln (Butter per capita consumption)	1990-2020	Intercept	-5.134	-3.700	0.001		0.9724	0.4792
		ln ((Butter price / CPI food) × 100)	-0.056	-1.870	0.074	-0.056		
		ln (Real per capita disposable income)	0.604	3.770	0.001	0.604		
		lag (ln (butter consumption per capita))	-0.056	-3.300	0.003			
		Dummy from years 2002 to 2010	-0.056	-3.300	0.003			
ln (Cheese per capita consumption)	1990-2020	Intercept	0.389	0.35	0.7299		0.9890	0.0378
		ln (Cheddar cheese price / CPI all) × 100)	–0.066	–2.64	0.0138	–0.066		
		ln (Real per capita disposable income)	0.304	2.88	0.0078	0.304		
		Trend [year – 1989]	0.008	4.48	0.0001			
		Dummy for 2009	–0.028	–1.80	0.0836			
ln (Dry skim milk products per capita consumption)	2005–2020	Intercept	1.413	9.81	<.0001		0.5900	0.3359
		((Nonfat dry milk price / CPI all) ×100)	–0.002	–1.26	0.2328	–0.124		
		Trend [year – 2004]	–0.022	–3.17	0.0089			
		Dummy for 2006	–0.211	–1.80	0.0999			
		Dummy for 2012	0.190	1.84	0.0927			
ln (Dry whey per capita consumption)	1990–2020	Intercept	2.842	14.12	<.0001		0.8852	0.6040
		ln ((Dry whey price / CPI all) × 100)	–0.364	–4.69	<.0001	–0.364		
		Trend [year – 1989]	–0.417	–11.68	<.0001			
		Dummy for years before 1992	–0.568	–4.94	<.0001			
ln (Frozen products per capita consumption)	1990–2020	Intercept	–0.509	–0.32	0.7551		0.9661	0.1662
		ln ((Retail price of ice cream / CPI all) × 100)	–0.185	–2.58	0.0156	–0.185		
		ln (Real per capita disposable icome)	0.384	2.41	0.0230	0.384		
		Trend [year – 1989]	–0.017	–5.99	<.0001			
ln (Other Class II solids per capita consumption)	1995–2020	Intercept	2.735	1.79	0.0871		0.5779	0.0445
		ln ((CPI other dairy products / CPI all) × 100)	–0.868	–2.91	0.0084	–0.868		
		ln (Real per capita disposable income)	0.277	2.42	0.0246	0.277		
		Dummy for 2000	–0.144	–1.92	0.0679			
		Dummy for 2002	–0.202	–2.72	0.0128			

[1] CPI = Consumer Price Index.
[2] Real per capita disposable personal income is in $1,000s.
[3] For terms that do not have constant elasticities, point elasticities are computed at the means of the variables. For the fluid milk quantity consumed, elasticities are computed for the fluid milk quantity consumed, not the change in fluid milk quantity consumed.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; USDA, Farm Service Agency; USDA, Foreign Agricultural Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Domestic demand quantities for hard manufactured products (butter, cheese, dry skim milk products, and dry whey) respond to associated wholesale prices included in the model. The regression for dry skim milk products is in a log-linear form, since the price response was a better fit than an equation in log-log form.

Income responses are found to be significant for butter and cheese but not for dry skim milk products and dry whey. For dry skim milk products, only data since 2005 were used to better represent the state of the industry in recent years. Since 2005, there has been a downward trend in the consumption of dry skim milk products. This trend may, in part, be due to a greater export demand bidding some of these products for the domestic market. For frozen products, demand responds to the average retail price of ice cream, real per capita disposable income, and trend. The demand for Other Class II responds to the CPI for other dairy products and per capita disposable income. For all the per capita demand equations except for frozen dairy products, dummy variables are included in the equations to improve statistical results.

Price and income elasticities are included in table 3. In cases where equations are in the log-log form, the coefficients for the parameters can be interpreted as elasticities. In cases where there are not constant elasticities, point elasticities are reported at the means of the variables. Price and income demand elasticities are all inelastic, which is typical for food products. Price elasticities estimates range from –0.035 for fluid milk to –0.868 for Other Class II. Staple products such as fluid milk would be expected to be very price inelastic. Products that are considered less essential, or luxury goods, are not as inelastic. Some Other Class II products may fall in this category. Income elasticity estimates range from 0.069 for fluid milk to 0.604 for butter.

Inelastic demand responses to both price and income were also reported for dairy products in a USDA Report to Congress concerning Dairy Checkoff Program[21] 2018 activities (USDA, 2020). In an independent analysis for the report, Texas A&M University researchers (using quarterly data from 1995.1 to 2018.4) estimated own-price elasticities for butter, cheese, and fluid milk of –0.121, –0.137, and –0.075, respectively. Price elasticities for all dairy products combined were estimated to be –0.066 on a milk-fat milk-equivalent basis and –0.063 on a skim-solids milk-equivalent basis.[22] The Texas A&M researchers estimated that butter and cheese inelastic income responses were 0.276 and 0.518, respectively. For fluid milk, the Texas A&M income elasticity estimate was –0.441, inelastic and negative, implying that fluid milk is an inferior good. While the USDA, ERS model income elasticity for fluid milk is not negative, it is very small (only 0.069).

While we did not find elasticity estimates in the literature for all frozen products combined as estimated in the USDA, ERS model, estimates for specific products have been published. Using quarterly household scanner data from 1988 through 1992, Bergtold et al. (2004) estimated demand elasticities for several processed foods including ice cream and yogurt. Price elasticities were estimated to be inelastic and varied by quarter, ranging from –0.810 to –0.910.

Differences between model elasticities displayed in table 3 and those from existing literature can be attributed to differences in methods, time periods, and the data series used in the analyses. Price elasticity analyses that make use of household scanner data (based on variations among households and specific products) tend to show higher price elasticities than analyses of annual national aggregates (based on variations for broad product categories over the years). While retail prices are commonly used for demand analysis, wholesale price proxies are used for most products in the USDA, ERS model—with the exceptions of fluid milk, frozen products, and Other Class II. Wholesale price elasticities tend to be smaller than retail price elasticities. Since a wholesale price for a particular product is lower than a retail price for that product, a marginal change at the wholesale level is larger in percentage terms than an equal marginal change at the retail level. Moreover, wholesale prices are known to be more variable

[21] Two research and promotion programs, overseen by USDA, Agricultural Marketing Service, are commonly called Dairy Checkoff programs. These programs include the Dairy Promotion and Research Program and the Fluid Milk Processor Promotion Program.

[22] To analyze aggregate demand for dairy products, product quantities are often converted to a common milk equivalent, usually based on the milk-fat content of the products (milk-fat milk-equivalent basis) and the skim-solids content of the products (skim-solids milk-equivalent basis).

than retail prices, as retailers do not typically pass along all the price variations in wholesale prices to consumers. For these reasons, percent changes in wholesale prices tend to be relatively large in comparison to corresponding percent changes in quantities demanded.

For some products, we could not find comparable elasticities for U.S. demand in recent literature. These include dry skim milk products, dry whey, and Other Class II. Most demand analyses in existing works are for retail products, not products typically used as ingredients, such as dry skim milk products and dry whey. Other Class II is a product aggregate constructed for USDA, ERS modeling purposes. While some elasticities are reported in the literature for products in the category, comparisons of these elasticities to the ERS model estimates are not particularly useful since none of the specific Other Class II products dominate the category.

Since retail prices and retail price indices are used for some demand equations, they must be projected (table 4). All retail prices and price indices are deflated by the CPI for all products.

Table 4

Equations for retail prices and retail price indexes (using annual data)

Dependent variable [1]	Period	Parameter [2]	Estimate	t-Value	Pr > |t|	Elasticities [3]	R-Square	Godfrey test 1st order (P-value)
Retail ice cream price / CPI all	1990–2020	Intercept	0.003	2.03	0.0527		0.9671	0.1617
		U.S. Class II price at test / CPI all	0.014	2.89	0.0076	0.086		
		lag (Retail ice cream price / CPI all)	0.745	9.48	<.0001			
		Dummy for 2009 to 2012	0.001	4.00	0.0005			
Year-over-year change for (CPI fresh whole milk / CPI all)	1990–2020	Intercept	0.000	–0.07	0.943		0.8910	0.6856
		Year-over-year change for (Class I price at 3.25 fat percent with average Class I differential / CPI all)	3.069	9.23	<.0001	0.297		
ln (Retail price, fresh whole milk, fortified / CPI all)	1990–2020	Intercept	–4.045	–587	<.0001		0.9799	0.8336
		ln (CPI fresh whole milk / CPI all)	1.283	21.08	<.0001	1.283		
		Dummy for years before 2001	0.067	7.32	<.0001			
		Dummy for years after 2011	–0.059	–6.7	<.0001			
ln (CPI other dairy products / CPI all)	1990–2020	Intercept	0.140	1.91	0.067		0.965	0.0374
		ln (U.S. Class II price at test / CPI all)	0.100	3.19	0.0037	0.100		
		lag (ln (CPI other dairy products / CPI all))	0.854	11.08	<.0001			
		Dummy for years after 2015	–0.023	–1.72	0.0967			
ln (CPI food / CPI all)	1990–2020	Intercept	0.000	0.15	0.8855		0.9864	0.0648
		lag (ln (CPI food / CPI all))	0.920	10.11	<.0001	0.920		

[1] CPI = Consumer Price Index.

[2] The U.S. Class II price at test is based upon estimated utilization of milk components used in Class II products consumed in the United States.

[3] For equations where elasticities are not constant, point elasticities are computed at the means of the variables.

Source: USDA, Economic Research Service analysis using data from USDA, Agricultural Marketing Service, and U.S. Department of Labor, Bureau of Labor Statistics.

The retail price of ice cream is estimated as a function of the U.S. Class II price at test (i.e., based on estimated U.S. milk fat and skim milk in Other Class II), a lag of the retail price from the previous year, and a dummy variable to obtain a better fit. For the CPI for fresh whole milk, a year-over-year specification is found to be a good fit to the data; it is estimated as a function of the Class I price at 3.25 percent milk-fat test plus the weighted-average Class I differential. The average retail price for fresh fortified whole milk in gallons is estimated in the model as a function of the CPI for fresh whole milk. The CPI for other dairy products also responds to the U.S. Class II price at test, the CPI for all dairy products, a lag of the CPI for other dairy products from the previous year, and a dummy for years after 2015. The real CPI for food is estimated as a function of the previous year's real CPI for food.

Manufacturing Allocation

Production of cheese, butter, and NDM depends, in part, on relative gross returns of these products to manufacturers (gross values in table 5). Equations in the model are used to estimate these gross values based on components in the associated products. The Cheddar cheese price is used as the proxy cheese price in the equation for the gross value of American cheese, which is mostly Cheddar. The mozzarella price is used as the proxy cheese price in the gross value equation for other cheese since mozzarella is the most prominent variety in the other cheese category and a price series for mozzarella is available. The mozzarella price is estimated in relationship to the Cheddar cheese price, the mozzarella price of the previous year, a dummy for 1995–98, and a dummy for 2010–12.

Table 5
Gross value and mozzarella price equations

Product	Gross value equation
American cheese	(Cheddar cheese price/100) × 10.043 + (butter price/100) × 0.304 + (dry whey price/100) × 6.1381
Other cheese	Mozzarella cheese price × 9.455 + (butter price/100) × 2.1 + (dry whey price/100) × 6.254
Butter and nonfat dry milk	(Butter price/100) × 4.475 + (nonfat dry milk price/100) × 8.998

Econometric estimation of mozzarella price

Dependent variable	Parameter [1]	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
Mozzarella price	Intercept	0.260	2.69	0.0126	0.9589	0.2098
	Cheddar cheese price	0.008	14.38	<.0001		
	lag (Mozzarella price)	0.315	5.76	<.0001		
	Dummy for 1995 to 1998	−0.129	−3.59	0.0014		
	Dummy for 2010 to 2012	0.111	2.96	0.0066		

[1] The mozzarella price is in dollars per pound, but the other wholesale dairy product prices are in cents per pound.

Source: USDA, Economic Research Service analysis using data from USDA, Agricultural Marketing Service.

The coefficients in the gross value equations are based upon estimated product yields per 100 pounds of milk. For American cheese, using Cheddar cheese as a proxy, 100 pounds of producer milk is estimated to yield about 10.043 pounds of cheese, with 0.304 pounds of whey cream butter and 6.1381 pounds of dry whey estimated as the byproduct quantities. Thus, multiplying these coefficients by the associated commodity prices and summing the values provides a proxy for the gross value of the milk used in American cheese manufacturing. For other cheese, using mozzarella as a proxy, 100 pounds of producer milk are estimated to yield about 9.455 pounds of cheese, 2.1 pounds of whey cream butter, and 6.254 pounds of dry whey. For the gross value of butter and NDM, 100 pounds of producer milk is estimated to yield about 4.475 pounds of butter and 8.998 pounds of NDM.

The manufacturing allocation quantities of major dairy products are projected using historical USDA, NASS data for American cheese, other cheese, and dry whey (table 6). American cheese production and other cheese production are estimated as functions of gross values of these cheeses relative to the gross value of butter and NDM. The equation for the production of American cheese is in log-log form and includes a lag of its production and two dummy variables to account for outliers, in addition to the relative price variable. The equation for other cheese production is linear and includes dummy variables and a trend variable, in addition to the relative gross-value variable. Dry whey production, as a ratio to cheese production, is estimated as a function of the real wholesale price of dry whey, trend, and two dummy variables to account for outliers. Projections for the production of dry whole milk and canned milk are exogenous values determined by the judgment of the modeler.

Table 6

Manufacturing allocation equations (using annual data from 1990 to 2020)

Dependent variable	Parameter [1 2]	Estimate	t-Value	Pr > |t|	Elasticities [3]	R-Square	Godfrey test 1st order (P-value)
ln (American cheese production)	Intercept	0.232	1.13	0.2703		0.9833	0.376
	ln (Gross value American cheese / gross value of butter and nonfat dry milk)	0.106	1.72	0.0975	0.106		
	lag (ln (American cheese production))	0.974	39.05	<.0001			
	Dummy for 1991	−0.076	−3.04	0.0055			
	Dummy for 2003	−0.054	−2.19	0.0381			
Other cheese production	Intercept	2,331.881	8.99	<.0001		0.9974	0.050
	Gross value other cheese / gross value of butter and nonfat dry milk	551.173	2.36	0.0265	0.120		
	Trend [year – 1989]	145.485	42.18	<.0001			
	Dummy for 2007	355.815	3.7	0.0011			
	Dummy from 2010 to 2019 x trend [year – 1989]	12.095	5.43	<.0001			
	Dummy for years after 2017	215.802	3.5	0.0017			
ln (Dry whey production / cheese production)	Intercept	−1.549	−32.13	<.0001		0.8841	0.1043
	ln (Dry whey price / CPI food)	0.017	0.73	0.469	0.017		
	Trend [year – 1989]	−0.035	−51.50	<.0001			
	Dummy for 2001	−0.071	−2.24	0.0339			
	Dummy for 2014	−0.146	−4.25	0.0002			

[1] Gross values are estimates of returns to processors for use of milk in the applicable products. Gross values for cheese reflect values of the cheese and whey. The gross value for butter-powder reflects returns of butter and nonfat dry milk as co-products.
[2] CPI = Consumer Price Index.
[3] For equations where elasticities are not constant, point elasticities are computed at the means of the variables.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; and U.S. Department of Labor, Bureau of Labor Statistics.

Production quantities of butter and dry skim milk products are determined from residual milk fat and skim solids left after milk fat and skim solids have been allocated to the other products using conversion factors listed in table 1. Quantities of residual milk fat and skim solids are divided by conversion factors in table 1 to calculate production quantities of butter and dry skim milk products. Even though production quantities of butter and dry skim milk products are allocated from residual milk fat and skim solids, the quantities are dependent upon prices. Allocation quantities for both types of cheeses, butter, and dry skim milk products depend upon relative prices due to the gross value terms in the cheese production equations.

While leap year adjustments are made for the production of most products for applicable years in the projection period, no explicit adjustment is made for dry whey production because of its relationship with cheese production, which includes the adjustment.

Since some dairy products are used as ingredients in other dairy products, it is necessary to make adjustments to avoid double counting milk solids. Historical data used to account for duplication are based on data from *Dairy Products, Utilization and Product Trends* (published by the American Dairy Product Institute) and calculations by the modeler. For the projection period, the proportion of dry skim milk products used in cheese to total cheese production is estimated as a function of trend and a dummy variable for the years before 2003. Condensed skim milk used in cheese is estimated in a negative relationship to dry skim milk products used in cheese production (given that they are substitutes) and a dummy variable for 2006–18. Other types of duplication, such as skim solids used for fluid milk fortification, are accounted for as constant percentages of the applicable dairy product quantities produced.

Table 7

Duplication adjustment equations (using annual data from 2000 to 2020)

Dependent variable	Parameter	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (Dry skim milk products used in cheese / cheese production)	Intercept	−2.825	−18.31	<.0001	0.7307	0.3880
	Trend [year - 1999]	−0.070	−6.15	<.0001		
	Dummy for years before 2003	−0.949	−4.81	0.0001		
ln (Condensed skim milk used in cheese)	Intercept	6.762	6.05	<.0001	0.6764	0.0564
	ln (Dry skim milk products used in cheese)	−0.470	−2.31	0.0328		
	Dummy for years 2006 to 2018	1.004	6.78	<.0001		

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service and American Dairy Products Institute.

Stocks

Year-end stocks are estimated for American cheese, other cheese, butter, dry skim milk products, and dry whey. Estimating ending stock values is complicated by their volatility. Ending stocks are expected to have a negative relationship with the annual price. In a year when prices are relatively high, owners of the stocks are more willing to sell higher quantities than in years when prices are low, bringing down stock levels toward the end of the year. The opposite is expected when prices are low in a particular year.

