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DOCUMENTATION OF A DYNAMIC AND SIMULTANEOUS ECONOMETRIC MODEL OF THE U.S. DAIRY INDUSTRY

By Ken Bailey
Professor of Agricultural Economics

DEPARTMENT OF AGRICULTURAL ECONOMICS
and
RURAL SOCIOLOGY

College of Agricultural Sciences
The Pennsylvania State University
Armsby Building
University Park, PA 16802-5600

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Documentation of a Dynamic and Simultaneous Econometric Model of the U.S. Dairy Industry[1]

By Ken Bailey[2]

Penn State University

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Introduction

The retail value of milk and dairy products in the U.S. dairy industry is estimated to exceed $90 billion per year. The industry is characterized by a great deal of uncertainty regarding volatile dairy commodity prices (cheese, butter, nonfat dry milk, dry whey, etc.) as well as farm-gate milk prices. This volatility and uncertainty is due to a number of reasons. Seasonality in the production, consumption, and inventories for milk and dairy products is one factor. Another is the lag between adjustments in the milk supply and changes in farm gate milk prices. A relatively new phenomenon is the impact of trade on the U.S. dairy industry. Thus changes in exchange rates, global policies, and real income in consuming nations now have a direct affect on the U.S. dairy industry. Given the size, complexity, and volatility of the industry, there is a need to develop a forecasting tool to help market participants better understand the future direction of prices. Such forecasting is essential for any business that uses budgeting and planning in their annual business cycles.

The price of milk and dairy commodities is fundamentally driven by supply and demand. Actual daily, weekly or monthly market prices may rise above or below these fundamental price levels, but ultimately will revert back to prices that clear the supply/demand balance. Thus it is possible to conceive of a forecasting model of the U.S. dairy industry that is based on estimated supply and demand equations. One could use monthly data for milk production, commodity supply and demand, and wholesale and retail prices to estimate an econometric model to use in forecasting prices.

When dairy commodity prices began to rise above support levels in the mid-1980's it became clear that there was a need for the market to better predict prices. The futures markets developed to help buyers and sellers of milk and dairy commodities deal with this risk. A forecasting tool would complement the use of the futures markets. But the state of the art for dairy forecasting is presently a reproduction of the futures prices along with a spreadsheet analysis of supply and demand. In fact, there presently isn't

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[2] The author is a professor in the Department of Agricultural Economics and Rural Sociology at The Pennsylvania State University.

a clear definition of what constitutes supply and demand on a commodity basis. Thus there hasn't been much progress over the last twenty years in the area of dairy price forecasting.

There have been many obstacles to developing such a model. First, the industry is very complicated since there are many products that can be made from milk. In fact milk is a source of three major components: milk fat, protein, and lactose/minerals. Historically USDA and other analysts combined protein, lactose and minerals into a category called "Solids Not Fat." Given the relative importance of protein relative to lactose in terms of pricing, this no longer makes sense. Pricing is another layer of complexity since federal and state orders, the price support program, and other policies affect market prices. Academics have made a career out of this complexity since the formulas and relationships are often beyond the comprehension of those outside the U.S. dairy industry. Availability and complexity of data is another problem. For example, trade data is very complicated for dairy (e.g. there are 154 types of cheese that are imported into the US each year). Tracing the supply and use of milk components through the system from production to ultimate consumption is another daunting task, but necessary if one is to develop a forecasting model. A final concern is to decide the frequency of data to be used in the model (annual, quarterly, or monthly). Prices are determined on a daily, weekly, and monthly basis in the U.S. Developing a model using monthly data results in many observations that are useful for estimation. However, this also creates estimation problems associated with autocorrelation of the error terms.

The objective of this report is to publish a monthly forecasting tool of the U.S. dairy industry. This model forecasts the milk supply as well as the supply and demand for American cheese, Other cheese, butter, nonfat dry milk, and dry whey. Trade is presently exogenous to the model, but can be endogenized at a later date. The principal use of the model will be for forecasting purposes, thus we settled on a monthly frequency for the data. It should be clear that our objective is not to publish a purely academic model of the industry. Rather, we delve into the complexities of the U.S. dairy industry using rich data sources. Our objective is clearly focused on developing an initial forecasting tool.

Literature Review

The first attempt to develop models of the U.S. dairy industry focused on annual simultaneous equation models that reflected both government intervention and multi-level markets. For example, Novakovic and Thompson (1977) developed an annual simultaneous equations model to analyze the impact of increased dairy imports on the U.S. dairy industry. The model described the dairy industry at three levels: farm, wholesale, retail. It included five major groups of products: fluid milk, butter, American cheese, nonfat dry milk, and frozen desserts. Kaiser, Streeter and Liu (1988) developed a dynamic dairy industry model that included both a fluid and manufacturing sector and incorporated both federal milk marketing orders and the dairy price support program.

By the mid-1980's it became apparent that the price support program was no longer the main determinant of milk and dairy commodity prices. Increasingly both the marketplace and government intervention were determining prices. Thus new studies presented the U.S. dairy sector as a mixture of the two policy regimes: a market equilibrium regime and a government regime. When prices were determined by competitive supply and demand conditions, a "market equilibrium" regime held. On the other hand, if the market price was at or below support levels, a "government support" regime held (Liu, Kaiser, Mount, Forker, 1991; and Liu, Sun, Kaiser, 1995). This same type of methodology was used in the FAPRI model (Westhoff and Brown, 1999).

Very few dairy industry models reflect short-run market dynamics. Kaiser (1994) developed a quarterly econometric model of the U.S. dairy industry. He divided the model into four markets for fluid milk, cheese, butter and frozen products, all expressed on a milk fat equivalent basis. The advantage of this type of model was that it better reflected the price formation process and government removals under the dairy price support program. Yet in many ways the model was similar to earlier models in that prices were determined by a combination of the market clearing identity and supply and demand equations.