We found it problematic to estimate useful regression equations using annual ending stocks as the dependent variables and annual prices as the explanatory variables. For some products, the estimated relationships were found to be insignificant. For other products, projections of ending stocks using such regression equations grow or shrink to unreasonable levels. Perhaps stocks at the end of December each year tend to be more related to prices near the end of the year than annual averages, or perhaps December ending stocks tend to reflect expectations for the following year more than reactions to annual averages for the current year.

For these reasons, a two-step process is used. In the first step (table 8), simple averages of the monthly ending stocks in the last quarter of the year are estimated. For each equation, the ratio of the average last-quarter stock value to the annual production quantity has a negative relationship with the product price. Dummy variables are used to account for outliers and to obtain better regression statistics. In the second step, year-end stocks are estimated from average stocks, reflecting the typical seasonal relationships that exist between average stocks for the last quarter of the year and year-end stocks (table 9). Projections using this approach are found to be more reasonable than projections using regressions for which annual ending stocks are estimated directly as functions of prices.

Table 8

Stock equations: average for last quarter of the year (using annual data from 1990 to 2020)

Dependent variable [1 2]	Parameter [3]	Estimate	t-Value	Pr > |t|	Elasticities [4]	R-Square	Godfrey test 1st order (P-value)
Butter stocks, avg. last qtr. / butter production for the year	Intercept	0.045	3.18	0.0038		0.7307	0.3880
	Butter price / CPI all	–0.032	–1.79	0.0846	–0.361		
	Trend [year – 1989]	0.003	8.13	<.0001			
	Dummy for 2002 to 2003	0.042	4.03	0.0004			
	Dummy for 1993 to 2000	–0.026	–3.71	0.001			
American cheese stocks, avg. last qtr. / American cheese production for the year	Intercept	0.178	21.53	<.0001		0.9840	0.1586
	Cheddar cheese price / CPI all	–0.062	–6.21	<.0001	–0.358		
	Dummy for 1994 and 1995	–0.023	–5.50	<.0001			
	Dummy for years after 2009	0.013	5.52	<.0001			
Other cheese stocks, avg. last qtr. / other cheese production for the year	Intercept	0.092	8.56	<.0001		0.9695	0.2531
	Mozzarella price / CPI all	–4.751	–5.13	<.0001	–0.987		
	Dummy for 1997	–0.021	–3.62	0.0012			
	Dummy for years after 2007	0.020	8.60	<.0001			
ln (Dry skim milk product stocks for human consumption, avg. last qtr. / dry skim milk products production for the year)	Intercept	–2.736	–22.02	<.0001		0.7451	0.9680
	ln (nonfat dry milk price / CPI all)	–0.294	–1.53	0.1364	–0.294		
	Dummy for 2006	–0.877	–3.00	0.0056			
ln (Dry whey stocks for human consumption, avg. last qtr. / dry whey production for the year)	Intercept	–3.722	–21.25	<.0001		0.9300	0.3310
	ln (Dry whey price / CPI all)	–0.128	–1.51	0.1438	–0.128		
	Dummy for 2007 and 2008	0.576	6.41	<.0001			
	Dummy for 2009 to 2012	0.312	4.41	0.0002			
	Dummy for years after 2012	0.811	14.56	<.0001			
	Dummy for 2017	0.307	2.52	0.0184			

[1] avg. = average.
[2] qtr. = quarter.
[3] CPI = Consumer Price Index.
[4] For equations where elasticities are not constant, point elasticities are computed at the means of the variables.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; and U.S. Department of Commerce, Bureau of Labor Statistics.

Table 9

Annual ending stock equations (using annual data from 1990 to 2020)

Dependent variable	Parameter [1 2]	Estimate [3]	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (Butter stocks, ending)	Intercept	–0.142	–1.10	0.2813	0.9751	0.0557
	ln (Butter stocks, avg. last qtr.)	1.007	34.22	<.0001		
ln (American cheese stocks, ending	Intercept	–0.023	–0.41	0.6861	0.9975	0.0776
	ln (American cheese stocks,avg, last qtr.)	1.004	112.40	<.0001		
ln (Other cheese stocks, ending)	Intercept	–0.003	–0.05	0.9581	0.9983	0.1451
	ln (Other cheese stocks, avg. last qtr.)	1.002	112.85	<.0001		
ln (Dry skim milk product stocks, ending)	Intercept	0.616	4.07	0.0003	0.9773	0.6459
	ln (Nonfat dry milk stocks, avg. last qtr.)	0.895	28.42	<.0001		
ln (Dry whey stocks, ending)	Intercept	0.447	3.05	0.0049	0.9593	0.2329
	ln (Dry whey stocks, avg. last qtr.)	0.900	23.35	<.0001		

[1] avg. = average.
[2] qtr. = quarter.
[3] Since equations are in double-log form with respect to price, coefficients can be interpreted as elasticities.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service.

Imports

U.S imports are estimated with regressions for butter, American cheese, other cheese, and milk components of whey products other than dry whey.[23] Imports of milk protein concentrate (MPC), fluid milk, and frozen products are exogenous variables based on averages of imports in recent years. For other products imported, aggregate milk fat and skim solids are estimated using regressions (table 10). Equations are estimated for imports under free trade agreements (FTAs), non-quota other cheese, and imports subject to a tariff rate quota (TRQ).

Imports of butter, American cheese, and most other cheeses are subject to TRQs that allow limited imports at lower in-quota tariff rates and unlimited imports at higher over-quota tariff rates. Estimates of in-quota and over-quota imports use data from the USDA, Foreign Agricultural Service (FAS) from 1995–2020. The International Trade Commission (ITC) is the data source used for imports under FTAs.

Imports of butter and American cheese are segregated into two groups, those subject to most-favored-nation TRQs and those under FTAs.[24] Imports of other cheese include these two groups but also a third group: non-quota imports of cheese from cows. Imports of cheese designated as from animals other than cows are not included in the model.

For imports subject to quota, the data used begins in 1995, the year when the World Trade Organization (WTO) began operating and TRQs became effective. Dummy variables are included to provide an adequate fit for the equations. The dependent variable is the log of the imports subject to the quota minus the log of the TRQ. The main explanatory variable in each equation is the domestic price[25] minus the foreign export price, raised to the third power. While the domestic price is projected by the model as an endogenous variable, the foreign export price is an exogenous variable projected by the Dairy ICEC. This formulation allows for imports to increase as the domestic price rises from low levels, level off at the TRQ level when the tariff is effective at limiting imports, and then rise further when the domestic price is high enough to encourage imports above the TRQ level. In contrast to most tables, average point elasticities are not shown in table 10 because price sensitivities change considerably over the range of price differences for imports subject to TRQs; a single average point elasticity for each equation could be misleading.

The equation for butter imports subject to a quota includes a dummy variable for 2015–17 and a dummy variable for years after 2017, reflecting higher butter imports in the respective time periods. U.S. residents have been consuming greater quantities of butter as perceptions about the health effects of milk fat have changed. Irish butter accounted for much of the increase. It contains at least 82 percent butterfat (compared with at least 80 percent for most U.S. butter), is sourced from cows that are mainly grass fed, and is usually sold at a premium price at retail.

For imports subject to FTAs, imports are estimated using log-linear equations, where the main variable is the domestic price minus the foreign export price. With this specification, imports increase at an increasing rate[26] as the domestic price rises relative to the foreign export price. As with the imports subject to TRQs, these equations include dummy variables for a better fit.

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[23] U.S. imports of dry whey have been negligible in most years.

[24] For modeling purposes, imports under all FTAs are lumped together into one quantity per product category. However, not all FTAs have the same terms. In some cases, imports under FTAs are subject to TRQs specific to that agreement. Adjustments would need to be made to the model if this level of detail were needed for a particular analysis.

[25] In the equations that use both domestic and international prices, domestic prices are divided by 100 because the domestic prices are in cents per pound. However, the foreign price series used by the modeler and reported in appendix A, are in U.S. dollars per pound (converted from the primary data, reported by USDA, Dairy Market News, which are in dollars per metric ton).

[26] See appendix F for an explanation of the phrase "increase at an increasing rate."

Although imports through FTAs may come from several different countries, the bulk of U.S. dairy FTA imports come from Mexico and Australia. Although Mexico was granted preferential access to the U.S. dairy market under the former North American Free Trade Agreement (NAFTA) beginning in 1994, access was increased gradually over the years until completely free trade was allowed. Free dairy trade with Mexico has continued under the United States-Mexico-Canada Agreement (USMCA), which became effective July 1, 2020. The United States-Australia Free Trade Agreement became effective in 2005, and preferential access has been gradually increased to imports from Australia since then. While no provisions for preferential dairy trade with Canada were reached under the former NAFTA agreement, some preferential access was allowed for dairy trade in both directions under USMCA. As a result, there were some USMCA dairy imports from Canada in the second half of 2020.

While there were significant imports of other cheese under NAFTA in some of the earlier years of the agreement, imports for most products under FTAs were negligible in the beginning years of the FTAs. While the model equation for other cheese FTA imports starts with data for 1995, the regression starting years for butter and American cheese are 2004 and 2005, respectively.

Imports of milk fat and skim solids in whey products other than dry whey are modeled as lags of previous year values. Dummy variables for 2014, an outlier, are included for both equations.

For some product categories, imports are exogenous projections in the model. In these cases, imports have been small, price data for regression analyses are not readily available, or imports were not found to be responsive to available prices. Values in the projection period are based on recent year averages or trends. This is the case for imports of NDM, dry whey, other whey products, evaporated and condensed milk, fluid milk, frozen products, and MPC.

Imports of dairy products, other than those listed above, are modeled as composite aggregates of milk fat and skim solids. The U.S. domestic price for butter and the Oceania export price for butter are used as proxies for prices in regression equations for milk fat imported in these products. For imports of skim solids of "other products," the U.S. domestic NDM price and the Oceania export price of SMP are used. Each equation is in the log-linear form. With this specification, imports increase at an increasing rate as domestic prices rise relative to foreign export prices. Trends and dummy variables account for changes in the relationship over time.

Table 10

Import equations (using annual data)

Dependent variable [1]	Period	Parameter [2 3 4 5]	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (Butter imports subject to quota) – ln (TRQ for butter)	1995–2020	Intercept	–0.376	–2.44	0.0233	0.9529	0.4291
		[(U.S. domestic butter price / 100 – Oceania butter export price) / (CPI all / 100)] [3]	7.751	3.83	0.0009		
		Dummy for 2015 to 2017	1.349	3.64	0.0014		
		Dummy for years after 2017	1.995	5.33	<.0001		
ln (Butter imports under free trade agreements)	2004–2020	Intercept	–0.507	–2.85	0.0145	0.6679	0.9490
		[(U.S. domestic butter price / 100 – Oceania butter export price) / (CPI all / 100)] [3]	7.461	7.39	<.0001		
		Dummy for 2004	–2.852	–4.11	0.0014		
		Dummy for 2007	1.598	2.97	0.0117		
		Dummy for years after 2016	2.007	6.46	<.0001		
ln (American cheese imports subject to quota) – ln (sum of TRQ for Cheddar and American cheese)	1995–2020	Intercept	–2.315	–5.36	<.0001	0.7607	0.4424
		[(U.S. domestic Cheddar cheese price / 100– Oceania Cheddar cheese export price) / (CPI all / 100)] [3]	13.163	4.08	0.0005		
		lag (ln (American cheese imports subject to quota))	0.616	5.13	<.0001		
		Dummy for 2002	0.358	1.21	0.2406		
ln (American cheese imports under free trade agreements	2005–2020	Intercept	1.642	11.38	<.0001	0.5134	0.0541
		(U.S. domestic Cheddar cheese price /100– Oceania Cheddar cheese export price) / (CPI all / 100)	3.178	1.58	0.1391		
		Dummy for 2011 and 2012	–1.275	–3.13	0.0080		
ln (Imports of other cheese subject to quota) – ln (sum of other cheese TRQs)	1995–2020	Intercept	–0.318	–14.58	<.0001	0.6253	0.0517
		[(U.S. domestic Cheddar cheese price / 100– Oceania Cheddar cheese export price) / (CPI all / 100)] [3]	3.980	4.08	0.0005		
		Dummy for 2000 to 2007	0.175	4.88	<.0001		
Imports of other cheese under free trade agreements	1995–2020	Intercept	–6.233	–1.73	0.0984	0.9193	0.0204
		(U.S. domestic Cheddar cheese price /100 – Oceania Cheddar cheese export price) / (CPI all / 100)	33.020	2.64	0.0151		
		Dummy for years after 2004	34.297	8.74	<.0001		
		Dummy for years 2006 and 2007	11.816	3.61	0.0016		
ln (Imports of other cheese, non-quota from cows)	1999–2020	Intercept	1.552	3.01	0.0075	0.6812	0.4623
		(U.S. domestic Cheddar cheese price /100 – Oceania Cheddar cheese export price) / (CPI all / 100)	0.902	3.15	0.0055		
		lag (ln (Imports of other cheese, non-quota from cows))	0.594	4.48	0.0003		

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Table 10 continued

Import equations (using annual data)

Imports of nonfat dry milk, dry whey, evaporated and condensed milk, fluid milk, frozen products, and milk protein concentrate are exogenous, with values are based on recent year averages or trends. There are numerous "other" products that do not fit within these categories, and these are modeled using the following regression equations:							
Dependent variable [1]	Period	Parameter [2 3 4 5]	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (Imports of milk fat in whey products other than dry whey)	2000–2020	Intercept	0.108	1.18	0.2548	0.6446	0.8162
		lag (ln (Imports of milk fat in whey products other than dry whey))	0.859	7.71	<.0001		
		Dummy for 2014	0.539	1.85	0.0814		
ln (Imports of skim solids in whey products other than dry whey)	2000–2020	Intercept	0.705	1.52	0.1470	0.6822	0.956
		lag (ln (Imports of skim solids in whey products other than dry whey))	0.834	7.56	<.0001		
		Dummy for 2014	0.498	2.41	0.0276		
ln (Milk fat in dairy imports not otherwise specified in the model)	2000–2020	Intercept	4.081	44.64	<.0001	0.7834	0.472
		(U.S. domestic butter price / 100 – Oceania butter export price) / (CPI all / 100)	0.636	2.10	0.0512		
		Dummy for 2005 to 2007	0.739	4.34	0.0004		
		Dummy for years after 2015	0.397	2.73	0.0143		
ln (Skim solids in dairy imports not otherwise specified in the model)	2000–2020	Intercept	5.447	84.85	<.0001	0.9082	0.1666
		(U.S. domestic nonfat dry milk price / 100 – Oceania SMP export price) / CPI all	0.463	1.27	0.2221		
		Dummy for years before 2009 × trend [year – 1999]	0.046	3.54	0.0027		
		Dummy for years after 2008 × trend [year – 1999]	−0.011	−2.31	0.0347		
		Dummy for years 2011 to 2013	0.083	1.42	0.1759		

[1] TRQ = tariff rate quota.
[2] Export prices are reported free on board (f.o.b.) at the foreign port. Prices used for the regressions are averages of midpoints of ranges reported in USDA *Dairy Market News*.
[3] CPI = Consumer Price Index.
[4] Superscripted 3s in the mathematical expressions indicate cubed terms.
[5] SMP = skim milk powder.

Source: USDA, Economic Research Service analysis using data from USDA, Agricultural Marketing Service; USDA, Foreign Agricultural Service; and U.S. Department of Commerce, Bureau of the Census.

Exports

Regression equations are used to project U.S. exports of butter, American cheese, other cheese, dry skim milk products, and dry whey, as well as exports of fat and skim solids in whey products other than dry whey (table 11). For dry skim milk products, butter, and American cheese, commercial exports are modeled instead of total exports. Government-subsidized exports are not included in the historical data for the regression. The last Government-subsidized exports of dairy products were in 2010, under the Dairy Export Incentive Program (DEIP), which was repealed with the Agricultural Act of 2014.

U.S. commercial export volumes of dairy products are much higher when U.S. prices fall below the export prices of competing countries, and the sensitivity of export quantities to small price changes becomes greater (MacDonald et al., 2016). To reflect these relationships, a log-level specification is used for most dairy export equations, reflecting the tendency of exports to rise exponentially when U.S. prices fall relative to the export prices of international competitors. Since price sensitivities change considerably over the range of price differences, single point elasticities for each equation are not reported in table 11. Oceania export prices, as reported by USDA, *Dairy Market News* (DMN), are used as world benchmark prices for butter, cheese, and SMP. For dry whey, the Western European price is used as the benchmark price since that is the only dry whey export price reported by DMN; the European Union is the largest competitor that U.S. exporters face in the global market for dry whey.

While dairy exports have increased substantially in recent years, trends have not followed a very steady path for most products. Moreover, it is difficult to predict if trends of recent years will be sustainable during the projection period. Since accounting for global supply and demand situations of trading partners and competitors is beyond the scope of the model, increasing exports of recent years are modeled through trends and dummy variables for the most part. For other cheese exports, an endogenous lag is a good fit in the regression equation.

The data periods for the export regressions vary from one product to another. The data periods begin in 1994 for cheese, 1996 for dry whey, and 2004 for butter and dry skim milk products. Data for Oceania export prices are readily available beginning in 1994, and data for the Western European dry whey prices are readily available beginning in 1996. Prior to 2004, most U.S. dairy exports of butter and NDM were subsidized through DEIP, with little or no commercial exports in most years.

For commercial exports of dry skim milk products, the dependent variable is not converted to log form, but an exponential term is used for the difference between the U.S. domestic price and the Oceania export price, while intercept and trend variables are in levels. This exponential term for the price difference reflects an increase in exports at an increasing rate when the domestic price falls relative to the Oceania export price. The trend for the increase in dry skim milk product exports over the historical period follows an upward linear path.