Heien (1977) focused early attention on the price determination process for agricultural sector models. He observed that the price determination process in the short run is characterized by supply being largely predetermined, with demand, stocks and price facing all the adjustment during a specified period of time. He recommended a price dependency specification based on the notion of excess demand. For monthly or quarterly models, price should be on the left-hand side and the rate of excess demand on the right. This specification would also reflect inertia and disequilibrium as prices adjusted to market signals over time. This same approach was later used by Westcott and Hoffman (1999). For dairy, Heien specified a short run model where the price of manufacturing grade milk was a function of the ratio of an index of dairy demand over the quantity of milk, and a lagged dependent variable to reflect a disequilibrium model. This concept of a monthly disequilibrium model for the U.S. dairy industry makes empirical sense given that the market is given new supplies of milk every month that must be purchased and processed, and that prices must adjust to new information every month. Thus in a practical sense the market is constantly in a state of disequilibrium and is always adjusting price in relation to new marketing information. This approach was used in an earlier component analysis model (Bailey, Dunn and Pajic).

Model Characteristics

The model can be characterized as a monthly econometric model that is adjusted for calendar composition and seasonality, is estimated in double log form in order to estimate elasticities, allocates milk components for fluid and manufacturing purposes, and solves simultaneously for four dairy commodity prices: block cheese, Grade AA butter, Western mostly nonfat dry milk, and Western mostly dry whey. The statistical program ***EViews*** was used for model estimation, data processing, and simulation.[3] The estimated results and variable definitions are presented in the Appendix.

The U.S. milk supply is broken out into two equations: one for cow numbers and the other for milk yield per cow. The yield equation is the simplest to estimate. First the data was deseasonalized, then estimated as a function of Income Over Feed Costs (milk less feed costs). The cow number equation was more complex. We used two variables: deflated Income Over Feed Costs (IOFC) and deflated slaughter cow prices. We assumed a positive sign for the milk variable and a negative sign for the slaughter price variable. Since we assumed it takes a period of time for milk producers to decide whether to slaughter a cow or add new cows to the national herd, we used a distributed lag model for the Income Over Feed

[3] See URL: http://www.eviews.com/.

Costs variable. After testing different lag lengths, we decided to use a 12-month distributed lag since it yielded the highest t-ratio's for the estimated coefficients.

All of the production and consumption variables were adjusted for calendar affects and seasonality. We divided all variables by the days in the month to arrive at a daily average figure. In that way we were able to compare months with 30 days to months with 31 days, and account for the month of February during leap year. We used the X-12 procedure to compute a monthly seasonal index for all production, consumption, and inventory variables in order to deseasonalize these variables prior to estimation. The X-12 procedure is relatively easy to do in EViews and produces a monthly seasonal index as well as a deseasonalized series.

Component accounting was used in the model in order to account for dairy product production. First we computed monthly U.S. milk production, and then estimated the amount of milkfat, protein, and other dairy solids (lactose/minerals) that were produced. On a percentage basis these component figures vary seasonally. Then we allocated some of these components to meet fluid processing needs and other fresh needs (based on demand equations for the finished products). The remaining components entered a pool of components available for manufacturing. These manufacturing components were first allocated to cheese needs (American and Other). The balance of manufacturing components were then allocated to butter production, nonfat production, and other residual dairy products. Thus the model is able to forecast how changes in milk production affect commodity production, particularly production of butter and nonfat dry milk.

The database used with the model explicitly accounts for monthly trade for all dairy products, particularly imports and exports. The problem is there isn't one figure for cheese or butter imports, or exports of nonfat dry milk. The reality is that the U.S. imports numerous products classified under the Harmonized Tariff Schedule. We developed a database to categorized all imports and all exports under the broad categories such as cheese, butter products, dry milk products, etc. We then calculated the component content of each line of product under the HTS for each class of product and then computed a butter, cheese, nonfat dry milk, and dry whey equivalent. Thus for butter we reflect imports of butter, butter substitutes, and anhydrous milk fats, all adjusted to a common fat level of 81 percent.

The model also uses estimated equations for domestic commercial disappearance. The data was first created for each dairy commodity by using an identity to solve for implied consumption. The USDA does not produce this statistic since they do not separate out exports from their disappearance figure. In this study we netted out exports from commercial disappearance to produce an implied consumption figure. We assume this is a proxy for domestic consumption. One problem with this figure is that it reflects all the errors measured in production, trade, and inventories. Thus it is difficult to estimate a monthly commercial disappearance equation for each dairy commodity.

A final characteristic of the model is that it reflects pricing under federal milk marketing orders. More specifically the model generates NASS prices, component prices, and class prices as these are used in various parts of the model. For example, the all-milk price, which reflects the average price a U.S. dairy farmer receives for their milk, was estimated as a function of the federal order milkfat and protein prices. We assume for the sake of simplicity that other state orders (Western New York, California, and Montana) are statistically related to the Federal Order pricing.

Component Accounting

One of the first studies to account for milk components was published by USDA in order to portray Commodity Credit Corporation (CCC) purchase of surplus dairy products and imports on a milk equivalent (ME), total solids basis (USDA 1991). This was a reporting requirement of the Food, Agriculture, Conservation and Trade Act of 1990. Their methodology converted pounds of CCC purchases of butter, nonfat dry milk and cheese into equivalent amounts of milk on a milk fat, nonfat solids (or skim), and total solids basis (skim and milkfat). Both the milk fat and nonfat solids ME's were computed by using estimated "component representation factors" (CRF) which represents the amount of components in both milk and specific dairy products. These CRF's attempted to account for all milk solids in finished products, and account for the by-products not reflected in the finished product totals. The total solids ME was then estimated by weighting the ME milk fat total by 0.4 and the ME nonfat solids total by 0.6.

USDA's methodology of accounting for milk products purchased by the CCC is used today to approximate total use of dairy products on a ME basis. This use is reported on both a ME milk fat and ME nonfat solids basis and used to develop supply and demand tables for milk. In essence, this methodology attempts to convert the milk components in finished dairy products into the equivalent amount of milk used to produce those products. But an ME milk fat conversion presents one view of milk and an ME nonfat solids presents another. And such approximations must make ad hoc assumptions regarding product yields for average products and by-product production and surplus component use.

Fallert (1973) argued that any model of the U.S. dairy industry must consider both the milk fat and solids-not-fat (SNF) sides of the industry. To that end Fallert developed a methodology to determine the amount of milk fat and SNF utilized in the production of all dairy products reported each month by the National Agricultural Statistics Service. This approach was based on the milk fat and SNF content of milk, product yield coefficients, and some accounting assumptions for by-products, namely whey and buttermilk. He compared the milk fat and SNF in net milk sales (after accounting for on-farm use) to that accounted for in domestic processing. This was a significant first step in direct component accounting. A major shortcoming of this approach, however, was that he did not account for imports and exports of dairy ingredients, which were very limited at the time. Another shortcoming was that the methodology focused on accounting for SNF. It would have been better to have separated protein from other dairy solids since the former has a much higher market value than the latter.

The methodology used in this paper to account for sources and uses of milk components (milk fat, protein, other dairy solids) was developed earlier by Bailey (2003, 2004). Milk components contained in imports, exports, production, stocks and government removals for individual dairy products were accounted for using the following:

$$(1)\quad C_k = \sum_i \beta_k^i * X^i * \alpha^i ,$$

$$s.t. \sum_k \beta_k^i = 1$$

where C_k is tons of component *k* (*mf*=milk fat, *pr*=protein, *os*=other dairy solids, and *m*=moisture) in finished dairy products, β_k^i is the percentage of component *k* in dairy product *i*, X^i is amount of dairy product *i*, and α^i is the percentage of dairy solids in product X^i. For example, regular ice cream must contain at least 20 percent dairy solids. Thus one can assume that α is 0.20. The balance of ice cream is moisture and non-dairy solids (sweeteners, stabilizers, and flavors). The dairy solids portion of ice cream contains 18 percent protein (β_{pr}), 60 percent milk fat (β_{mf}), and 22 percent other dairy solids (β_{os}). The source of component levels in dairy products was USDA's nutrient database (USDA, 2005). The coefficients and other assumptions used in this study are contained in Appendix Table A.

Data Sources

We used numerous data sources in the development of the dairy industry model. For milk production we used USDA's Milk Production report (NASS). For monthly component levels we used the USDA's Agricultural Marketing Service (AMS) website. For inventory we used the USDA's National Agricultural Statistics Service (NASS) Cold Storage and Dairy Products reports. For dairy commodity production we used NASS Dairy Products report. Estimated U.S. fluid milk consumption was provided by USDA's AMS. The data source for imports and exports was the U.S. International Trade Commission. There were numerous sources for prices: federal order prices (AMS), monthly commodity prices (AMS's Dairy Market News), and retail prices (Bureau of Labor Statistics). Macro economic data also came from numerous sources.

The model required the construction of a number of variables and indexes. The trade variables and domestic consumption variables were already discussed. Two other variables were constructed for use in the model. One is called "Other Fresh Dairy Products" and is simply the summation of monthly production of yogurt, sour cream, and cottage cheese. The other variable is called "Frozen Desserts" and is the monthly sum of regular, low fat, nonfat, and soft ice cream plus frozen yogurts, frozen juices, and other frozen dairy products. Both of these indexes reflect the production of Class II type dairy products.

Model Specification & Overview

Recall that the model solves simultaneously for four dairy commodity prices: block cheese, butter, nonfat dry milk, and dry whey. Thus the entire model is related to these four prices. That includes linkage equations, milk supply, dairy product production, commodity consumption and inventories, etc. The market clearing conditions conceptually solves for a price such that supply is equal to demand (Supply-Demand=0).

The procedure we used for estimating individual equations was to first specify the model according to theoretical concerns and practical knowledge of the industry. We used a double log specification as the coefficients for prices and income would be elasticities. Also we assumed *a priori* that the estimation results would yield elastisities with the correct signs (positive for supply and negative for demand). Next, we changed the specification and added and dropped variables as long as these new variables had proper signs and statistically significant student t-ratios. We were less concerned with overall R-squares and more concerned with forecasting ability. Thus we looked for specifications that provided robust estimated elasticities and tried to avoid the use of lagged dependent variables. Use of lagged dependent variables are great for improving R-squares and historical simulation results, but are usually bad for forecasting purposes since they don't allow the explanatory variables to work and therefore misses crucial turning points.

The statistical results of the model are provided in Appendix Tables B and C. The major elements of the model can be expressed as follows:

- Milk production (a function of the all-milk price)
- Price linkages:
  - NASS prices
  - Federal Order component prices
  - Federal Order prices
  - All-milk price (a function of Federal Order component prices)
  - Retail-to-wholesale linkage equations
- Fluid and fresh demand (a function of retail prices)
- Dairy commodity production (a function of wholesale commodity prices)
- Dairy commodity consumption (a function of retail and/or wholesale prices)
- Dairy commodity prices (a function of supply/demand factors)
- Market clearing identities (defines ending stocks)

The simulation model was developed by first estimating individual equations and then constructing the proper identities and market clearing conditions. The model solves dynamically from one month to the next. The solution begins with the milk supply which is a function of lagged all-milk prices. Thus supply is recursive. Next the price linkages and federal order prices are all solved using starting values for the four wholesale dairy commodity prices. These prices are then used to solve for the commodity production and demand equations. Once values for these variables are determined they are then directed into the market clearing identities. Once a iteration is complete, if supply does not equal demand, a new price is then fed through the system. The model then iterates until a solution is reached where supply equals demand for all four commodity prices.