Note that the equation for exports of dry whey includes a logged trend term. This reflects exports that increased over the data period, but the increase was at a decreasing rate.[27] Exports of whey products other than dry whey, modeled as composite quantities of milk fat and skim solids in these products, are projected as functions of domestic cheese consumption and dummy variables. The increase in the supply of available whey solids from cheese consumption accounts for some of the increase in exports of these products. Dummy variables account for the increase in exports in response to greater global demand.

Exports of evaporated and condensed milk, fluid milk, frozen product, anhydrous milkfat, and casein products are exogenous in the model. Other products are treated as exogenous composites of milk fat and skim solids and are categorized as either Class II or Class IV product exports. These exogenous quantities are determined by the modeler based on data from recent years.

[27] See appendix F for an explanation of the phrase "increase at a decreasing rate."

Table 11
Export equations (using annual data)

Dependent variable	Period	Parameter [1 2 3]	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (Butter commercial exports)	2004–2020	Intercept	4.245	28.92	<.0001	0.7087	0.8157
		(U.S. domestic butter price / 100 – Oceania butter export price)/ (CPI all / 100)	−6.808	−3.94	0.0015		
		Dummy for 2014	1.897	3.77	0.0021		
ln (American cheese commercial exports)	1994–2020	Intercept	3.997	29.40	<.0001	0.8906	0.9116
		(U.S. domestic Cheddar cheese price / 100 – Oceania Cheddar cheese export price) / (CPI all / 100)	−2.542	−4.24	0.0003		
		Dummy for years after 2010	1.063	7.31	<.0001		
ln (Other cheese exports)	1994–2020	Intercept	0.685	4.16	0.0004	0.994	0.0103
		(U.S. domestic butter price / 100 – Oceania butter export price) / (CPI all / 100)	−0.632	−3.35	0.0029		
		lag (ln (Other cheese exports))	0.895	29.94	<.0001		
		Dummy for years 2011 to 2014	0.119	1.99	0.0587		
Dry skim milk product commercial exports	2004–2020	Intercept	219.082	3.59	0.0030	0.9456	0.1151
		exp [(U.S. domestic nonfat dry milk price / 100 – Oceania SMP export price) / (CPI all / 100)]	−37.289	−7.34	<.0001		
		Trend [year - 2003]	85.316	15.51	<.00		
ln (Dry whey exports)	1996–2020	Intercept	5.192	53.67	<.0001	0.7214	0.1013
		(U.S. domestic dry whey price / 100 – Western Europe dry whey export price) / (CPI all / 100)	−3.614	−2.27	0.0342		
		ln (Trend) [year – 1995]	0.317	8.82	<.0001		
		Dummy for 2019	−0.428	−2.91	0.0085		
Exports of milk fat in whey products other than dry whey	1990–2020	Intercept	−18.616	−8.28	<.0001	0.9615	0.0529
		Domestic cheese consumption	0.003	9.81	<.0001		
		Dummy for years after 2008	6.505	5.99	<.0001		
Exports of skim solids in whey products other than dry whey	1990–2020	Intercept	−1,045.280	−9.70	<.0001	0.9820	0.0225
		Domestic cheese consumption	0.169	12.75	<.0001		
		Dummy for years after 2008	295.839	5.45	<.0001		
		Dummy for years after 2011	174.375	3.23	0.0032		

Exports of evaporated and condensed milk, fluid milk, frozen products, anhydrous milkfat, casein products are exogenous in the model. Other products are modeled as exogenous composites of milk fat and skim solids and categorized as either Class II or Class IV products.

[1] Export prices are reported free on board (f.o.b.) at the foreign port. Prices used for the regressions are averages of midpoints of ranges reported in USDA *Dairy Market News*.
[2] CPI = Consumer Price Index
[3] SMP = skim milk powder.

Source: USDA, Economic Research Service analysis using data from USDA, Agricultural Marketing Service; USDA, Foreign Agricultural Service; and U.S. Department of Commerce, Bureau of the Census.

Product Balance Equations

Product balance equations are used to balance supply and demand elements for major products, including total cheese, American cheese, other cheese, butter, dry skim milk products, dry whey, and canned milk. The product balance equations, in combination with the equations for their associated elements, solve for market-clearing dairy product prices in most cases.[28] The basic form of the product balance equations is as follows:

[28] The model does not include a canned milk price. The balance equation for canned milk solves for domestic commercial disappearance of the product.

[Beginning commercial stocks + production + imports] = [Domestic commercial disappearance + commercial exports + shipments to U.S. territories + (net Government removals, barters, and donations) + ending commercial stocks]

Some of the product balance equations have more detail. For the commercial disappearance of dry skim milk products, a term is included in the balance equation to separate use for cheese from other uses. For dry skim milk products and dry whey, exogenous animal use projections (based on data of recent years) are netted out to project human commercial use of these products.

Classified Milk Prices and the All-Milk Price

FMMO class price projections are computed from dairy product prices based on FMMO formulas (see appendix C). Since actual FMMO class prices are calculated from monthly and weekly dairy product pricing factors, but model class price projections are calculated from annual dairy product pricing factor projections, some simplification is necessary for modeling purposes. For model projections, the Class I differential is the weighted average of the Class I differentials for all FMMOs combined for the most recent data year.

Based on the projected production of dairy products and conversion factors in table 1, milk fat and skim solids from U.S. milk marketings (milk production minus farm use) are divided in the model among the four FMMO milk classes. An all-milk price at 3.5 percent milk fat is estimated as a function of the U.S. "blend" price, calculated using FMMO class prices and U.S. quantities of milk fat and skim milk used to produce products in each of the four milk classes. Since the majority of U.S. milk is subject to FMMO pricing, prices for milk outside of FMMO regulation are assumed to be similar due to competitive factors (table 12). The all-milk price at 3.5 percent is then adjusted to project an all-milk price at test.

Table 12

Weighted average (wtd. avg.) U.S. class prices and all-milk price derived from Federal order minimum prices (FO min. prices)

Wtd. avg. U.S. milk fat price using FO min. prices	$\dfrac{\sum_{j=I}^{IV}[\,(\text{Milk fat per U.S.class use})_j \times (\text{Federal order class milk fat price})_j\,]}{\sum_{j=I}^{IV}(\text{Milk fat per U.S.class use})_j}$
Wtd. avg. U.S. skim price using FO min. prices	$\dfrac{\sum_{j=I}^{IV}[\,(\text{Skim milk per U.S.class use})_j \times (\text{Federal order class skim milk price})_j\,]}{\sum_{j=I}^{IV}(\text{Skim milk per U.S.class use})_j}$
Wtd. avg. U.S. "blend" price at 3.5 percent milk fat using FO min. prices	(0.965 × wtd. Avg. U.S. skim price per hundredweight using FO min. prices) + 3.5 × wtd. avg. U.S. fat price using FO min. prices

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Table 12 continued

Weighted average (wtd. avg.) U.S. class prices and all-milk price derived from Federal order minimum prices (FO min. prices)

Econometric estimation for all-milk price at 3.5 percent milk fat						
Dependent variable	Parameter	Estimate	t-Value	Pr > |t|	R-Square	Godfrey test 1st order (P-value)
ln (All milk price at 3.5 percent milk fat)	Intercept	0.193	3.60	0.0012	0.9895	0.4737
	ln (Wtd. avg. U.S. "blend" price at 3.5 percent milk fat using FO min. prices)	0.935	47.12	<.0001		
All-milk price at test	All milk price at 3.5 percent milk fat + (U.S. fat test – 3.5) × wtd. avg, U.S. milk fat price using FO min. prices					

FO min. prices = Federal Milk Marketing Order minimum prices.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; and USDA, Agricultural Marketing Service.

Calculation of Milk-Equivalent Values

Dairy supply and use projections are presented in *USDA Agricultural Projections* on both the milk-fat and skim-solids milk-equivalent bases. Milk-equivalent values are computed by dividing a milk fat or skim solids value by the associated test of producer milk. For example, 100 pounds of milk fat with a producer milk-fat test of 3.8 percent convert to 2,632 pounds of milk (100 pounds/0.038). For imports and commercial exports, the aggregate total milk fat and skim solids associated with the dairy products are calculated by the model, and conversion factors and exogenous milk fat and skim solids year-end tests are used to convert these totals to milk-equivalent values. However, for commercial stocks, the model projections do not include every product used for the historical milk-equivalent calculations. Statistical relationships are used to estimate total stocks based on the aggregate stock levels of products explicitly estimated in the model.

Calibration of Model Based on Committee Judgment

The model results are calibrated for each projection year by adjusting intercept terms in the projection equations based on the judgment of the Dairy ICEC. To illustrate how the model is calibrated, we use the milk per cow equation below as an example, where ypc = yield per cow and mf_ratio = milk feed ratio. The parameters a0, a1, and a2 are constants that have been calculated through regression analysis.

ypc = a0 + a1 × lag(mf_ratio) + a2 × trend – a3 × (dummy for years after 2014 × trend)

Suppose that Dairy ICEC agrees, after deliberation, that the 2022 milk per cow projection should be 24,305 pounds per head. To allow milk per cow to be calibrated to the consensus projection, an intercept adjuster (ypc_adj) is included in the model. For 2022, ypc_adj would be calculated as follows:

If year = 2022, then

ypc_adj = 24,305 – [a0 + a1 × lag(mf_ratio) + a2 × trend – a3 × (dummy for years after 2014 × trend)]

The intercept adjuster is then incorporated into the model as follows. This results in a projection of 24,305 pounds of milk per cow in 2022.

$$\text{ypc} = (\text{a0} + \text{ypc\_adj}) + \text{a1} \times \text{lag(mf\_ratio)} + \text{a2} \times \text{trend} - \text{a3} \times (\text{dummy for years after 2014} \times \text{trend})$$

Note that this adjustment applies only to 2022. Similarly, adjustments could be made for other years. Notice that only the intercept (a0) has been adjusted—not the gradient estimates (a1, a2, or a3). This allows scenario analyses to reflect statistical relationships among variables as determined by the regression analyses.

It is important to note that such adjustments result in changes to the values of other endogenous values in the model in a manner consistent with the economic relationships reflected by the model equations. For example, if the intercept adjuster from the above equation were to result in milk per cow being lower in 2022 than what the model would otherwise generate, the tighter projected milk supply would result in less milk solids available for the production of dairy products. Tighter supplies of dairy products result in higher dairy product prices, and higher dairy product prices result in higher farm-level milk prices. Since the model parameters include lags, projections of endogenous values for subsequent years would also be affected. For example, with the higher all-milk price in 2022, milk per cow in 2023 would be higher than it would have been without the adjustment since milk per cow depends upon the lag of the milk-feed ratio in the model equation.

A very practical reason for using intercept adjusters is the calibration of the model to short-term projections. The baseline projections are typically determined each October. Projections for the current year and the following year are based on short-term projections published in the USDA, *World Agricultural Supply and Demand Estimates (WASDE)* report. In 2021, the model documented in this report was calibrated to October *WASDE* projections for 2021 and 2022. Intercept adjustments were made for years after 2022 based on further deliberations of the Dairy ICEC.

Note that intercept adjusters are normally used for setting the baseline numbers. For scenario analyses, baseline intercept adjusters are not usually changed. They would only be changed for a scenario analysis in a case where the impacts of an explicit shift in one of the endogenous variables are being studied.

Scenario Analysis Example

To provide an understanding of how the model can be used, a scenario analysis example is provided, examining how a 1-year shock to feed prices would change the outlook for the dairy industry over the projection period.[29] In the example, the feed value in 2022 has been increased by 10 percent ($1.05 per hundredweight (cwt) of feed), and the results are compared against the baseline (table 13). The milk-feed ratio for 2022 in this scenario is 1.67, compared to 1.84 for the baseline. Although many results are available (up to 179 endogenous variables in the model), the impacts for a few important selected variables are provided in table 13. After a 1-year shock, the supply and use variables adjust over time, and the impacts tend to attenuate toward baseline levels over the projection period.

[29] Time has passed since the USDA baseline used for this example was formulated. The actual values for 2021 and 2022 differ from the baseline projections, and the newer *USDA Long Term Projections to 2032* have been published. However, in analyzing the effects of an input change, the impacts are of greater interest (scenario minus baseline) than the baseline and scenario levels. Model impacts are usually very similar regardless of the baseline values used.

Table 13
Scenario analysis, 10 percent higher feed prices in 2022 compared to baseline

	Units	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Feed value proxy												
Baseline	Dollars per cwt of feed	10.51	10.47	9.74	9.45	9.23	9.04	8.85	8.81	8.80	8.79	8.80
Scenario		10.51	11.52	9.74	9.45	9.23	9.04	8.85	8.81	8.80	8.79	8.80
Impact		0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milk-feed ratio												
Baseline	All-milk price / feed value	1.75	1.84	1.97	2.03	2.10	2.15	2.21	2.21	2.28	2.33	2.37
Scenario		1.75	1.67	2.03	2.05	2.11	2.15	2.21	2.22	2.28	2.33	2.37
Impact		0.00	-0.17	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Milk production												
Number of milk cows												
Baseline	Thousand head	9,474	9,449	9,434	9,433	9,438	9,452	9,471	9,496	9,519	9,549	9,584
Scenario		9,474	9,449	9,415	9,421	9,429	9,444	9,464	9,489	9,513	9,544	9,579
Impact		0	0	−19	−12	−9	−8	−7	−6	−6	−6	−5
Milk per cow												
Baseline	Pounds	23,959	24,305	24,532	24,835	24,992	25,218	25,441	25,737	25,884	26,110	26,333
Scenario		23,959	24,305	24,510	24,842	24,995	25,219	25,442	25,738	25,885	26,111	26,333
Impact		0	0	−22	7	3	1	1	1	0	0	0
Milk production												
Baseline	Billion pounds	227.0	229.7	231.4	234.3	235.9	238.4	240.9	244.4	246.4	249.3	252.4
Scenario		227.0	229.7	230.8	234.0	235.7	238.2	240.8	244.2	246.3	249.2	252.2
Impact		0.0	0.0	−0.7	−0.2	−0.2	−0.2	−0.2	−0.2	−0.1	−0.1	−0.1
Milk-fat milk-equivalent basis												
Domestic use												
Baseline	Billion pounds	220.9	224.4	226.8	229.4	230.7	232.7	234.9	237.7	239.7	242.1	244.8
Scenario		220.9	224.4	226.5	229.2	230.5	232.5	234.7	237.6	239.6	242.0	244.7
Impact		0.0	0.0	−0.3	−0.2	−0.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Exports												
Baseline	Billion pounds	11.8	11.0	10.2	10.2	10.5	10.8	11.1	11.5	11.6	11.9	12.3
Scenario		11.8	11.0	10.0	10.1	10.5	10.7	11.0	11.4	11.5	11.9	12.2
Impact		0.0	0.0	−0.2	−0.1	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0
Skim-solids milk-equivalent basis												
Domestic use												
Baseline	Billion pounds	180.0	182.3	183.3	184.9	185.4	186.5	187.8	189.6	190.6	192.0	193.6
Scenario		180.0	182.3	183.0	184.6	185.2	186.4	187.7	189.5	190.5	191.9	193.5
Impact		0.0	0.0	−0.4	−0.2	−0.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Exports												
Baseline	Billion pounds	51.4	51.8	52.5	53.6	54.6	55.8	57.1	58.5	59.7	61.1	62.4
Scenario		51.4	51.8	52.3	53.5	54.6	55.8	57.1	58.5	59.7	61.0	62.4
Impact		0.0	0.0	−0.1	−0.1	−0.1	−0.1	0.0	0.0	0.0	0.0	0.0
Domestic wholesale prices												
Cheddar cheese												
Baseline	Cents per pound	168.1	172.0	176.4	177.0	177.4	178.2	179.4	179.2	181.8	184.9	188.2
Scenario		168.1	172.0	180.2	179.1	178.5	178.9	179.9	179.6	182.1	185.2	188.4
Impact		0.0	0.0	3.7	2.1	1.1	0.7	0.5	0.4	0.3	0.3	0.3
Butter												
Baseline	Cents per pound	168.1	176.0	174.8	182.6	188.3	190.1	191.8	192.1	200.2	203.2	208.1
Scenario		168.1	176.0	176.9	182.2	187.7	189.7	191.5	191.9	200.0	203.2	208.1
Impact		0.0	0.0	2.0	−0.4	−0.6	−0.4	−0.3	−0.2	−0.1	−0.1	0.0
Nonfat dry milk												
Baseline	Cents per pound	125.1	138.4	131.7	124.0	123.7	121.9	123.0	121.3	130.1	134.3	138.6
Scenario		125.1	138.4	141.0	126.5	124.8	122.5	123.3	121.5	130.3	134.4	138.7
Impact		0.0	0.0	9.3	2.5	1.0	0.6	0.3	0.2	0.2	0.1	0.1
Dry whey												
Baseline	Cents per pound	56.0	51.0	47.9	46.5	46.9	46.7	46.8	46.3	46.5	46.9	46.4
Scenario		56.0	51.0	48.2	46.7	47.0	46.7	46.9	46.4	46.6	47.0	46.4
Impact		0.0	0.0	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
All-milk price												
Baseline	Dollars per cwt	18.43	19.22	19.19	19.17	19.34	19.39	19.55	19.48	20.06	20.44	20.83
Scenario		18.43	19.22	19.72	19.36	19.42	19.44	19.58	19.51	20.09	20.46	20.85
Impact		0.00	0.00	0.54	0.19	0.08	0.05	0.04	0.03	0.02	0.02	0.02

cwt = hundredweight.

Source: USDA, Economic Research Service analysis using data from USDA, National Agricultural Statistics Service; USDA, Agricultural Marketing Service; USDA, Foreign Agricultural Service; USDA, Farm Service Agency; U.S. Department of Labor, Bureau of Labor Statistics; U.S. Department of Commerce, Bureau of the Census; and American Dairy Products Institute.