The market clearing identities requires that the number of endogenous variables is identical to the number of equations. EViews requires that every identity or equation identify one endogenous variable. This is the variable on the left hand side. For the model simulation to work the solution must identify a commodity price such that supply equals demand. Thus the following identity can be used:

P s.t. PRD(P) + IMP + BSTK = CON(P) + ESTK(P) + EXP

where P is the wholesale price, PRD is production, IMP is imports, BSTK is beginning stocks, CON is consumption, ESTK is ending stocks, and EXP is exports.

The problem with EViews is that this equation will identify PRD as the endogenous variable. We already have an estimated behavioral equation for PRD. Thus, for this reasons, we endogenized the wholesale prices by estimating price as a function of supply and demand factors. Then, we used the following market clearing identity to clear the market and endogenize inventories:

ESTK(P) = PRD(P) + IMP + BSTK – CON(P) – EXP

Statistical Results

Milk Production

Supply was defined as an identity equal to cow numbers times milk yield per cow. The latter is the easiest equation in the system to estimate. That's because milk yields are mostly a function of seasonality and trend, although price does play a very limited role in explaining yields. Cow numbers are much more difficult to estimate. Theoretically the cow number equation is an investment decision. In reality cows are entering the herd as replacements and exiting the herd as either culls or dead cows. Thus we attempted to estimate this balance using one equation. Our specification estimates cow numbers as a function of lagged prices for milk, feed and slaughter cow prices. As gross returns rise (milk less feed costs), cow numbers eventually expand. The opposite also occurs. There is a lag however, between changes in milk and feed prices and changes in cow numbers. When milk prices rise relative to feed costs, it takes time for the average U.S. producer to get permits, build facilities, and buy cows. On the other hand, as milk prices fall relative to feed costs, most producers at first may expand milk production and then attempt to refinance their short term operating loans. A sustained decline in milk prices eventually leads to some farms exiting the industry. As for slaughter cow prices, generally speaking, as slaughter prices rise, it is more economical to replace low performing cows with replacements. Thus we would expect positive coefficients for milk prices and negative coefficients for slaughter prices.

The main price variable for both milk yields and cow numbers is deflated Income Over Feed Costs (IOFC). The specification for IOFC is provided in the appendix but basically reflects gross earnings for a milk cow producing 65 pounds of milk per day. For feed costs we reflected a ration that consists of corn, soybean meal, and premium alfalfa hay. The index IOFC was deflated by the consumer price index (CPI).

The milk yield equation was first deseasonalized and was then estimated as a function of monthly trend and a 4-month distributed lag for deflated IOFC (polynomial of degree one). There is no statistical test one can use to specify the lag length or degree of polynomial. Our view was that milk yields were mainly a function of seasonality, weather conditions, and trend, with only limited causality from prices. However, any causality would only result from near term prices. In other words, market prices 1-4 months old would have an impact on monthly milk yields, not prices from 6-12 months prior.

For the cow number equation, we estimated a number of specifications using a lagged dependent variable and lag lengths of 8-12 months. We restricted the lagged dependent variable to 0.25 as it was clearly very statistically significant. However, any coefficient over this level of 0.25 would not be particularly useful for forecasting. We settled on a lag length of 8 months and a polynomial of degree two for both IOFC and the deflated slaughter cow prices. EViews provides student t-ratios for the individual monthly coefficients that are estimated from the polynomial. Thus we attempted a number of combinations of lag lengths (8-12) and degrees of the polynomial. The results provided a reasonable balance between R-square, coefficient for the lagged dependent variable, the t-ratio's for the individual coefficients for IOFC and slaughter prices.

NASS Price Linkages and Federal Order Prices

The model solves simultaneously for four dairy commodity prices: CME block cheese, CME butter, and the Western mostly nonfat and dry whey. The model also relies on a number of other price variables in order to reach a solution. In one way or another, these price variables are related to these four key dairy commodity prices. Thus a number of price linkage equations were estimated and identities specified.

The model contains four equations for the 4-week NASS survey and four equations for the 2-week NASS survey prices for cheese, butter, nonfat dry milk, and dry whey. These prices are highly correlated to our four dairy commodity prices since there is often a lag and basis difference between the Chicago and Western mostly commodity prices and the NASS survey. These factors are reflected in the intercepts and slopes for these linkage equations.

Once the NASS price linkage equations are estimated, we constructed identities based on the federal order formulas to develop component prices and class prices. These identities are updated whenever there is a change in the make allowances and yield factors that determine the federal order component prices.

Retail and Other Price Linkage Equations

There are a number of other retail and wholesale prices that are fundamentally related to the four dairy commodity prices. For the case of fluid milk, the retail price is a function of the Class I mover plus a farm-to-retail markup that is likely correlated with the CPI. Thus we estimated the retail fluid price of milk as a function of the Class I mover and the CPI. The wholesale price of mozzarella as reported in Dairy Market News for Wisconsin was estimated as a function of the CME block cheese price. The retail butter price was estimated as a function of the lagged CME butter price. Other retail prices used in the model were specified as a function of either federal order prices or the four dairy commodity prices. Fundamentally speaking, all of the price linkage equations are directly or indirectly related to the four dairy commodity prices.

Fluid and Class II Demand

Once the price linkage equations and federal order identities are established we can estimate and then simulate all the demand variables. We used estimated U.S. fluid milk consumption data provided by USDA's AMS. The data is an estimate based on fluid consumption reported by federal orders and California. The data is provided for whole milk, reduced fat, low fat, nonfat, and butter milk. The data set appears to be consistent only back to 2000. The dependent variables for the various fluid milks were corrected for the days in the month and seasonality, and then divided by population. The per capita consumption was then estimated as a function of the real retail price of fluid beverage milk and real per capita disposable income. A double log specification was used to produce elasticities as coefficients.

The consumption of frozen desserts and other Class II products was also corrected for calendar affects, seasonality, and divided by population. Consumption of these variables were estimated as a function of the own price and deflated per capita disposable income. Again a double log specification was employed.

The resulting elasticities that were estimated are short run elasticities since they were estimated using monthly data. A summary of the demand elasticities are provided in Table 1.

Commodity Production

Production of dairy commodities is estimated as a function of the supply of available milk components, economic returns to commodity production, seasonality, and trend. We begin with the calculation of available milk components.

The documentation in the appendix illustrates how milk components are computed and allocated. We begin with milk production and multiple monthly milk production by monthly components levels. This provides the supply of available milk components (milk fat, protein, and lactose/minerals, or Other Dairy Solids). Next we estimate the demand for fluid, other fresh, and frozen desserts. We then calculate the components in these classes of dairy demand and subtract them from the supply of fluid milk. The result is the supply of milk components available for manufacturing purposes.

Next we allocate the supply of manufacturing milk components to cheese and then butter/nonfat dry milk uses. We use the supply of available manufacturing components as one variable and the ratio of returns to a cheese plant relative to a butter/powder plant as another variable in the commodity supply specifications. If milk production rises, there will be more components available for manufacturing. If the returns to butter/nonfat dry milk rise relative to cheese, then more of the available manufacturing components will be allocated to butter/powder plants relative to cheese plants.

Our next task is to define cheese production data. There are three variables that define cheese production: American, Mozzarella, and "residual" cheese production. The two major classes of cheese production are American and Mozzarella. The balance or left over cheese is defined simply as a residual class of cheese production.

American cheese production is divided by the number of days in the month to produce daily average cheese production. We then compute a seasonal index for daily average production. Thus daily average American cheese production is estimated as a function of the supply of available manufacturing components (in this case protein), the seasonal index for American cheese production, and the relative returns of a cheese plant vs. a butter/nonfat dry milk plant. We assume *a priori* that the coefficient on the relative returns variable is positive. This assumes a positively sloped cheese supply equation.

We used a yield function to determine the relative economic returns of a cheese plant vs. a butter/nonfat plant. The gross returns for a cheese plant using 100 pounds of milk are defined as follows:

Gross returns for a cheese plant = 10.53*(1-0.005)*cz_40b_m_dlb_pri + 5.81*(1-0.02)*wy_west_m_dlb_pri + 0.26508*rm_c2bf_m_dcwt_pri

where cz_40lb_m_dlb_pri = CME block cheese price, $/lb
wy_west_m_dlb_pri = dry whey price, Western mostly, $/lb
rm_c2bf_m_dcwt_pri = Class II butterfat price, $/cwt

In this identity we assume that 100 pounds of milk will yield 10.53 pounds of cheese, 5.81 pounds of dry whey, and 0.27 pounds of whey butter. There are numerous identities one can use to specify gross returns for cheese production, but all use some form of the Van Slyke cheese yield formula.

The gross returns for a butter/nonfat dry milk plant using 100 pounds of milk are defined as follows:

Gross returns for a butter/nonfat dry milk plant = 4.48*bt_aa_m_dlb_pri+8.13*nf_west_m_dlb_pri

where bt_aa_m_dlb_pri = CME Grade AA butter price, $/lb
nf_west_m_dlb_pri = Nonfat dry milk price, Western mostly, $/lb

In this identity we assume that 100 pounds of milk will yield 4.48 pounds of Grade AA butter and 8.13 pounds of nonfat dry milk. Again, there are numerous identities one can use to define the yields for a butter/nonfat dry milk plant, some of which have buttermilk as a joint product. For example, USDA's Farm Services Agency has used such an identity in their past calculations for the Dairy Price Support Program.

Mozzarella and residual cheese production were estimated by first dividing the dependent variables by the days in the month to produce a measure of daily average production. Both equations were then specified and estimated as a function of TREND and the seasonal index for daily average mozzarella cheese production. We could not find a statistically significant fit for the relative returns of cheese to butter/powder production.

Both butter and nonfat dry milk are considered residual uses of milk components. For these specifications we estimated daily average production as a function of the manufacturing components available after first allocating components to cheese production. We assumed that cheese production would receive milk components first, and then production of butter/nonfat dry milk would serve a balancing function. Thus daily average butter production was estimated as a function of the relative returns of cheese to butter/nonfat dry milk production, residual manufacturing milk fat components available after cheese allocation, a seasonal index of daily average butter production, and trend.

For nonfat dry milk production, we specified daily average production as a function of relative returns of cheese vs. butter/nonfat dry milk, residual protein available after cheese production, and an index of daily average nonfat dry milk production.

For both butter and nonfat dry milk production, the appropriate sign for the gross returns variable for the cheese vs. butter/nonfat dry milk variable should be a negative sign. For simplicity sake we used the same specification for this variable in the cheese, butter and nonfat dry milk equation. Assuming *a priori* a negative sign implies a positive relationship between butter and nonfat dry milk production and the butter and nonfat dry milk wholesale prices (which is in the denominator of the ratio).

A final production equation is for dry whey. The production of dry whey is a by-product of cheese production. Thus as more cheese is produced, more whey effluent is available for processing. Thus we used a variable that represents total cheese production. We also used a seasonal index of daily average whey production and trend.

Commodity Demand

Domestic consumption for dairy commodities was estimated on a per capita basis. We also removed the calendar affects and deseasonalized the per capita variables to remove predictable and repeatable influences on domestic consumption. These variables were then specified as a function of the real own price, a real cross price or substitute price, and real per capita income. In some cases we could not identify a substitute or complement in the specification (e.g. cheese). Also, we made no *a priori* restriction on the signs of the disposable income elasticities.

For butter we used the CME Grade AA butter price as the own price and the CPI for margarine as the substitute price. The wholesale CME price was used instead of a retail price since most butter is purchased for use in other dairy products, in other food products, or for fast food or institutional use.