There are no changes to milk production in 2022 because milk production responds to the milk-feed ratio with a 1-year lag in the model.[30] Due to the lower milk-feed ratio in 2022, the number of milk cows for the scenario in 2023 is 19,000 head lower than the baseline, and milk per cow is 22 pounds below baseline. Since milk cow numbers in the scenario analysis depend on milk cow numbers from the previous year, the impact to milk cow numbers remains negative in 2024 even though the milk-feed ratio in 2023 is higher than the baseline. Milk cow numbers remain below the baseline for the projection period but attenuate toward the baseline over time. Milk per cow responds positively after 2023 and attenuates toward the baseline, as milk-feed ratios are higher due to higher all-milk prices. The impact to milk production in 2023 is –0.7 billion pounds but thereafter attenuates toward baseline levels, falling to –0.1 billion pounds for the last 3 years of the projection period.

With lower milk production, most dairy product prices are higher. As a result, domestic use under the scenario falls below the baseline on both a milk-fat milk-equivalent basis and a skim-solids milk-equivalent basis. Again, impacts attenuate toward baseline numbers over time.

Impacts to exports on a milk-fat basis follow a pattern not typical of other variables—with negative impacts in 2023 and 2024 (–0.2 billion pounds and –0.1 billion pounds, respectively), impacts that round to 0 in 2025 through 2027, negative impacts in 2028 through 2030 (–0.1 billion pounds in both years), and an impact that rounds to 0 in 2031. This pattern is due to the offsetting effects of higher cheese prices (lowering exports of cheese) and lower butter prices (raising exports of butter) during part of the projection period. On a skim-solids basis, scenario exports fall below baseline levels by 0.1 billion pounds in 2023 through 2026 but attenuate to 0 (rounded) by 2027.

With lower milk production, most scenario wholesale dairy product prices are higher than baseline prices during most of the projection period. The impact to the Cheddar cheese price is +3.7 cents in 2023, attenuating to +0.3 cent for the last 3 years of the projection period. The NDM price has the largest impact of the wholesale dairy product prices in 2023 (+9.3 cents), with the impacts falling to +0.1 cent for 2030 and 2031. The impact to the dry whey price is +0.3 cent in 2023 and +0.1 cent in the following years. The impacts to the butter price follow a different type of pattern, with an impact of +2.0 cents in 2023, –0.4 cent in 2024, –0.6 cent in 2025, and then attenuating to 0 in 2031. With the relatively high impact to the NDM price compared with the other wholesale prices, some milk allocation shifts from the production of cheese to the production of dry skim milk products, leaving more milk fat available for butter production. With higher butter production in 2024 through 2030, the scenario butter price is lower than the baseline price.

With higher wholesale dairy product prices across the board in 2023, the impact to the all-milk price is +$0.54 per cwt that year. Higher prices for cheese, NDM, and dry whey offset lower prices for butter in the remaining years, resulting in an impact to the all-milk price $0.19 per cwt in 2024, attenuating to +$0.02 per cwt for the last 3 years of the projection period.

Concluding Remarks

The Annual U.S. Dairy Sector Model used by USDA, Economic Research Service (ERS) serves two major purposes:

(1) to aid in the development of dairy projections, as published in *USDA Agricultural Projections* each year, and

[30] There could be some within-year responses that the model is not able to capture.

(2) as a tool for analyzing scenarios involving changing market conditions and various Federal Government policies. These uses include supporting Dairy ICEC projections for the monthly *World Agricultural Supply and Demand Estimates* report and internal staff analyses requested by USDA offices or agencies.

In addition, USDA, Farm Production and Conservation Business Center uses model results to help budget for various dairy-related farm programs. Also, USDA, Agricultural Marketing Service uses the basic structure of the model in an expanded regional model to analyze changes and proposed changes to Federal Milk Marketing Orders (U.S. Department of Agriculture, 2018).

This Technical Bulletin is intended to provide transparency concerning how the model is used (along with judgment of the Dairy ICEC) to produce USDA Agricultural Projections for the dairy sector and how the model is used for analyzing changing market conditions and various Federal Government policies. Other dairy analysts may find the report useful in developing their own dairy sector models. Over time, changes will be made to the model to improve its structure, adapt to Federal Government policy changes, and account for changing market conditions.

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Appendix A: Descriptive Statistics

Table A-1
Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Animal use of dry skim milk products	ADPI	Mil. lbs.	1990–2020		31	14.99	8.15	3.40	34.80
Animal use of dry whey	ADPI	Mil. lbs.	1990–2020		31	54.77	47.88	5.50	174.90
Class I differential	AMS	$/cwt	1990–2020		31	2.72	0.12	2.56	2.88
CPI for all products	BLS	Index, 1982–84=100	1990–2020		31	195.66	39.51	130.70	258.81
Cull cow price	AMS	$/cwt	1990–2020		31	54.33	17.19	30.33	101.82
Dairy ingredient fat proportion in fluid use	ERS, ADPI	Proportion	1990–2020		31	0.00	0.00	0.00	0.00
Dairy ingredient fat proportion in frozen products	ERS, ADPI	Proportion	1990–2020		31	0.03	0.05	0.00	0.15
Dairy ingredient SNF proportion in frozen products	ERS, ADPI	Proportion	1990–2020		31	0.25	0.16	0.09	0.57
Dairy ingredient SNF proportion in fluid use	ERS, ADPI	Proportion	1990–2020		31	0.01	0.00	0.00	0.01
Dry skim milk products used in cultured products	ERS, ADPI	Mil. lbs.	1996–2020	Data readily available since 1996.	25	55.32	27.95	21.40	127.00
Dry skim milk products used in other dairy products	ERS, ADPI	Mil. lbs.	1996–2020	Data readily available since 1996.	25	151.48	52.99	79.30	276.40
Export price for Oceania butter	AMS	$/lb.	1995–2020	WTO began in 1995.	26	1.27	0.59	0.47	2.43
Export price for Oceania cheese	AMS	$/lb.	1994–2020	Data readily available since 1994.	27	1.38	0.45	0.77	2.09
Export price for Oceania skim milk powder	AMS	$/lb.	2004–20	Regression for dry skim milk products starts with 2004 data.	17	1.28	0.37	0.91	2.01
Export price for Western Europe dry whey	AMS	$/lb.	1996–2020	Data readily available since 1996.	25	0.38	0.14	0.20	0.67
Exports of dry whole milk under DEIP	FAS	Mil. lbs.	1990–2001	DEIP exports of dry whole milk ended in 2001.	12	28.56	19.94	0.00	60.00
Exports of evap. & cond. milk	Census	Mil. lbs.	1990–2020		31	40.55	23.94	7.28	96.14
Exports of frozen products	Census	Mil. lbs.	1990–2020		31	89.29	35.18	27.99	156.17
Farm use of milk	NASS	Mil. lbs.	1990–2020		31	1,242.74	319.46	956.00	1,996.00
Fat differential	AMS	$/cwt	1990–99	Used for proxy for Class I and II prices at test prior to 2000.	10	0.10	0.04	0.05	0.19
Fat in exports of AMF and butteroil	Census, ERS	Mil. lbs.	1990–2020		31	9.83	9.99	0.00	40.01

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Table A-1 continued

Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Fat in exports of casein	Census, ERS	Mil. lbs.	1990–2020		31	0.08	0.03	0.04	0.17
Fat in exports of fluid milk products	Census, ERS	Mil. lbs.	1990–2020		31	3.87	2.48	1.10	8.33
Fat in exports of frozen products	Census, ERS	Mil. lbs.	1990–2020		31	10.71	4.22	3.36	18.74
Fat in exports of other Class II products	Census, ERS	Mil. lbs.	1990–2020		31	10.72	4.99	2.08	22.11
Fat in fluid milk imports	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	0.47	0.38	0.01	2.01
Fat in imports of frozen products	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	0.89	0.55	0.00	1.95
Fat in imports of MPC	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	8.13	2.25	1.72	10.84
Fat of dry skim milk products used in Class II products	Census, ERS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	1.65	0.38	0.99	2.48
Fat used in production of MPC	NASS, ERS	Mil. lbs.	2009–20	MPC production data readily available since 2009.	12	1.54	0.43	1.06	2.48
Fat proportion for domestic fluid use	ERS	Proportion	1990–2020		31	0.02	0.00	0.02	0.02
Fat proportion for domestic use of frozen products	ERS	Proportion	1990–2020		31	0.09	0.00	0.08	0.09
Fat proportion in exports of American cheese	ERS	Proportion	1990–2020		31	0.31	0.06	0.00	0.33
Fat proportion in exports of frozen products	ERS	Proportion	1990–2020		31	0.12	0.00	0.12	0.12
Fat proportion in exports of other cheese	ERS	Proportion	1994–2020	Regression for other cheese exports begins with 1994.	27	0.26	0.00	0.25	0.26
Fat proportion in for exports of evap. & cond. milk	ERS	Proportion	1990–2020		31	0.09	0.00	0.09	0.10
Fat proportion in imports of American cheese	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.33	0.00	0.33	0.34
Fat proportion in imports of butter	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.81	0.00	0.81	0.81
Fat proportion in imports of dry skim milk products	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.01	0.00	0.01	0.01
Fat proportion in imports of dry whey	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.01	0.00	0.00	0.01
Fat proportion in imports of evap. & cond. milk	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.09	0.00	0.09	0.09

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Table A-1 continued

Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Fat proportion in imports of frozen products	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.09	0.02	0.05	0.11
Fat proportion in imports of MPC	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.08	0.00	0.08	0.08
Fat proportion in imports of other cheese	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.26	0.00	0.26	0.27
Fat proportion in Other Class II solids	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.49	0.06	0.38	0.60
Fat test for December	NASS	Percent	1990–2020		31	3.85	0.09	3.78	4.13
Fat test of milk	NASS	Percent	1990–2020		31	3.71	0.08	3.65	3.95
Fat test year-end adjustment	ERS	Proportion	1990–2020		31	0.14	0.02	0.09	0.19
Feed value for the MPP-Dairy program (now DMC program) as initially formulated	ERS	$/cwt	2014–20	Program has been in effect since 2014.	7	8.81	0.91	7.91	10.67
Feed value proxy, 16 percent protein	NASS	$/cwt of feed	1990–2020		31	6.65	2.34	4.04	12.25
Government removals of cheese	FSA	Mil. lbs.	1990–2020	Program ended in 2014.	24	8.34	15.93	–2.20	76.89
Government removals of butter	FSA	Mil. lbs.	1990–2013	Program ended in 2014.	24	82.26	150.63	–6.70	442.86
Government removals of cheese	FSA	Mil. lbs.	1990–2013	Program ended in 2014.	24	10.78	17.43	–2.20	76.89
Government removals of NDM	FSA	Mil. lbs.	1990–2013	Program ended in 2014.	24	241.87	249.14	–81.51	824.29
Imports of dry skim milk products	Census	Mil. lbs.	1990–2020		31	2.89	2.72	0.33	11.85
Imports of dry whey	Census	Mil. lbs.	1995–2020	Data readily available since 1995.	26	0.42	0.92	0.00	4.44
Imports of evap. & cond. milk	Census	Mil. lbs.	1990–2020		31	37.28	25.26	4.00	81.53
Imports of frozen products	Census	Mil. lbs.	1995–2020	Data readily available since 1995.	26	10.05	6.34	0.06	23.15
Manufactures' ending stocks of evap. & cond. milk	NASS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	38.24	6.82	19.49	53.87
Manufacturers' beginning stocks of dry skim milk products for animal use	NASS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	2.38	3.67	0.60	16.16
Manufacturers' beginning stocks of dry whey products for animal use	NASS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	3.05	1.84	0.46	6.62

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Table A-1 continued

Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Manufacturers' beginning stocks of dry whole milk	NASS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	7.96	6.90	1.56	31.01
Manufacturers' beginning stocks of evap. & cond. milk	NASS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	38.31	6.95	19.49	53.87
Manufacturers' ending stocks of dry skim milk products of animal use	NASS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	2.62	3.80	0.60	16.16
Manufacturers' ending stocks of dry whey for animal use	NASS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	2.96	1.87	0.46	6.62
Manufacturers' ending stocks of dry whole milk	NASS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	8.30	6.99	1.56	31.01
MILC payments received by small operators / milk production	FSA, ERS	$/cwt	2002–13	Program was in effect from 2002 to 2013.	12	0.13	0.14	0.00	0.37
MPC imports	Census	Mil. lbs.	1995–2020	Data readily available since 1995.	26	107.28	29.64	22.70	142.97
Population (resident plus armed forces over-seas)	Census	Millions	1990–2020		31	294.33	24.63	250.13	329.72
Price of alfalfa hay	NASS	Millions	1990–2020		31	125.28	41.58	75.51	206.08
Price of corn	NASS	$/bushel	1990–2020		31	3.20	1.28	1.86	6.67
Price of soybean meal	AMS	$/short ton	1990–2020		31	262.33	94.86	141.58	478.67
Production of dry whole milk	NASS	Mil. lbs.	1990–2020		31	98.91	47.78	30.52	175.13
Proportion of fat in dry whey exports	ERS	Proportion	1996–2020	Regression for dry whey exports begins with 1996.	25	0.01	0.00	0.01	0.01
Proportion of fat used in exports of butter	ERS	Proportion	2004–20	Regression for butter starts with 2004 data.	17	0.81	0.00	0.81	0.81
Proportion of fat used in exports of dry skim milk products	ERS	Proportion	2004–20	Regression for dry skim milk products starts with 2004 data.	17	0.01	0.00	0.01	0.01
Proportion of SNF in dry whey exports	ERS	Proportion	1996–2020	Regression for dry whey exports begins with 1996.	25	0.94	0.00	0.94	0.94
Proportion of SNF used in exports of butter	ERS	Proportion	2004–20	Regression for butter starts with 2004 data.	17	0.01	0.00	0.01	0.01
Proportion of SNF used in exports of dry skim milk products	ERS	Proportion	2004–20	Regression for dry skim milk products starts with 2004 data.	17	0.95	0.00	0.95	0.95
Real per capita disposable income	BEA	$/person	1990–2020		31	37,047.97	5,889.29	27,910.87	48,688.68
Shipments of American cheese to U.S. territories	Census	Mil. lbs.	1990–2020		31	22.97	7.80	8.00	35.00
Shipments of butter to U.S. territories	Census	Mil. lbs.	1990–2020		31	2.58	1.41	1.00	6.00

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Table A-1 continued

Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Shipments of cheese to U.S. territories	Census	Mil. lbs.	1990–2020		31	67.81	19.39	38.00	100.00
Shipments of dry skim milk products to U.S. territories	Census	Mil. lbs.	1990–2020		31	6.71	4.32	1.00	15.00
Shipments of evap. & cond. milk to U.S. territories	Census	Mil. lbs.	1990–2020		31	44.84	18.23	19.00	80.00
Shipments of other cheese to U.S. territories	Census	Mil. lbs.	1990–2020		31	44.84	14.77	17.00	70.00
SNF in exports of casein	Census, ERS	Mil. lbs.	1990–2020		31	5.48	1.78	2.34	11.08
SNF in exports of AMF and butteroil	Census, ERS	Mil. lbs.	1990–2020		31	0.01	0.02	0.00	0.10
SNF in exports of fluid milk products	Census, ERS	Mil. lbs.	1990–2020		31	11.41	7.18	3.63	28.00
SNF in exports of frozen products	Census, ERS	Mil. lbs.	1990–2020		31	8.93	3.52	2.80	15.62
SNF in exports of other Class II products	Census, ERS	Mil. lbs.	1990–2020		31	40.07	12.65	7.18	57.67
SNF in exports of Other Class IV products	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	77.46	51.53	12.15	189.07
SNF in fluid milk import	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	1.25	1.23	0.03	6.72
SNF used in production of MPC	NASS, ERS	Mil. lbs.	2009–20	MPC production data readily available since 2009.	12	121.43	33.54	83.65	194.76
SNF in imports of frozen products	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	0.94	0.58	0.01	2.10
SNF in imports of MPC	Census, ERS	Mil. lbs.	1995–2020	Data readily available since 1995.	26	94.32	26.06	19.96	125.70
SNF of dry skim milk products used in Class II products	Census, ERS	Mil. lbs.	1996–2020	Data readily available since 1996.	25	196.87	45.40	117.86	294.64
SNF proportion for domestic fluid use	ERS	Proportion	1990–2020		31	0.09	0.00	0.09	0.09
SNF proportion for domestic use of frozen products	ERS	Proportion	1990–2020		31	0.10	0.00	0.09	0.10
SNF proportion for exports of evap. & cond. milk	ERS	Proportion	1990–2020		31	0.22	0.00	0.21	0.22
SNF proportion in exports of American cheese	ERS	Proportion	1990–2020		31	0.29	0.05	0.00	0.30
SNF proportion in exports of frozen products	ERS	Proportion	1990–2020		31	0.10	0.00	0.10	0.10
SNF proportion in exports of other cheese	ERS	Proportion	1994–2020	Regression for other cheese exports begins with 1994	27	0.35	0.02	0.32	0.40
SNF proportion in imports of American cheese	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.30	0.00	0.29	0.30
SNF proportion in imports of butter	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.02	0.00	0.02	0.02
SNF proportion in imports of dry skim milk products	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.95	0.00	0.95	0.95
SNF proportion in imports of dry whey	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.87	0.26	0.00	0.94

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Table A-1 continued

Exogenous variables, descriptive statistics (not including dummy variables or intercept adjusters)

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
SNF proportion in imports of evap. & cond. milk	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.22	0.00	0.21	0.22
SNF proportion in imports of frozen products	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.09	0.00	0.09	0.10
SNF proportion in imports of MPC	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.88	0.00	0.88	0.88
SNF proportion in imports of other cheese	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.33	0.01	0.32	0.34
SNF proportion in Other Class II solids	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.51	0.06	0.40	0.63
SNF test for December	NASS	Proportion	1995–2020	Data readily available since 1995.	26	0.09	0.00	0.09	0.09
SNF test of milk	NASS	Proportion	1990–2020		31	0.09	0.00	0.09	0.09
SNF test year-end adjustment	ERS	Proportion	1995–2020	Data readily available since 1995.	26	0.00	0.00	0	0
Tariff rate quota for American cheese	FAS	Mil. lbs.	1995–2020	WTO began in 1995	26	35.21	4.19	22.90	36.99
Tariff rate quota for butter	FAS	Mil. lbs.	1995–2020	WTO began in 1995	26	14.62	1.80	8.77	15.38
Tariff rate quota for other cheese	FAS	Mil. lbs.	1995–2020	WTO began in 1995	26	261.86	4.70	245.68	264.54
Trend beginning in 1990	ERS	Annual increment	1990–2020		31	16.00	9.09	1	31
Trend beginning in 1996	ERS	Annual increment	1996–2020	Regression for dry whey exports begins with 1996 data.	25	13	7.36	1	25
Trend beginning in 2000	ERS	Annual increment	2000–20	Trend used for ratio of dry skim milk products used in cheese/ cheese production and for SNF in other imports.	21	11.00	6.20	1	21
Trend beginning in 2004	ERS	Annual increment	2004–20	Trend used for regression for dry skim milk product exports.	17	9.00	5.05	1	17
Trend beginning in 2005	ERS	Annual increment	2005–20	Regression for per capita con-sumption of dry skim milk prod-ucts begins with 2005 data.	16	8.50	4.76	1	16
USDA barter program American cheese exchanged	FSA, ERS	Mil. lbs.	2009–10	Barter program was in effect for 2 years.	2	11.50	7.78	6	17
USDA barter program fat in fluid milk exchanged	FSA, ERS	Mil. lbs.	2009–10	Barter program was in effect for 2 years.	2	0.32	0.07	0.27	0.36
USDA barter program nonfat dry milk exchanged	FSA, ERS	Mil. lbs.	2009–10	Barter program was in effect for 2 years	2	–54.00	15.56	–65	–43
USDA barter program SNF in fluid milk exchanged	FSA, ERS	Mil. lbs.	2009–10	Barter program was in effect for 2 years.	2	2.36	0.49	2.01	2.71

Note: For a key to abbreviations, see table A-3.