Most American cheese is purchased for use in the fast food industry, or purchased for use in processed cheese. For that reason we used the CME block cheese price in our demand specification. The block price is highly correlated with the barrel cheese price, thus we simply used the block price. We also specified two other variables in the American cheese consumption model: the retail price of gasoline and the unemployment rate. We hypothesized that as gasoline prices rose, there would be less family disposable income available for discretionary expenditures on fast food. The same logic was applied for use of the unemployment rate.

Miscellaneous cheese was defined as all cheese consumption other than American cheese. Most of this cheese consumption is for Mozzarella cheese. Thus miscellaneous cheese consumption was specified as a function of the wholesale price of mozzarella cheese, real disposable income, and the unemployment rate.

Nonfat dry milk consumption was estimated as a function of the wholesale price of Western nonfat dry milk, and CME price of block cheese, and real disposable income. We attempted to reflect the market reality that when cheese prices rise relative to nonfat dry milk prices, nonfat dry milk is used to supplement the protein levels in cheese vats. Unfortunately, the cross price elasticity of cheese is larger than the nonfat dry milk own price elasticitity, which may be contribute to instability under model simulation.

The final equation estimated is domestic consumption of dry whey. This equation was specified as a function of the wholesale price of dry whey and real disposable income.

Wholesale Prices

We initially attempted to specify and estimate all supply and demand equations and solve for the wholesale prices under model simulation using a market clearing identity. Such a solution would find a set of four market prices for cheese, butter and nonfat dry milk such that the market clearing identities (supply equal to demand) are met. The problem is that EViews is not designed to solve in this fashion. As stated earlier, every equation, whether estimated or an identity, must first designate an endogenous variable (the left most variable in the specification). That would be hard to do when you consider that the wholesale prices are endogenous variables. There would be no way to identify these endogenous variables in the model solution.

Thus, to overcome this problem with EViews, we specified wholesale price equations as a function of supply and demand variables and directly estimated them. Since price was on the left hand side of the equation, it was easier for EViews to identify them as endogenous variables.

A study was undertaken to identify the correlation between the wholesale dairy commodity prices and supply and demand variables. The approach take is similar to using a stocks-to-use ratio to explain monthly corn or soybean prices. The problem with dairy, however, is that the process of producing milk and processing dairy commodities is more of a flow concept rather than a stock concept. For corn, this commodity is produced once a year and then consumed throughout the year. Milk and dairy commodities, on the other hand, are produced every day.

To overcome these issues, we used production, ending stocks, consumption, and stocks variables and analyzed the correlation of these variables to commodity prices. We deseasonalized and detrended these variables prior to model estimation. For American cheese, block cheese prices were estimated as a function of deseasonalized and detrended ending stocks (we used a non-linear specification) and a lagged dependent variable. Clearly stocks are an important variable in determining cheese prices. For butter we estimated the wholesale price as a function of deseasonalized production, imports, domestic consumption, and a lagged dependent variable. In the case of butter, monthly production is an important variable in determining prices. For wholesale whey prices we used a deseasonalized stocks-to-use ratio. For nonfat dry milk, we had some difficulty estimating this relationship. Ideally one would solve for the nonfat price based on supply, demand and market clearing identities. Given the restrictions with EViews, we attempted to find a relationship between the Western price of U.S. nonfat dry milk and various supply/demand relationships. We could not find any reasonable estimation. Thus, given the reliance of U.S. nonfat dry milk prices on global prices, we estimated the U.S. price as a function of the EU world price of nonfat dry milk (as reported bi-weekly by USDA) and the U.S. dollar-euro exchange rate.

Market Clearing Identities

Since we endogenized prices and estimated specific equations for production and consumption, we left ending stocks as a market-clearing identity. Note that beginning stocks are an identity equal to lagged stocks, imports and exports are exogenous, and government removals and DEIP exports are also exogenous. Thus the model avoids being over identified by solving for ending stocks via an identity.

Table 1. Estimated Short-run Demand Elasticities

	Own Price	Cross Price	Income
Fluid milk, whole	-0.214		-2.260
Fluid milk, reduced fat	-0.072		0.130
Fluid milk, low fat	-0.073		-0.307
Fluid milk, fat free	-0.050		-0.221
Other fresh (yogurt, ice cream)	-0.706		2.978
Frozen desserts	-0.323		0.181
Butter	-0.150*	0.083**	1.321
American cheese	-0.033		0.236
Other cheese (mainly mozzarella)	-0.026		1.404
Nonfat dry milk	-0.205	0.730***	0.789
Dry whey	-0.374		-3.526

*Fixed estimation.
**CPI for margarine.
***CME block cheese price.

Estimation Issues and Model Simulation

It is very easy to be critical of any econometric model, particularly one as complex as dairy. Either the estimated elasticities are not large enough or significant enough, important variables seem to be missing, or the presence of dummy variables and lagged dependent variables causes concerns about the significance of the model.

Our objective with this model has been to develop a consistent database, document all required identities, estimate price linkage equations, estimate behavioral equations, and to simulate them in order for forecast prices. As for the behavioral equations, we used double log specifications in order to estimate coefficients that would provide elasticities. We included variables that were either theoretically appropriate or were deemed important based on our understanding of the industry. We only kept variables that had the correct signs and were reasonably significant. Thus supply equations had to have positive own price elasticities and demand equations had to have negative elasticities. As for the case of dummy variables, they were only used if there was an obvious outlier in the errors and the use would improve the overall fit of the model (elasticities became more significant).

One of the problems encountered was the trade-off between estimating a model that fit the data well from a historical perspective, but provided a very poor forecasting tool. For example, we often restricted the use of lagged dependent variables. Their use greatly improved the overall fit of the model. However, when forecasting, the size of the lagged dependent variable became a critical factor.

We provide model simulation results in Figure 1 in order to judge the ability of the model to simulate as an overall system. We focused our results on the four wholesale dairy commodity prices that we forecasted. A Monte Carlo simulation was developed and used to compute a mean and a confidence interval around the mean. The results were also compared to the actual data. The results indicate that the overall model did a reasonably good job in explaining past performance in simulating wholesale prices.

Summary and Conclusion

The objective of this study was to develop a forecasting tool for the U.S. dairy industry. The study was successful and produced a database and an initial forecasting model. The strength of the database and model is that it is very detailed, accounts for seasonality and calendar affects, and provides a component accounting methodology for forecasting dairy product production. The component accounting procedure further breaks out milk fat, protein, and lactose/minerals.

The study was largely successful in developing a framework for further analysis. Three areas are recommended. First, trade should be endogenized. Greater attention should be devoted to explaining over quota imports and exports. Second, cow numbers are critical for forecasting the milk supply. It is recommended that slaughter be separated from cow numbers and estimated. Third, nonfat dry milk supply and demand should be better endogenized in order to accurately forecast monthly government removals and sell backs to the market. That would be very important today given the current environment of reduced exports and greater CCC purchases. Perhaps a fourth area for further research would be to better estimate the impact of autocorrelation of error terms. This is a prevalent concern when using monthly data.

To conclude, the approach used in this study to develop a database and forecasting model appears to have been fruitful. The model does a good job of predicting the milk supply and then allocating those milk components to alternative production uses (fluid and fresh, cheese, and then residual). The model also solves simultaneously for four prices—block cheddar cheese, butter, nonfat dry milk, and dry whey. Finally, the model separates predictable patterns, such as the number of days in the month and seasonality, from economic and other relationships. Greater resources are needed to improve the forecasting ability of the model by endogenizing more variables and improving others. That said, the model represents a “state of the art” method of forecasting milk supply, demand and prices. The best use of such a model is to forecast market prices based not on speculation and futures data, but on market fundamentals of supply and demand. Such an approach should prove practical since cash and futures prices tend to revert back to market fundamentals when viewed on a weekly or monthly basis. Thus the model should be able to reveal trends before they are reflected in the actual cash or futures markets.

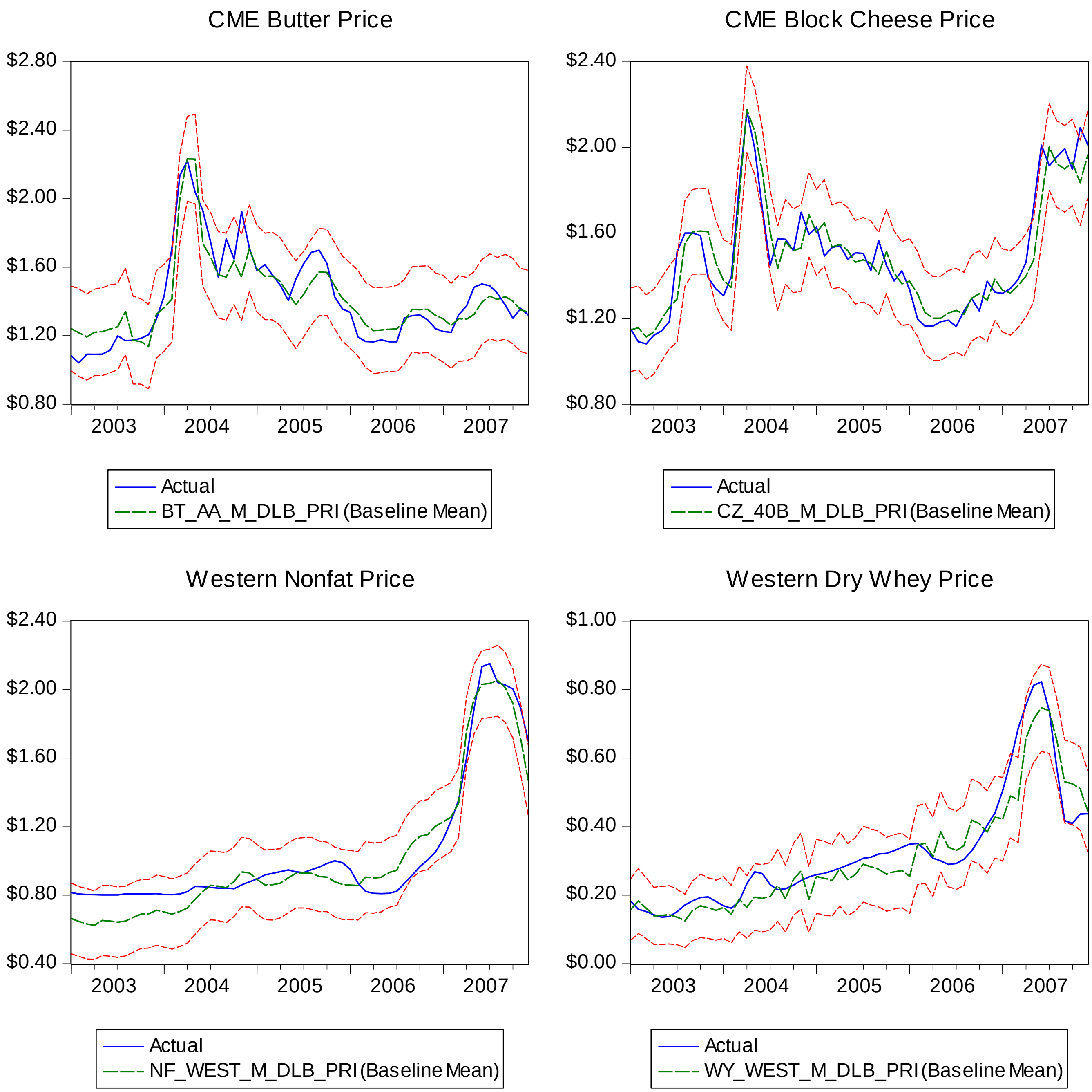

Figure 1. Actual vs. Simulated for Dairy Commodity Prices ($/lb) Over the Historical Period January 2003 – December 2007.