Source: Compiled by USDA, Economic Research Service.

Table A-2
Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
All-milk price	NASS	$/cwt	1990–2020		31	15.65	2.96	12.10	24.00
All-milk price at 3.5 percent butterfat	NASS, ERS	$/cwt	1990–2020		31	15.28	2.81	11.88	23.43
Average commercial stocks of American cheese in the 4th quarter	NASS, ERS	Mil. lbs.	1990–2020		31	525.67	149.47	300.56	803.63
Average commercial stocks of butter in the 4th quarter	NASS, ERS	Mil. lbs.	1990–2020		31	101.24	69.47	11.00	275.12
Average stocks of dry skim milk products for human use in the 4th quarter	NASS, ERS	Mil. lbs.	1990–2020		31	134.90	70.57	45.80	317.98
Average stocks of dry whey for human use in the 4th quarter	NASS, ERS	Mil. lbs.	1990–2020		31	46.64	16.14	28.90	95.14
Average stocks of other cheese in the 4th quarter	NASS, ERS	Mil. lbs.	1990–2020		31	282.96	161.25	76.35	588.64
Beginning commercial stocks of American cheese	NASS	Mil. lbs.	1990–2020		31	509.54	151.83	229.66	800.34
Beginning commercial stocks of butter	NASS	Mil. lbs.	1990–2020		31	92.76	67.93	12.24	273.81
Beginning stocks of commercial cheese	NASS	Mil. lbs.	1990–2020		31	778.10	301.67	322.90	1,344.79
Beginning stocks of dry whey for humans	NASS	Mil. lbs.	1990–2020		31	48.77	15.26	31.17	96.18
Beginning stocks of other cheese	NASS	Mil. lbs.	1990–2020		31	268.57	153.11	69.99	572.13
Beginning total stocks of dry skim milk products	NASS	Mil. lbs.	1990–2020		31	142.28	70.62	49.41	321.79
Beginning total stocks of dry whey	NASS	Mil. lbs.	1990–2020		31	51.23	15.26	31.51	97.86
Class I base price at 3.25 percent butterfat	AMS	$/cwt	1996–2020	Used in equation for retail price of milk, which begins in 1996.	25	17.58	2.98	13.34	25.65
Class I base price at test of fluid milk	AMS, ERS	$/cwt	1990–2020		31	15.41	2.37	11.99	22.59
Class II price at test	AMS, ERS	$/cwt	1990–2020		31	24.10	6.67	14.67	37.90
Commercial exports of butter	Census	Mil. lbs.	2004–20	Commercial exports very small or 0 in many years before 2004.	17	70.14	53.35	9.72	178.32
Commercial exports of dry skim milk products	Census	Mil. lbs.	2004–20	Commercial exports very small or 0 in many years before 2004.	17	1,015.47	436.60	262.10	1,786.13
Condensed skim milk used in cheese production	ERS	Mil. lbs.	2000–20	Data calculated with consistent method beginning with year 2000.	21	116.23	60.48	30.60	220.90
CPI for food	BLS	Index, 1982–84=100	1990–2020		31	195.65	42.77	132.40	267.22
CPI for fresh whole milk	BLS	Index, 1982–84=100	1990–2020		31	175.39	33.19	122.40	227.74
CPI for other dairy products	BLS	Index, Dec. 1997=100	1990–2020		31	118.63	26.59	76.52	151.91

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Domestic use of canned milk	ERS	Mil. lbs.	1996–2020	Dependence on other variables.	25	463.80	63.21	320.42	582.49
Domestic comm. disappearance of cheese	ERS	Mil. lbs.	1990–2020		31	9,264.97	1,947.88	6,133.90	12,591.83
Domestic comm. disappearance of American cheese	ERS	Mil. lbs.	1990–2020		31	3,834.74	690.78	2,736.85	5,128.42
Domestic comm. disappearance of butter	ERS	Mil. lbs.	1990–2020		31	1,430.93	339.65	901.41	2,091.79
Domestic comm. disappearance of dry skim milk prod.	ERS	Mil. lbs.	2005–20	Better fit of regression equation.	16	953.41	111.59	779.40	1,141.11
Domestic comm. disappearance of dry skim milk products minus use in cheese	ERS	Mil. lbs.	2005–20	To be consistent with variable for comm. dis of dry skim milk products.	16	687.47	89.32	464.19	798.45
Domestic consumption of frozen products	ERS	Mil. lbs.	1990–2020		31	6,775.12	188.73	6,416.35	7,133.74
Domestic disappearance of dry whey	ERS	Mil. lbs.	1990–2020		31	657.70	175.95	357.06	953.37
Domestic fluid use	ERS	Mil. lbs.	1990–2020		31	53,211.42	2,905.23	46,356.00	55,433.00
Domestic use of fat in Other Class II products	ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	1,183.14	249.05	859.22	1,678.40
Domestic use of SNF Other Class II products	ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	1,225.40	186.22	830.32	1,491.44
Domestic use of Other Class II total solids	ERS	Mil. lbs.	1995–2020	Depends on other variables that begin in 1996.	26	2,408.54	336.86	1,796.23	2,925.88
Domestic comm. disappearance of other cheese	ERS	Mil. lbs.	1990–2020		31	5,430.23	1,263.69	3,371.09	7,487.27
Dry skim milk products used in cheese production	ERS, ADPI	Mil. lbs.	2000–20	Data calculated with consistent method beginning with year 2000.	21	249.31	95.38	88.10	435.86
Ending commercial stocks of American cheese	NASS	Mil. lbs.	1990–2020		31	527.99	151.44	295.64	801.72
Ending commercial stocks of butter	NASS	Mil. lbs.	1990–2020		31	85.61	59.36	12.24	189.66
Ending stocks of commercial cheese	NASS	Mil. lbs.	1990–2020		31	812.73	309.19	393.18	1,396.31
Ending stocks of dry whey for humans	NASS	Mil. lbs.	1990–2020		31	49.53	15.47	31.17	96.18
Ending stocks of other cheese	NASS	Mil. lbs.	1990–2020		31	284.74	160.28	69.99	594.59
Ending total stocks of dry skim milk production	NASS	Mil. lbs.	1990–2020		31	150.25	73.67	58.02	321.79
Ending total stocks of dry whey	NASS	Mil. lbs.	1990–2020		31	52.00	15.37	31.51	97.86
Exports of commercial American cheese	Census	Mil. lbs.	1994–2020	Oceania price readily available since 1994.	27	82.34	68.98	3.84	221.92
Exports of commercial cheese	Census	Mil. lbs.	1994–2020	Oceania price readily available since 1994.	27	346.30	291.75	42.72	811.74
Exports of dry whey	Census	Mil. lbs.	1996–2020	Western Europe price readily available since 1996.	25	409.21	107.43	218.54	582.69

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Exports of fat in major dairy products	Census, ERS	Mil. lbs.	1990–2020		31	128.16	116.41	9.16	359.72
Exports of fat in whey products other than dry whey	Census, ERS	Mil. lbs.	1990–2020		31	9.01	8.30	0.07	22.72
Exports of milk fat in all products	Census, ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	214.68	141.80	46.95	454.71
Exports of milk in all products on a milk-fat milk-equivalent basis	Census, ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	5,718.45	3,715.81	1,280.10	12,174.65
Exports of milk in all products on a skim-solids milk-equivalent basis	Census, ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	23,655.88	14,507.92	5,214.22	47,215.99
Exports of other cheese	Census	Mil. lbs.	1994–2020	Oceania price readily available since 1994.	27	263.95	226.95	38.88	631.46
Exports of SNF in all products	Census, ERS	Mil. lbs.	1995–2020	Dependence on other variables.	26	2,091.43	1,296.65	453.41	4,222.14
Exports of SNF in major dairy products	Census, ERS	Mil. lbs.	1990–2020		31	984.56	763.74	113.75	2,406.65
Exports of SNF in whey products other than dry whey	Census, ERS	Mil. lbs.	1990–2020		31	687.31	530.58	61.46	1,529.77
F.O. butterfat price	AMS	$/lb.	1990–2020		31	1.61	0.55	0.73	2.61
F.O. Class I price	AMS	$/cwt	1990–2020		31	17.20	3.18	13.07	26.14
F.O. Class I skim price	AMS	$/cwt	1990–2020		31	11.89	2.33	9.09	18.42
F.O. Class II price	AMS	$/cwt	1990–2020		31	14.34	3.02	10.76	23.34
F.O. Class II skim price	AMS	$/cwt	1990–2020		31	8.99	2.30	6.15	15.53
F.O. Class III price	AMS	$/cwt	1990–2020		31	14.20	3.06	9.74	22.34
F.O. Class III skim price	AMS	$/cwt	1990–2020		31	8.87	2.32	5.55	14.52
F.O. Class IV price	AMS	$/cwt	1990–2020		31	13.63	3.00	10.00	22.09
F.O. Class IV skim price	AMS	$/cwt	1990–2020		31	8.28	2.29	5.58	14.26
F.O. nonfat solids price	AMS	$/lb.	1990–2020		31	0.92	0.25	0.62	1.58
F.O. other solids price	AMS	$/lb.	1990–2020		31	0.15	0.13	0.01	0.47
F.O. protein price	AMS	$/lb.	1990–2020		31	2.58	0.60	1.65	3.89
Fat from other dairy products used for fluid products	ERS, ADPI	Mil. lbs.	1990–2020		31	0.08	0.15	0.00	0.45
Fat from other dairy products used in cheese production	ERS, ADPI	Mil. lbs.	1990–2020		31	2.81	0.85	1.02	4.28
Fat from other dairy products used in frozen products	ERS, ADPI	Mil. lbs.	1990–2020		31	20.60	31.85	0.90	88.27
Fat quantity required in fluid milk products	ERS	Mil. lbs.	1990–2020		31	1,059.41	64.66	957.52	1,133.19
Fat used to produce hard manufactured products	ERS	Mil. lbs.	1990–2020		31	3,954.08	848.65	2,877.30	5,565.67

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Feed margin for MPP-Dairy and DMC (before change than included premium alfalfa)	FSA	$/cwt	1990–2020		31	8.56	1.78	4.54	13.33
Gross return proxy for manufacturers of American cheese	ERS	$/cwt	1990–2020		31	17.55	3.38	12.85	26.31
Gross return proxy for manufacturers of butter and dry skim milk products	ERS	$/cwt	1990–2020		31	16.31	3.32	12.29	25.47
Gross return proxy for manufacturers of other cheese	ERS	$/cwt	1990–2020		31	19.33	3.91	14.26	28.95
Imports of American cheese	Census	Mil. lbs.	1990–2020		31	38.33	18.81	13.87	85.35
Imports of American cheese subject to TRQ	Census, ERS	Mil. lbs.	1995–2020	WTO began in 1995.	26	39.97	19.60	13.50	85.35
Imports of American cheese under FTAs	Census, ERS, USITC	Mil. lbs.	2005–20	Very little imports under FTAs before 2005.	16	1.44	0.71	0.15	2.55
Imports of butter	Census	Mil. lbs.	1990–2020		31	25.22	24.14	0.52	84.34
Imports of butter subject to TRQ	Census, ERS	Mil. lbs.	1995–2020	WTO began in 1995.	26	27.41	22.91	0.52	80.59
Imports of butter under FTAs	Census, ERS, USITC	Mil. lbs.	2005–20	Very little imports under FTAs before 2005.	16	2.85	2.29	0.16	7.92
Imports of cheese	Census	Mil. lbs.	1990–2020		31	316.56	48.59	241.70	403.78
Imports of fat in dairy products	Census, ERS	Mil. lbs.	2000–20	Dependence on other variables.	21	216.98	48.96	130.40	276.48
Imports of fat in major dairy products	Census, ERS	Mil. lbs.	1995–2020	WTO began in 1995.	26	114.28	26.98	71.97	157.95
Imports of fat in products not otherwise specified	Census, ERS	Mil. lbs.	2000–20	Better regression fit.	21	84.78	30.52	40.37	140.75
Imports of fat in whey products other than dry whey	Census, ERS	Mil. lbs.	2000–20	Better regression fit.	21	2.17	1.29	0.85	4.45
Imports of fat on a milk-equivalent basis	Census, ERS	Mil. lbs.	2000–20	Dependence on other variables.	21	5,797.96	1,283.03	3,504.46	7,490.54
Imports of non-quota cow cheese	Census, ERS	Mil. lbs.	1999–2020	Better regression fit.	22	51.39	12.92	33.32	74.66
Imports of other cheese	Census	Mil. lbs.	1990–2020		31	278.23	34.26	218.40	333.74
Imports of other cheese subject to TRQ	Census, ERS	Mil. lbs.	1995–2020	WTO began in 1995.	26	209.82	27.02	162.66	255.40
Imports of other cheese under FTAs	Census, ERS, USITC	Mil. lbs.	1995–2020	No significant cheese imports under FTAs before 1995.	26	18.91	14.29	1.48	40.06
Imports of SNF in dairy products	Census, ERS	Mil. lbs.	2000–20	Dependence on other variables.	21	535.08	54.98	425.72	626.55
Imports of SNF in major dairy products	Census, ERS	Mil. lbs.	2000–20	Dependence on other variables.	21	120.81	18.49	90.60	150.60
Imports of SNF in products not otherwise specified	Census, ERS	Mil. lbs.	2000–20	Better regression fit.	21	237.25	54.06	162.89	330.36

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Imports of SNF in whey products other than dry whey	Census, ERS	Mil. lbs.	2000–20	Better regression fit.	21	71.96	30.98	39.10	135.88
Imports of SNF on a milk-equivalent basis	Census, ERS	Mil. lbs.	2000–20	Dependence on other variables.	21	6,069.72	648.00	4,835.38	7,157.79
Manufacturers' beginning stocks of dry skim milk products for humans	NASS	Mil. lbs.	1990–2020		31	148.05	71.40	56.95	320.05
Manufacturers' ending stocks of dry skim milk products for humans	NASS	Mil. lbs.	1990–2020		31	140.36	68.63	49.41	320.05
Milk cow annual average	NASS	Thous. head	1990–2020		31	9,310.45	223.79	9,010.00	9,993.00
Milk cows (annual average) year-over-year change	NASS, ERS	Thous. head	1990–2020		31	–21.23	77.60	-167.00	125.00
Milk per cow (average)	NASS	Pounds	1990–2020		31	19,415.23	2,744.74	14,782.00	23,777.00
Milk production	NASS	Mil. lbs.	1990–2020		31	180,517.90	24,436.66	147,697.00	223,220.00
Mozzarella price for the Midwest	AMS	Cents/lb.	1990–2020		31	2.11	0.30	1.70	2.78
Net fat from raw milk used in fluid products	ERS	Mil. lbs.	1990–2020		31	1,056.17	67.49	949.41	1,132.77
Net fat required for cheese production	ERS	Mil. lbs.	1990–2020		31	2,638.41	616.61	1,725.05	3,719.39
Net fat required for production of frozen products	ERS	Mil. lbs.	1990–2020		31	596.81	49.12	490.93	659.90
Net SNF from raw milk used in fluid products	ERS	Mil. lbs.	1990–2020		31	4,753.13	219.27	4,219.22	5,018.52
Net SNF required for cheese production	ERS	Mil. lbs.	1990–2020		31	7,657.99	1,886.50	5,020.90	11,107.08
Net SNF required for production of frozen products	ERS	Mil. lbs.	1990–2020		31	503.24	112.68	286.00	634.38
Per capita cheese consumption	ERS	Pounds	1990–2020		31	31.16	4.05	24.52	38.32
Per capita consumption of American cheese	ERS	Pounds	1990–2020		31	12.93	1.29	10.80	15.55
Per capita consumption of butter	ERS	Pounds	1990–2020		31	4.80	0.76	3.56	6.34
Per capita consumption of dry skim milk prod.	ERS	Pounds	2005–20	Very little imports under FTAs before 2005.	16	3.04	0.40	2.38	3.73
Per capita consumption of dry whey	ERS	Pounds	1990–2020		31	2.30	0.80	1.12	3.62
Per capita consumption of fluid milk products	ERS	Pounds	1990–2020		31	182.62	23.19	140.59	219.46
Per capita consumption of frozen products	ERS	Pounds	1990–2020		31	23.19	2.24	19.82	26.48
Per capita consumption of other cheese	ERS	Pounds	1990–2020		31	18.23	2.80	13.48	22.79
Per capita consumption of other Class II products	ERS	Pounds	1995–2020	Dependence on other variables.	26	7.97	0.79	6.23	9.05
Production of American cheese	NASS	Mil. lbs.	1990–2020		31	3,919.23	750.24	2,768.93	5,337.53
Production of butter	NASS	Mil. lbs.	1990–2020		31	1,520.06	297.30	1,151.25	2,145.39
Production of canned milk	NASS	Mil. lbs.	1990–2020		31	515.86	61.85	343.15	615.18
Production of cheese	NASS	Mil. lbs.	1990–2020		31	9,365.07	2,240.92	6,054.86	13,253.42
Production of dry skim milk products	NASS	Mil. lbs.	1990–2020		31	1,659.90	526.53	882.07	2,704.51

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
Production of dry whey	NASS	Mil. lbs.	1990–2020		31	1,072.88	92.14	869.70	1,237.28
Production of frozen products	NASS	Mil. lbs.	1990–2020		31	6,855.97	183.34	6,444.35	7,207.92
Production of other cheese	NASS	Mil. lbs.	1990–2020		31	5,445.83	1,495.93	3,165.22	7,915.89
Quantity of fat required for frozen products	ERS	Mil. lbs.	1990–2020		31	617.41	22.25	566.64	661.20
Quantity of SNF required for frozen products	ERS	Mil. lbs.	1990–2020		31	672.81	16.38	625.78	706.30
Ratio of dry skim milk products used in cheese to cheese production	ERS	Ratio	1990–2020		31	0.03	0.01	0.01	0.05
Retail price of fresh whole fortified milk	BLS	$/gal.	1996–2020	Beginning of data series in 1996.	25	3.14	0.34	2.61	3.80
Retail price of ice cream	BLS	$/lb.	1990–2020		31	3.85	0.88	2.53	5.04
SNF from other dairy products used for fluid products	ERS	Mil. lbs.	1990–2020		31	24.69	16.69	3.00	55.98
SNF from other dairy products used in cheese production	ERS	Mil. lbs.	1990–2020		31	355.25	106.19	130.13	548.56
SNF from other dairy products used in frozen products	ERS	Mil. lbs.	1990–2020		31	169.57	107.31	57.90	379.00
SNF quantity required in fluid milk products	ERS	Mil. lbs.	1990–2020		31	4,777.82	218.01	4,247.92	5,024.92
SNF used to produce hard manufactured products	ERS	Mil. lbs.	1990–2020		31	9,483.74	2,439.69	6,043.46	14,136.61
Total fat in canned milk	ERS	Mil. lbs.	1990–2020		31	42.23	5.00	27.51	50.32
Total fat in dry skim milk products	ERS	Mil. lbs.	1990–2020		31	13.28	4.21	7.06	21.64
Total fat in dry whey	ERS	Mil. lbs.	1990–2020		31	10.73	0.92	8.70	12.37
Total fat required for dry whole milk production	ERS	Mil. lbs.	1990–2020		31	26.43	12.72	8.24	46.41
Total fat required for production of American cheese	ERS	Mil. lbs.	1990–2020		31	1,286.29	246.23	908.76	1,751.78
Total fat required for production of butter	ERS	Mil. lbs.	1990–2020		31	1,223.31	239.61	925.61	1,727.04
Total fat required for production of other cheese	ERS	Mil. lbs.	1990–2020		31	1,354.92	372.19	787.51	1,969.47
Total SNF in butter	ERS	Mil. lbs.	1990–2020		31	23.04	12.44	3.45	39.69
Total SNF required for canned milk production	ERS	Mil. lbs.	1990–2020		31	106.45	12.80	75.12	128.08
Total SNF required for dry whey production	ERS	Mil. lbs.	1990–2020		31	1,008.51	86.61	817.52	1,163.05
Total SNF required for dry whole milk production	ERS	Mil. lbs.	1990–2020		31	69.02	34.17	21.06	124.34
Total SNF required for production of American cheese	ERS	Mil. lbs.	1990–2020		31	3,335.27	638.45	2,356.36	4,542.24
Total SNF required for production of other cheese	ERS	Mil. lbs.	1990–2020		31	4,677.97	1,285.00	2,718.92	6,799.75
Total SNF required for production of NDM	ERS	Mil. lbs.	1990–2020		31	1,580.22	501.26	839.73	2,574.69
U.S. Class I fat	ERS	Mil. lbs.	1990–2020		31	1,056.17	67.49	949.41	1,132.77

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Table A-2 continued

Endogenous variables, descriptive statistics

Description	Data source	Units	Data period used	Reason for period other than 1990–2020	N	Mean	Std Dev	Min	Max
U.S. Class I milk quantity	ERS	Mil. lbs.	1990–2020		31	53,248.04	2,825.87	46,325.56	56,092.91
U.S. Class I skim milk quantity	ERS	Mil. lbs.	1990–2020		31	52,191.87	2,784.05	45,330.62	55,060.81
U.S. Class I SNF	ERS	Mil. lbs.	1990–2020		31	4,753.13	219.27	4,219.22	5,018.52
U.S. Class II fat	ERS	Mil. lbs.	1990–2020		31	1,660.96	270.19	1,298.12	2,210.89
U.S. Class II milk quantity	ERS	Mil. lbs.	1990–2020		31	18,396.37	2,249.56	13,607.13	22,042.31
U.S. Class II skim milk quantity	ERS	Mil. lbs.	1990–2020		31	16,735.42	2,242.50	12,078.01	20,721.38
U.S. Class II SNF	ERS	Mil. lbs.	1990–2020		31	1,524.69	203.21	1,094.70	1,858.34
U.S. Class III fat	ERS	Mil. lbs.	1990–2020		31	2,669.34	604.75	1,767.95	3,729.70
U.S. Class III milk quantity	ERS	Mil. lbs.	1990–2020		31	87,083.54	19,824.73	58,873.61	123,062.60
U.S. Class III skim milk quantity	ERS	Mil. lbs.	1990–2020		31	84,414.20	19,220.54	57,105.66	119,332.90
U.S. Class III SNF	ERS	Mil. lbs.	1990–2020		31	7,709.60	1,842.48	5,121.37	11,107.09
U.S. Class IV fat	ERS	Mil. lbs.	1990–2020		31	1,284.74	261.06	967.74	1,835.97
U.S. Class IV milk quantity	ERS	Mil. lbs.	1990–2020		31	20,689.83	6,663.92	11,391.11	34,384.67
U.S. Class IV skim milk quantity	ERS	Mil. lbs.	1990–2020		31	19,405.09	6,418.89	10,281.77	32,548.70
U.S. Class IV SNF	ERS	Mil. lbs.	1990–2020		31	1,774.15	606.46	922.09	3,029.52
U.S. fat pounds in marketings	NASS	Mil. lbs.	1990–2020		31	6,671.21	1,052.40	5,309.21	8,771.50
U.S. marketings	NASS	Mil. lbs.	1990–2020		31	179,275.17	24,698.14	145,723.00	222,135.10
U.S. SNF pounds in marketings	ERS	Mil. lbs.	1990–2020		31	15,761.56	2,319.02	12,677.81	19,869.70
U.S. weighted average "blend price" at 3.5 percent butterfat	ERS	$/cwt	1990–2020		31	15.06	2.93	11.50	23.36
U.S. weighted average "blend price" at test	ERS	$/cwt	1990–2020		31	15.41	3.07	11.66	23.90
U.S. weighted average fat price (Class I, II, III, and IV)	ERS	$/cwt	1990–2020		31	1.62	0.55	0.73	2.62
U.S. weighted average skim price (Class I, II, III, and IV)	ERS	$/cwt	1990–2020		31	9.74	2.22	6.64	15.56
Wholesale price of grade AA butter	AMS	cents/lb.	1990–2020		31	146.65	47.63	70.88	233.03
Wholesale price of dry whey	AMS	cents/lb.	1990–2020		31	31.32	14.60	14.32	65.38
Wholesale price of NDM	AMS	cents/lb.	1990–2020		31	108.34	26.36	79.45	176.85
Wholesale price of Cheddar cheese	AMS	cents/lb.	1990–2020		31	151.16	25.25	113.13	215.51

Note: For a key to abbreviations, see table A-3.

Source: Compiled by USDA, Economic Research Service.

Table A-3
Key to abbreviations used in tables A-1 and A-2

$/cwt	dollars per hundredweight
$/lb.	dollars per pound
ADPI	American Dairy Products Institute
AMF	anhydrous milk fat
AMS	USDA, Agricultural Marketing Service
BEA	U.S. Department of Commerce, Bureau of Economic Analysis
BLS	U.S. Department of Labor, Bureau of Labor Statistics
Census	U.S. Department of Commerce, Bureau of the Census
cents/lb.	cents per pound
comm.	commercial
CPI	Consumer Price Index
DEIP	Dairy Export Incentive Program
DMC	Dairy Margin Coverage program
ERS	USDA, Economic Research Service
Evap. & cond.	evaporated and condensed
F.O.	Federal Order
FAS	USDA, Foreign Agricultural Service
FTA	free trade agreement
max	maximum
mil. lbs.	million pounds
min	minimum
MPC	milk protein concentrate
MPP-Dairy	Margin Protection Program for Dairy Producers
N	number of observations
NASS	USDA, National Agricultural Statistics Service
NDM	nonfat dry milk
SNF	solids nonfat
std dev	standard deviation
USITC	U.S. International Trade Commission
WTO	World Trade Organization

Appendix B: Complete List of Model Equations

Milk Production

Change in milk cows from previous year = –363.800

+ 121.056 × lag (all milk price/16 percent protein feed value)

– 15.263 × (cull cow price proxy/all milk price) + 121.96 × dummy for years after 2004

+ 79.544 × dummy for years after 2010

[For years when the Milk Income Loss Contract (MILC) program was in operation, adjustments have been made to the all-milk price to account for payments received by dairy operations that produce less than the annual production cap. For more information, see appendix D.]

Milk cows = lag (milk cows) + change in milk cows from previous year

Milk per cow = 14,091.050 + 133.218 × lag (all milk price/16 percent protein feed value)

+ 315.654 × trend [year – 1989]

– 11.316 × dummy for years after 2014 × trend [year – 1989]

[For years when the MILC program was in effect, payments per hundredweight for those programs were added to the all-milk price.]

Milk production = (milk cows × milk per cow) / 1,000

[For leap years, the milk production projection is adjusted by multiplying by 366/365. Hereafter, such adjustments are designated as “Includes leap year adjustments.”]

Marketings = milk production – farm use

Milk fat marketed = marketings × milk-fat test for producer milk

Skim solids marketed = marketings × skim-solids test for producer milk

Demand for Fluid Milk and Dairy Products

Year-over-year change in fluid milk consumption per capita = –116.574

– 6.375 × ln ((CPI fresh whole milk/CPI all) × 100)

+ 12.530 × ln (real disposable personal income per capita) – 3.243 × dummy for years after 2009

ln (Cheese consumption per capita) = 0.389

– 0.066 × ln (Cheddar cheese price/CPI all) × 100)

+ 0.304 × ln (real disposable income per capita) + 0.008 × trend [year – 1989]

+ 0.008 × trend [year – 1989] – 0.028 × dummy for 2009 ln (Butter consumption per capita) = –5.134 – 0.056 × ln ((Butter price CPI food) × 100)

+ 0.604 × ln (real disposable personal income per capita)

+ 0.394 × lag (ln (butter consumption per capita)) – 0.056 × dummy for years 2002 to 2010

ln (Consumption of dry skim milk products per capita) = +1.413

– 0.002 × ((nonfat dry milk price/CPI all) × 100) – 0.022 × trend [year – 2004]

– 0.211 × dummy for 2006 +0.190 × dummy for 2012

ln (Consumption of frozen products per capita) = –0.509

– 0.185 × ln (retail price of ice cream/CPI all)

+ 0.384 × ln (real disposable personal income per capita) – 0.017 × trend [year – 1989]

ln (Other Class II per capita) = 2.735

– 0.868 × ln ((CPI other dairy products/CPI all) × 100)

+ 0.277 × ln (real disposable personal income per capita) – 0.144 × dummy for 2000

– 0.202 × dummy for 2002

ln (Dry whey consumption per capita) = 2.842 – 0.364 × ln ((dry whey price/CPI all) × 100)

– 0.030 × trend [year – 1989] – 0.568 × dummy for years before 1992

Domestic disappearance estimates are as follows for total cheese, butter, dry skim milk products, dry whey, frozen products, and Other Class II:

Per capita consumption × population = domestic disappearance [commercial[31] disappearance for products that were previously part of the Dairy Products Price Support Program]

American cheese and other cheese domestic commercial disappearance estimates are solved as residuals in balance equations for those products.

Other cheese consumption per capita = domestic commercial disappearance of other cheese/population

American cheese consumption per capita = cheese consumption per capita – other cheese consumption per capita

[Adjustments are made for leap year projections.]

Retail Prices

Retail price of ice cream/CPI all = 0.003

+ 0.014 × (Class II price at test/CPI all)

+ 0.745 × lag (retail price of ice cream/CPI all)

+ 0.001 × dummy for years 2009 to 2012

[31] The term "commercial," with respect to domestic disappearance or exports, distinguishes these quantities from Federal Government use of products purchased through the Dairy Products Price Support Program and exports subsidized by the Dairy Export Incentive Program. Both programs were repealed by the Agricultural Act of 2014.

(CPI for fresh whole fluid milk/CPI for all) – lag (CPI for fresh whole fluid milk/CPI for all) = 0.000

+ 3.609 × ln (Class I price at 3.25 percent fat percent with average Class I differential/CPI for all)

ln (Retail price for whole fluid milk [fortified]/CPI all) = –4.045 + 1.283 × ln (CPI for fresh milk/CPI all)

+ 0.067 × dummy for years before 2001 – 0.059 × dummy for years after 2011

ln (CPI for other dairy products/CPI all) = 0.140 +0.100 × ln (Class II price at test/CPI all)

+ 0.854 lag (ln (CPI other dairy products/CPI all)) – 0.023 × dummy for years after 2015

ln (CPI for food/CPI all) = 0.000 +0.920 × lag (ln (CPI food/CPI all))

Gross Value and Mozzarella Wholesale Price

Gross value for American cheese = (Cheddar cheese price/100) × 10.043 + (butter price/100) × 0.304

+ (dry whey price/100) × 6.1381

Gross value of other cheese = mozzarella cheese price × 9.455 + (butter price/100) × 2.1

+ (dry whey price/100) × 6.254

Gross value of butter and NDM = (Butter Price/100) × 4.475 + (nonfat dry milk price/100) × 8.998

Mozzarella price = 0.260 + 0.008 × (Cheddar cheese price) + 0.334 × lag (mozzarella price)

– 0.129 × dummy for years 1995 to 1998 + 0.111 × dummy for years 2010 to 2012

Production of Dairy Products

ln (Production of American cheese) = 0.232

+ 0.106 × ln (gross value for American cheese/gross value for butter and NDM)

+ 0.974 × lag (ln (production of American cheese)) – 0.076 × dummy for 1991 – 0.054 × dummy for 2003

[Includes leap year adjustments.]

Production of other cheese = 2,331.881

+ 551.173 × (gross value for other cheese/gross value for butter and NDM)

+ 145.485 × trend [year – 1989] + 335.815 × dummy for 2007

+ 12.095 × dummy for years 2010 to 2019 × trend [year –1989]

+ 215.802 × dummy for years after 2017

[Includes leap year adjustments.]

Total cheese production = American cheese production + other cheese production

Production of butter = butterfat available for butter production/0.805

Production of dry skim milk products = skim solids available for production of dry skim milk products/0.952

ln (Dry whey production / cheese production) = –1.549 + 0.017 × ln (dry whey price / CPI for food)

–0.017 × trend [year – 1989] – 0.071 × dummy for 2001 – 0.146 × dummy for 2014

[Leap year adjustments are reflected in this equation since the adjustments are made for the cheese production equations.]

Production of frozen products = domestic consumption of frozen products – imports of frozen products

+ exports of frozen products

Duplication Adjustments

ln (Dry skim milk products used in cheese/cheese production) = –2.825

– 0.070 × trend [year – 1999] – 0.949 × dummy for years before 2003

Dry skim milk products used in cheese =

cheese production × (dry skim milk products used in cheese/cheese production)

ln (Condensed milk solids used in cheese) = 6.762 – 0.470 × (dry skim milk products used in cheese)

+ 1.004 × dummy for years 2006 to 2018

Skim solids from dry skim milk products used in Class II products other than frozen products =

dry skim milk products used in cultured products × 0.952

+ dry skim milk products used in Class II dairy products other than frozen or cultured × 0.952

Skim solids from dry skim milk products and condensed milk solids used in cheese =

0.952 × dry skim milk products used in cheese

+ 0.993 × condensed milk solids used in cheese

Skim solids used in fortification of fluid milk = fluid milk skim solids × typical skim solids fortification percentage

Skim solids from other dairy products used in frozen dairy products =

skim solids in frozen products × typical percentage of frozen skim solids from other dairy products

Fat from dry skim milk products used in Other Class II = dry skim milk used in cultured product × 0.008

+ dry skim milk products used in Class II dairy products besides frozen or cultured products × 0.008

Fat from dry skim milk products used in Class II products other than frozen products =

dry skim milk products used in cultured products × 0.008

+ dry skim milk products used in Class II products other than frozen or cultured × 0.008

Fat from dry skim milk products and condensed milk solids used in cheese =

dry skim milk products used in cheese × 0.008

+ condensed milk solids used in cheese × 0.007

Fat added to fluid milk as result of fortification process =

fat in fluid products × typical percentage of fat from fortification

Fat from other dairy products used in frozen products =

fat in frozen products × typical percentage of fat from other dairy products

Net fat used in cheese = fat required for cheese production

– milk fat from dry skim milk products and condensed milk solids used in cheese

Net fat used in frozen products = fat required for frozen products production

– fat from other dairy products used in frozen products

Net fat used in fluid products = fat required for fluid products

– fat added to fluid milk because of the fortification process

Net skim solids used in cheese = skim solids required for cheese production

– skim solids from dry skim milk products and condensed milk solids used in cheese

Net skim solids used in frozen products = skim solids required for frozen products production

– skim solids from other dairy products used in frozen products

Net skim solids used in fluid products = skim solids required for fluid products

– skim solids added to fluid milk for fortification

Stocks

Butter stocks average last quarter/butter production for the year = 0.045 – 0.032 × butter price / CPI all

+ 0.003 × trend [year – 1989] + 0.042 × dummy for years 2002 and 2003

– 0.026 × dummy for years 1993 to 2000

(American cheese stocks average last quarter/American cheese production for the year) = 0.178

– 0.0.062 × (Cheddar cheese price/CPI all) – 0.023 × dummy for years 1994 and 1995

+ 0.013 × dummy for years after 2009

(Other cheese stocks average last quarter/other cheese production for the year) = 0.092

– 4.751 × (mozzarella price/CPI all) – 0.021 × dummy for 1997

+ 0.020 × dummy for years after 2007

ln (NDM stocks for human consumption average last quarter/dry skim milk products production for the year)

= –2.736 – 0.294 × ln (NDM price / CPI all) – 0.877 × dummy for 2006

ln (Dry whey stocks for human consumption, average last quarter/dry whey production for the year) = –3.722

– 0.128 × ln (dry whey price/CPI for food) + 0.576 × dummy for 2007 and 2008

+ 0.312 × dummy for years 2009 to 2012 + 0.811 × dummy for years after 2012

$+ 0.307 \times$ dummy for 2017

ln (Butter ending stocks) = –0.142 + 1.007 × ln (butter stocks average last quarter)

ln (American cheese endings stocks) = –0.023 + 1.004 × ln (American cheese average stocks last quarter)

ln (other cheese ending stocks) = –0.003 + 1.002 × ln (other cheese ending stocks average last quarter)

ln (NDM ending stocks for human use) = 0.616 + 0.895 × ln (NDM for human use average stocks for last quarter)

Dry skim milk products ending stocks = NDM ending stocks for human use

+ dry skim milk ending stocks for animal feed

ln (Dry whey ending stocks for human consumption) = 0.447

+ 0.900 × ln (dry whey stocks for human consumption average last quarter)

Dry whey ending stocks = dry whey ending stocks for human consumption

+ dry whey ending stocks for animal feed

Total cheese ending stocks = American cheese ending stocks + other cheese ending stocks

For stocks of all dairy products included in the model, beginning stocks are equal to the previous year ending stocks.

Imports

ln (Butter imports subject to TRQ) – ln (butter TRQ) = – 0.376

+ 7.751 × {[(U.S. domestic butter price/100 – Oceania export butter price) / U.S. CPI all]^3}

+ 1.349 × dummy for years 2015 to 2017 + 1.995 × dummy for years after 2017

ln (Butter imports under FTAs) = –0.507

+ 7.461 × (U.S. domestic butter price/100 – Oceania export butter price) / (U.S. CPI all)

– 2.858 × dummy for 2004 +1.598 × dummy for 2007 + 2.007 × dummy for years after 2016

Butter imports = butter imports subject to quota + butter imports under FTAs

ln (American cheese imports subject to TRQ) – ln (sum of TRQs for American cheese) = –2.315

+ 13.163 × ({[(U.S. domestic Cheddar cheese price/100 – Oceania export cheese price) / U.S. CPI all]

– 0.03}^{3}) – 1.275 × dummy for years 2011 and 2012

ln (American cheese imports under FTAs) = 1.642

+ 3.178 × (U.S. domestic Cheddar cheese price/100 – Oceania export cheese price) / U.S. CPI all

– 1.275 × dummy for years 2011 and 2012

American cheese imports = American cheese imports subject to TRQ

+ American cheese imports under FTAs

ln (other cheese imports subject to TRQ) – ln (sum of TRQs for other cheese) = –0.318

+ 3.980 × ({[(U.S. domestic Cheddar cheese price/100 – Oceania export cheese price) / U.S. CPI all]

– 0.36}^{3}) – 0.175 × dummy for years 2000 to 2007

ln (other cheese imported under FTAs) = –6.233

+ 33.020 × (U.S. domestic Cheddar cheese price / 100 – Oceania export cheese price) / U.S. CPI all

+ 34.297 × dummy for years after 2004 +11.816 × dummy for years 2006 and 2007

ln (other cheese imports not subject to TRQ from cows) = 1.552

+ 0.902 × (U.S. domestic Cheddar cheese price/100 – Oceania export cheese price) / U.S. CPI all

+ 0.594 × lag (ln (other cow cheese imports not subject to TRQ))

Imports of other cheese = imports of other cheese subject to TRQ

+ imports of other cheese under FTAs + imports of other cow cheese not subject TRQ

Total cheese imports = American cheese imports + other cheese imports

Imports of fat in major dairy products = $\sum_i$ import quantity $_i$ × import fat percent $_i$

where the i series includes dry skim milk products, other cheese, dry whey, American cheese, butter, and condensed milk

ln (Imports of milk fat in whey products other than dry whey) = 0.108

+ 0.859 × lag (ln (imports of dry whey products other than dry whey)) + 0.539 × dummy for 2014

ln (imports of fat in products not otherwise specified in model) = 4.081

+ 0.636 × (U.S. domestic butter price/100 – Oceania butter price) / (CPI all /100)

+ 0.739 × dummy for years 2005 to 2007 + 0.397 × dummy for years after 2015

Fat in imports of frozen dairy products = imports of frozen dairy products × frozen dairy products imports fat percent

Fat in imports MPC = imports of MPC × MPC imports fat percent

Imports of fat = $\sum_j$ import fat quantity $_j$

where the j series includes major dairy products, whey products other than dry whey, fluid milk products, frozen dairy products, MPC, and other products not otherwise specified

Imports on a milk-fat milk-equivalent basis = imports of fat/fat test for producer milk

Imports of skim solids in major dairy products = $\sum_i$ import quantity $_i$ × import skim solids percent $_i$

where the i series includes dry skim milk products, other cheese, dry whey, American cheese, butter, and condensed milk

ln (Imports of skim solids in whey products other than dry whey = 0.705

+ 0.834 × lag (ln (imports of skim solids in whey products other than dry whey))

+ 0.498 × dummy for 2014

Imports of skim solids in dairy products not otherwise specified = 5.447

+ 0.463 × (U.S. domestic price of NDM/100 – Oceania SMP export price) / U.S. CPI all

+ 0.046 × dummy for years before 2009 × trend [year – 1989]

– 0.011 × dummy for years after 2008 × trend [year – 1989]

+ 0.083 × dummy for years 2011 to 2013

Imports of skim solids in frozen dairy products =

imports of frozen dairy products × frozen dairy products skim solids percent

Skim solids in MPC imports = MPC imports × percent of skim solids in MPC imports

Imports of skim solids = $\sum_j$ import skim solids quantity $_j$

where the j series includes major dairy products, whey products other than dry whey, fluid milk products, frozen dairy products, MPC, and other products not otherwise specified

Imports on a skim-solids milk-equivalent basis = imports of skim solids/skim-solids test for producer milk

Exports

ln (Butter commercial exports) = 4.245

– 6.808 × (U.S. domestic butter price / 100 – Oceania export butter price) / CPI all

+ 1.897 × dummy for 2014

ln (American cheese commercial exports) = 3.997

– 2.542 × (U.S. domestic Cheddar cheese price/100 – Oceania export cheese price)/CPI all

+1.063 × dummy for years after 2010

ln (other cheese exports) = 0.685

–0.632 × (U.S. domestic Cheddar cheese price/100 – Oceania export cheese price) / CPI all

+ 0.895 × lag (ln (other cheese exports))

+ 0.119 × dummy for years 2011 to 2014

Dry skim milk products commercial exports = 219.082

– 37.289 × exp [(U.S. domestic nonfat dry milk price /100 – Oceania SMP export price) / (CPI all/100)]

+ 85.316 × trend [year – 2003]

ln (dry whey exports) = 5.192

– 3.614 × (U.S. domestic dry whey price / 100 – Western European dry whey export price) / U.S. CPI all

+ 0.317 × trend [year – 2005] – 0.428 × dummy for 2019

Total cheese exports = American cheese exports + other cheese exports

Exports of fat in major dairy products = $\sum_i$ export quantity $_i$ × export fat percent $_i$

where the i series includes dry skim milk products, other cheese, dry whey, American cheese, butter, and condensed milk

Exports of fat in whey products other than dry whey = –18.616 + 0.003 × (domestic cheese consumption)

+ 4.505 × dummy for years after 2008

Exports of fat in frozen products = exports of frozen products × frozen products exports fat percent

Exports of fat = $\sum_m$ export fat quantity $_m$

where the m series includes major dairy products; fluid products; frozen products; Other Class II; whey products other than dry whey (dry whey is part of major dairy products); MPC and milk powders other than dry skim milk products; anhydrous milkfat and butteroil; and casein products

Exports on a milk-fat milk-equivalent basis = exports of fat/fat test of producer milk

Exports of skim solids in major dairy products = $\sum_i$ export quantity i × export skim solids percent $_i$

where the i series includes dry skim milk products, other cheese, dry whey, American cheese, butter, and condensed milk

Exports of skim solids in products in whey products other than dry whey = –1,045.280

+ 0.169 × (domestic cheese consumption) +295.839 × dummy for years after 2008

+ 174.375 × dummy for years after 2011

Exports of skim solids in frozen dairy products =

exports of frozen dairy products × skim solids percent for frozen dairy products.

Exports of skim solids = $\sum_m$ export skim solids quantity $_m$

where the m series includes major dairy products; fluid products; frozen products; Other Class II; whey products other than dry whey (dry whey is part of major dairy products); MPC and milk powders other than dry skim milk products; anhydrous milkfat and butteroil; and casein products

Exports on a skim-solids milk-equivalent basis = exports of skim solids/skim-solids test of producer milk

Product Balance Equations

Cheese: beginning commercial stocks + production + imports = domestic commercial disappearance

+ commercial exports + shipments to U.S. territories + net Government removals + Government barters

+ ending commercial stocks

American cheese: beginning commercial stocks + production + imports = domestic commercial disappearance

+ commercial exports + shipments to U.S. territories + net Government removals + Government barters

+ ending commercial stocks

Other cheese: beginning stocks + production + imports = domestic disappearance + exports

+ shipments to U.S. territories + ending stocks

Butter: beginning commercial stocks + production+ imports = domestic commercial disappearance

+ commercial exports + shipments to U.S. territories + net Government removals

+ commercial ending stocks

Dry skim milk products[32]*:* beginning manufacturers' stocks + production + imports

= domestic commercial disappearance + commercial exports + shipments to U.S. territories

+ net Government removals + Government barters + animal use + ending manufacturers' stocks

Dry whey: beginning manufacturers' stocks + production + imports = domestic disappearance + exports

+ animal use

+ ending manufacturers' stocks

Canned milk [condensed and evaporated]: beginning manufacturers' stocks + production + imports

= domestic disappearance + exports + shipments to U.S. territories + ending manufacturer's stocks

Classified Milk Prices and All-Milk Price

Protein price = [(Cheddar cheese price – 0.2003) × 1.383] + ({[(cheese price – 0.2003) × 1.572]

– butterfat price ×0.90} × 1.17)

Butterfat price = (butter price – 0.1715) × 1.211

Other solids price = (dry whey price – 0.1991) × 1.03

Nonfat solids price = (NDM price – 0.1678) × 0.99

Class III skim milk price = 3.1 × protein price + 5.9 × other solids price

Class IV skim milk price = 9 × nonfat solids price

Class II skim milk price = Class IV skim price + 0.7

Class I skim milk price = (Class III skim milk price + Class IV skim milk price)/2 + 0.74

Class I milk price = 0.965 × Class I skim milk price + 3.5 × (butterfat price + (Class I differential/100))

Class II milk price = 0.965 × Class II skim milk price + 3.5 × (butterfat price + 0.007)

Class III milk price = 0.965 × Class III skim milk price + 3.5 × butterfat price

Class IV milk = 0.965 × Class IV skim milk price + 3.5 × butterfat price

U.S. milk fat price using Federal milk marketing order (FMMO) formulas =

((U.S. Class I fat × (butterfat price + (Class I differential/100)))

+ (U.S. Class II fat × (butterfat price + .007))

[32] Dry skim milk products include nonfat dry milk, skim milk powder, and dry skim milk for animal use. For stocks, skim milk powder is not included due to lack of data.

+ (U.S. Class III fat × butterfat price) + (U.S. Class IV fat × butterfat price))

/ (U.S. Class I fat + U.S. Class II fat + U.S. Class III fat + U.S. Class IV fat)

U.S. skim milk price using FMMO formulas =

((U.S. Class I skim × Class I skim milk price) + (U.S. Class II skim × Class II skim milk price)

+ (U.S. Class III skim × Class III skim price) + (U.S. Class IV skim × Class IV skim milk price))

/ (U.S. Class I skim + U.S. Class II skim + U.S. Class III skim + U.S. Class IV skim)

Class I price adjusted to average fat content for fluid milk consumption =

(Average fat content for fluid milk consumption × (butterfat price + (Class I differential/100)))

+((1 – average fat content for fluid milk consumption) × Class I skim milk price)

Minimum price for milk used in fluid milk products at 3.25 percent milk fat =

3.25 × (butterfat price +(Class I differential/100)) +(1 –. 0325) × Class I skim price)

Class II price at Class II test = (((U.S. Class II fat/U.S. Class II) × 100) × (butterfat price + 0.007))

+(((1 – (U.S. Class II fat/U.S. Class II)) × (Class II skim price))

U.S. weighted average price for Classes II, III, and IV = (Class II price × U.S. Class II quantity

+ Class III price × U.S. Class III quantity + Class IV price × U.S. Class IV quantity)

/(U.S. Class II quantity + U.S. Class III quantity + U.S. Class IV quantity)

U.S. “blend price” at 3.5 percent milk fat = ((0.965 × U.S. skim milk price using FMMO formulas)

+ (3.5 × U.S. milk fat price using FMMO formulas))

U.S. “blend price” at test = ((1 – fat test of producer milk) × U.S. skim milk price using FMMO formulas)

+ (Fat test of producer milk × U.S. milk fat price using FMMO formulas))

ln (All milk price at 3.5 percent milk fat) = 0.193 +0.935 × ln (U.S. “blend price” at 3.5 percent milk fat)

All milk price at test = all milk price at 3.5 percent milk fat

+ ((fat test of producer milk – 3.5) × U.S. milk fat price using FMMO minimum prices

Average annual feed margin for Dairy Margin Coverage [DMC] program = all milk price

– feed price proxy used in DMC program

Allocation of Milk and Components

Milk fat quantities associated with production of other cheese, American cheese, dry skim milk products, dry whole milk, and dry whey are calculated as follows using conversion factors listed in table 1:

Production of product × milk fat percent

Skim solids quantities associated with production of other cheese, American cheese, butter, dry whole milk, and dry whey are calculated as follows using conversion factors listed in table 1:

Production of product × skim solids percent

U.S. Class I fat = net fat used in fluid products

U.S. Class II fat = net fat used in frozen products + Other Class II fat used in domestic consumption

+ fat from exports of Other Class II

– (fat from MPC imports – fat from exports of casein products

+ imports from fat from products not otherwise classified in model)

U.S. Class III fat = net fat used in cheese + fat from exports of anhydrous milkfat and butteroil

U.S. Class IV fat = fat available for butter production + fat from canned milk production

+ fat in dry whole milk production + fat from dry skim milk production + fat from MPC production

U.S. Class I skim solids = net skim solids used in fluid products

U.S. Class II skim solids = net skim solids used in frozen products

+ Other Class II skim solids used in domestic consumption

+ skim solids from exports of Other Class II

– (skim solids from MPC imports – skim solids from exports of casein products

+ imports from skim solids from products not otherwise classified in model)

U.S. Class III skim solids = net skim solids used in cheese

+ skim solids from exports of anhydrous milkfat and butteroil

U.S. Class IV skim solids = skim solids available for butter production

+ skim solids from canned milk production + skim solids in dry whole milk production

+ skim solids from dry skim milk production + skim solids from MPC production

U.S. Class I skim milk = (Class I skim solids/skim-solids test for producer milk) × (1 – fat test for producer milk)

U.S. Class II skim milk = (Class II skim solids/skim-solids test for producer milk) × (1 – fat test for producer milk)

U.S. Class III skim milk = (Class III skim solids/skim-solids test for producer milk) × (1 – fat test for producer milk)

U.S. Class IV skim milk = (Class IV skim solids/skim-solids test for producer milk) × (1 – fat test for producer milk)

U.S. Class I milk = U.S. Class I skim milk + U.S. Class I fat

U.S. Class II milk = U.S. Class II skim milk + U.S. Class II fat

U.S. Class III milk = U.S. Class III skim milk + U.S. Class III fat

U.S. Class IV milk = U.S. Class IV skim milk + U.S. Class IV fat

Fat for cheese, butter, and milk powders = milk fat marketed – U.S. Class I fat – U.S. Class II fat

U.S. Class IV fat = fat for cheese, butter, and milk powders – U.S. Class III fat

Skim solids for cheese, butter, and milk powders = skim solids marketed – U.S. Class I skim solids

– U.S. Class II skim solids

U.S. Class IV skim solids = skim solids for cheese, butter, and milk powders – U.S. Class III skim solids

Fat used in fluid products =

fluid use × assumed fat percentage of milk in domestically consumed fluid products

+ fat in exports of fluid products

Skim solids used in fluid products =

fluid use × assumed skim solids percentage of milk in domestically consumed fluid products

+ skim solids in exports of fluid products

Fat used in domestic consumption of Other Class II =

total solids of Other Class II consumed domestically × assumed fat percentage of the total solids

Skim solids used in domestic consumption of Other Class II =

total solids of Other Class II consumed domestically

× assumed skim solids percentage of the total solids

Fat used in production of frozen products = production of frozen products × fat percentage for frozen products

Skim solids used in production of frozen products = production of frozen products

× skim solids percentage for frozen products

Appendix C: Federal Milk Marketing Order Price Formulas

Announced milk prices are per 100 pounds (cwt), rounded to the nearest cent. Component prices are per pound, rounded to nearest 1-hundredth cent. Product prices and pricing factors are per pound, rounded to the nearest 1-hundredth cent.

For advanced cheese, dry whey, butter, and nonfat dry milk prices, the prices are 2-week weighted averages of the weekly *National Dairy Products Sales Report* (NDPSR) prices, rounded to the nearest 1-hundredth cent.

For cheese, dry whey, butter, and nonfat dry milk prices, the prices are 4- or 5-week weighted averages of NDPSR prices, rounded to the nearest one-hundredth cent.

Class I:

- Base Class I price = (base skim milk price for Class I x 0.965) + (advanced butterfat pricing factor x 3.5)
- Base skim milk price for Class I = ((advanced Class III skim milk pricing factor + advanced Class IV skim milk pricing factor) / 2) + $0.74
- Advanced Class III skim milk pricing factor = (advanced protein price x 3.1) + (advanced other solids price x 5.9)
    - Advanced protein price = ((advanced cheese price – 0.2003) x 1.383) + ((((advanced cheese price – 0.2003) x 1.572) – advanced butterfat pricing factor x 0.9) x 1.17)
    - Advanced other solids price = (advanced dry whey price – 0.1991) x 1.03
- Advanced Class IV skim milk pricing factor = advanced nonfat solids price x 9
    - Advanced nonfat solids price = (advanced nonfat dry milk price – 0.1678) x 0.99
- Advanced butterfat pricing factor = (advanced butter price – 0.1715) x 1.211
- Class II skim milk price = advanced Class IV skim milk pricing factor + 0.70
- Class II nonfat solids price = Class II skim milk price/9

Class II:

- Class II price = (Class II skim milk price x 0.965) + (Class II butterfat price x 3.5)
    - Class II skim milk price = advanced Class IV skim milk pricing factor + 0.70
    - Class II butterfat price = butterfat price + 0.007
        - Butterfat price = (butter price – 0.1715) x 1.211

Class III:

- Class III price = (Class III skim milk price x 0.965) + (butterfat price x 3.5)
    - Class III skim milk price = (protein price x 3.1) + (other solids price x 5.9)
        - Protein price = ((cheese price – 0.2003) x 1.383)+ ((((cheese price – 0.2003) x 1.572) – butterfat price x 0.9) x 1.17)

        - Other solids price = (dry whey price – 0.1991) x 1.03

Class IV:

- Class IV price = (Class IV skim milk price x 0.965) + (butterfat price x 3.5)
    - Class IV skim milk price = nonfat solids price x 9
        - Nonfat solids price = (nonfat dry milk price – 0.1678) x 0.99

Somatic cell adjustment rate = cheese price x 0.0005, rounded to fifth decimal place (per 1,000 somatic cell count).

Source: *Milk Marketing Order Statistics, Price Formulas 2019*, U.S. Department of Agriculture, Agricultural Marketing Service.

Appendix D: Modeling Supply Impacts of the Milk Income Loss Contract Program

From 2002 through 2013, the USDA Farm Service Agency (FSA) administered the Milk Income Loss Contract program (MILC). When the program began, MILC payments were made to dairy farmers when the Boston Class I milk price fell below $16.94 per cwt. FSA issued payments up to a maximum of 2.4 million pounds of milk produced and marketed by each participating operation per fiscal year. Later adjustments were made to the program, including an adjustment for feed costs. The production cap per operation was raised to 2.9 million pounds in 2009.

According to classical economic theory, producers maximize profits by equating marginal cost with marginal revenue. Based on this premise, the MILC program would have had no supply effect for operations that produced more than the cap in a fiscal year since each additional pound did not generate additional revenue from the program. For the sake of this discussion, we call these producers large operators. For small operators, however, producing less than the cap in a fiscal year, the MILC program would have had supply effects since each additional pound of production would have resulted in a higher payment to the operation. Adjustments to the milk-feed ratio to account for historical MILC payments to small producers were made to help improve the regression coefficients used in projecting milk cow numbers and milk per cow.

Although data are available concerning total payments made through the MILC program during its years of operation, data are not available for direct payments to small operators versus large operators. However, estimates of these distributions are made for modeling purposes based on data provided by USDA, NASS concerning milk production by farm size groupings for 2002–12 (table D-1). Milk production data by farm size group are not available for 2013; trends from the data were used for that year.

Based on the percentages displayed in table D-1, we can estimate payments made to small and large operations. Taking the estimated payments made to small operations each year and dividing by U.S. milk production, we estimate dollars per cwt to adjust to the all-milk price for each year of the program to account for milk production supply responses (table D-2). Model regression equations for milk cow numbers and milk per cow include milk-feed ratio terms, with the all-milk price serving as the numerator of the ratio.

Although the model does not account for payments made to large producers, such payments may have had at least some indirect effects on U.S. milk production. To the extent that the payments made to large producers enhanced their wealth, the payments may have led them to invest more in their operations and influenced their attitudes toward risk. However, such wealth effects on supply response due were likely lower than marginal-revenue effects on supply resulting from payments made to small operators. Since payments to large producers did not increase per-unit net returns from additional production, the additional household wealth from the payments would have been more likely to be spread among many uses in addition to farming, such as household consumption, savings, and investments (Westcott and Young, 2004). It would be difficult to estimate the supply response of the wealth effects on the supplies provided by the large operators. The issue is discussed in the context of more recent Federal Government programs in appendix E.

Table D-1

Estimated Milk Income Loss Contract (MILC) program estimated distributional information for production and operations from 2002 through 2012 (quantities in millions of pounds)

Year	Production cap per operation	Milk production	Milk production of small operations	Percent of total milk production by small operations	Number of large operations	MILC-eligible production for large operations	Total MILC-eligible production	Percent of total production eligible for MILC payments	Percent of total MILC payments paid to small operators	Percent of total MILC payments paid to large operators
2002	2.400	170,063	58,780	34.6	10,917	26,200	84,981	50.0	69.2	30.8
2003	2.400	170,348	56,096	32.9	10,857	26,057	82,153	48.2	68.3	31.7
2004	2.400	170,832	53,502	31.3	10,725	25,739	79,241	46.4	67.5	32.5
2005	2.400	176,931	52,565	29.7	10,862	26,069	78,634	44.4	66.8	33.2
2006	2.400	181,782	50,594	27.8	10,922	26,213	76,808	42.3	65.9	34.1
2007	2.400	185,654	44,421	23.9	10,884	26,122	70,543	38.0	63.0	37.0
2008	2.400	189,978	43,219	22.7	10,655	25,571	68,790	36.2	62.8	37.2
2009	2.985	189,202	45,942	24.3	9,230	27,551	73,493	38.8	62.5	37.5
2010	2.985	192,877	44,456	23.0	9,336	27,869	72,325	37.5	61.5	38.5
2011	2.985	196,255	40,829	20.8	9,504	28,370	69,200	35.3	59.0	41.0
2012	2.985	200,642	39,925	19.9	9,709	28,982	68,907	34.3	57.9	42.1

Small operations = dairy operations producing less than the production cap per year.

Large operations = dairy operations producing the production cap or more per year.

Source: USDA, Economic Research Service estimates using data from USDA, National Agricultural Statistics Service.

Table D-2

Estimated Milk Income Loss Contract (MILC) program payments to small and large operators and dollars per hundredweight (cwt) added to all-milk price in modeled milk supply equations

	U.S. milk production	Total MILC payments	Percent paid to small operators	Estimated payments: To small operators	Estimated payments: To large operators	Dollars per cwt added to all-milk price for model (payments to small operators / U.S. milk production)
Year	*Million pounds*	*Million dollars*	*Percent*	*Million dollars*	*Million dollars*	
2002	170,063	879	69.2	608	271	0.36
2003	170,348	932	68.3	636	296	0.37
2004	170,832	207	67.5	140	67	0.08
2005	176,931	7	66.8	5	2	0.00
2006	181,782	450	65.9	296	154	0.16
2007	185,654	60	63.0	38	22	0.02
2008	189,978	0	62.0	0	0	0.00
2009	189,202	900	62.5	563	337	0.30
2010	192,877	55	61.5	34	21	0.02
2011	196,255	0	59.0	0	0	0.00
2012	200,642	460	57.9	267	193	0.13
2013	201,260	285	57.4	164	121	0.08

Small operations = dairy operations producing less than the production cap per year.

Large operations = dairy operations producing the production cap or more per year.

Source: USDA, Economic Research Service estimates using data from USDA, National Agricultural Statistics Service and USDA, Farm Service Agency.

Appendix E: Difficulties in Attempting To Model Supply Responses to Current U.S. Government Risk-Management Programs

Several ongoing risk-management programs are available to U.S. dairy producers. USDA agencies have their own methods of projecting revenues and expenses from these programs, and no attempts at such projections were made with this model. However, other USDA agencies often use the *USDA Agricultural Projections* as the starting point in their analyses.

This appendix explains why the effects of current risk-management programs on milk supply response are not included in the model. Information concerning how to find more information about the programs is provided.

Dairy Margin Coverage Program (DMC) and the Margin Protection Program for Dairy (MPP-Dairy)

DMC was established by the Agriculture Improvement Act of 2018. The Act replaced a similar program, MPP-Dairy, established by the Agricultural Act of 2014. DMC is a voluntary program that protects dairy producers when the difference between the U.S. all-milk price and the national average feed cost (as calculated by a formula) falls below a certain dollar amount selected by the dairy farmer. Premiums paid by dairy farmers depend upon the level of coverage chosen. See *Dairy Margin Coverage Fact Sheet* (USDA, Farm Service Agency, 2019) for more information.

It is important to note that payments made through the program are based on each participating operation's historical base milk production. Currently, the production history used is the highest milk production of the operation in 2011, 2012, or 2013. Newer operations have other options for determining the production history base. The production history determined for a participating dairy operation may only be adjusted once to reflect any increase in the national average milk production.

The Consolidated Appropriations Act of 2021 authorized eligible DMC participants the opportunity to create a supplemental production history and receive supplemental payments. In accordance with a final rule issued by USDA in December 2021, eligible dairy operations with less than 5 million pounds of established production history can enroll supplemental pounds based upon a formula using 2019 actual milk marketings. Supplemental DMC coverage is applicable to calendar years 2021, 2022, and 2023. Participating dairy operations with supplemental production may receive supplemental payments in addition to payments based on their established production history.

Payments made through DMC can be said to be "partly decoupled." Payments depend on national dairy market conditions but not on the current production level of the operation. Therefore, payments do not increase with each additional pound of production. However, decoupled payments can affect production since they affect farmer wealth, risk attitudes, and liquidity (Mark et al., 2016; Westcott, 2005).

Revenue from a partly decoupled program would not have the same effects on supply as an equal amount of revenue due to an increase in price since payments from a partly decoupled program such as DMC do not increase with production. Moreover, some supply response from DMC could come from risk reduction received by dairy farmers, even if no indemnity payments are made to dairy farmers. As a result, it is difficult to determine how to model such responses.

Dairy Revenue Protection Program (Dairy-RP)

Dairy-RP insures against unexpected declines in each participating operation's quarterly revenue from milk sales relative to a guaranteed coverage level. The expected revenue is based on futures prices for milk or dairy products (depending on an option chosen by the dairy producer) and the amount of covered milk production elected by the producer. The program is administered by USDA, Risk Management Agency, and dairy farmers purchase policies from private insurance agents. U.S. Federal Government premium subsidies are available, depending upon parameters chosen by the dairy farmer. See the *Dairy Revenue Protection Fact Sheet* (USDA, Risk Management Agency, 2019) for more information.

The milk production covered under the program is indexed to the State or region where the dairy producer is located. The American Farm Bureau (2017) noted, "The farmer chooses how much milk production to cover during the quarter. The farmer's elected volume of milk will be indexed using average expected State milk yield per cow. For example, a farmer electing to insure 1 million pounds of milk with an expected State average milk yield of 5,000 pounds per cow would be covering the equivalent of 200 milking cows (1,000,000÷5,000 = 200). These animal unit equivalents would be used to determine the actual State-indexed milk production volume and actual revenue once USDA announced the final milk and component prices."

As with the DMC program, there could be supply responses from Dairy-RP related to both risk reduction and indemnity payments received. While the covered milk production chosen by the dairy farmer may be related to the current production levels of the operation, this is not necessarily the case; covered milk production is indexed to a State or region where the farmer is located, not the production level of the operation. Given these complexities, no attempt was made to model supply response for Dairy-RP.

Livestock Gross Margin for Dairy Cattle (LGM-Dairy)

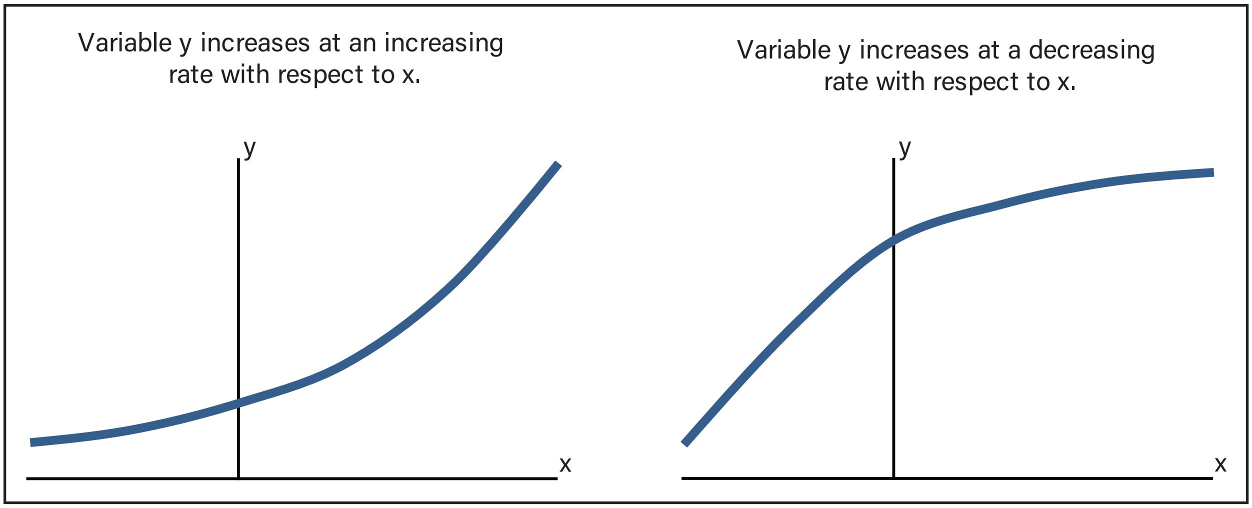
LGM-Dairy, administered by the USDA, Risk Management Agency, enables dairy farmers to purchase premium-subsidized margin insurance coverage based on futures prices for Class III milk, corn, and soybean meal. The program provides flexibility on pounds covered, as well as on the quantities of corn and soybean meal per hundredweight of milk production. Participating farmers receive indemnities based on changes in their insured margins during the coverage period. Federal subsidies are based on the deductible chosen by the dairy farmer. For more information, see the *Livestock Gross Margin Insurance for Dairy Cattle Fact Sheet* (USDA, Risk Management Agency, 2021).

Dairy farmers may sign up for LGM-Dairy any week throughout the year, insuring expected milk production for the following 11-month period. Thus, the program is related to the current production levels of the dairy farmer. However, as with DMC and Dairy-RP, it is difficult to determine supply-response effects from risk reduction. Moreover, participation in the program has been relatively small compared to other programs. For these reasons, the supply response for LGM-Dairy was not included in the model.

Appendix F: Functions That Increase at Increasing or Decreasing Rates

Some of the model functions for imports or exports in this report are described as "increasing at an increasing rate" or "increasing at a decreasing rate." A dependent variable (y) increases at an increasing rate with respect to an explanatory variable (x) if y increases as x increases and the gradient of the function increases as the magnitude of x increases. A dependent variable (y) increases at a decreasing rate with respect to an explanatory variable (x) if y increases as x increases, but the gradient of the function decreases as the magnitude of x increases. These concepts are illustrated in figure F-1.

Figure F-1
A dependent variable increasing at in increasing (or decreasing) rate with respect to an explanatory variable



Source: USDA, Economic Research Service.