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Appendix Table A: Component Conversions Used for Processed Dairy Products

	Dairy Content Coefficient β (%)	Conversion to MT[1]	Dairy Component Content (%):			
			Protein	Fat	Moisture	OS
Butter	1.0	0.4536	0.6%	80.5%	16.5%	2.4%
Cheese:						
Cheddar	1.0	0.4536	24.9%	33.0%	37.0%	5.1%
Other American Cheese	1.0	0.4536	24.1%	31.2%	39.6%	5.1%
Total American Cheese	1.0	0.4536	24.7%	32.6%	37.6%	5.1%
Swiss	1.0	0.4536	28.4%	27.4%	38.0%	6.2%
Brick & Muenster	1.0	0.4536	23.3%	29.9%	41.4%	5.4%
Cream & Neufchatel	1.0	0.4536	8.8%	29.2%	58.0%	4.1%
Hispanic	1.0	0.4536	21.5%	22.5%	49.0%	7.0%
Mozzerella	1.0	0.4536	21.0%	23.7%	47.0%	8.3%
Other Italian Types	1.0	0.4536	27.6%	24.1%	40.3%	8.0%
Total Italian Types	1.0	0.4536	22.3%	23.8%	45.6%	8.2%
All Other Types	1.0	0.4536	22.2%	27.5%	44.0%	6.2%
Misc/Other Cheese			22.2%	27.5%	44.0%	6.2%
Processed Cheese	1.0	0.4536	22.2%	31.3%	39.2%	7.4%
Processed Foods and Spreads	1.0	0.4536	16.4%	21.2%	47.7%	14.7%
Processed Cold Pack & Foods	1.0	0.4536	19.7%	24.5%	43.1%	12.8%
Cottage Cheese:						
Curd	1.0	0.4536	17.3%	0.4%	79.8%	2.5%
Creamed	1.0	0.4536	12.5%	4.0%	79.0%	4.5%
Lowfat	1.0	0.4536	12.4%	1.0%	82.5%	4.1%
Canned Milk:						
Whole Milk	1.0	0.4536	7.9%	8.7%	27.2%	56.2%
Skim Milk	1.0	0.4536	7.6%	0.2%	79.4%	12.9%
Bulk Condensed Milk:						
Whole Sweetened	1.0	0.4536	2.8%	3.0%	74.5%	19.7%
Whole Unsweetened	1.0	0.4536	2.8%	3.0%	74.5%	19.7%
Skim Sweetened	1.0	0.4536	7.6%	0.2%	79.4%	12.9%
Skim Unsweetened	1.0	0.4536	7.6%	0.2%	79.4%	12.9%
Condensed or Evap Buttermilk	1.0	0.4536	8.4%	2.2%	75.0%	15.8%
Dry Whole Milk	1.0	0.4536	26.3%	26.7%	2.5%	44.5%
Nonfat Dry Milk, Human	1.0	0.4536	36.2%	0.8%	3.2%	59.9%
Dry Skim Milk, Animal	1.0	0.4536	36.2%	0.8%	3.2%	59.9%
Dry Buttermilk	1.0	0.4536	34.3%	5.8%	3.0%	57.0%
Yogurt, Plain & Flavored	1.0	0.4536	5.3%	1.6%	85.1%	8.1%
Condensed Whey:						
Sweet-type Human	1.0	0.4536	6.7%	0.6%	50.0%	42.8%
Sweet-type Animal Feed	1.0	0.4536	6.7%	0.6%	50.0%	42.8%

Appendix Table A--***continued***

	Dairy Content Coefficient β (%)	Conversion to MT[1]	Dairy Component Content (%): Protein	Fat	Moisture	OS
Dry Whey:						
Human Food	1.0	0.4536	12.9%	1.1%	3.2%	82.8%
Animal Feed	1.0	0.4536	12.9%	1.1%	3.2%	82.8%
Reduced Lactose & Minerals:						
Human Food	1.0	0.4536	19.0%	2.5%	0.1%	78.4%
Animal Feed	1.0	0.4536	19.0%	2.5%	0.1%	78.4%
Whey Solids, Wet Blends:						
Animal Feed	1.0	0.4536	12.8%	1.3%	0.1%	85.9%
Whey Protein Concentrate:						
Human Food	1.0	0.4536	57.0%	5.0%	0.1%	37.9%
Animal Feed	1.0	0.4536	57.0%	5.0%	0.1%	37.9%
Lactose	1.0	0.7258	0.1%	0.0%	5.0%	94.9%
Ice Cream:						
Regular	0.2	2.0412	18.0%	60.0%	0.0%	22.0%
Low Fat	0.2	2.0412	19.5%	25.0%	0.0%	55.5%
Nonfat	0.2	2.0412	20.0%	1.3%	0.0%	78.8%
Sherbert	0.2	2.0412	5.0%	10.0%	0.0%	85.0%
Frozen Yogurt	0.2	2.0412	22.5%	25.0%	0.0%	52.5%
Other Frozen Dairy Products	0.2	2.0412	18.0%	50.0%	0.0%	32.0%
Water & Ice Juices	0.2	2.0412	20.0%	20.0%	0.0%	60.0%
Mixes for Frozen Products:						
Regular	0.2	2.0412	18.0%	60.0%	0.0%	22.0%
Low Fat	0.2	2.0412	19.5%	25.0%	0.0%	55.5%
Nonfat	0.2	2.0412	20.0%	5.0%	0.0%	75.0%
Sherbert	0.2	2.0412	5.0%	10.0%	0.0%	85.0%
Yogurt	0.2	2.0412	22.5%	25.0%	0.0%	52.5%
Fluid Beverages:						
Whole milk	1.0	453.6	3.3%	3.3%	88.0%	5.4%
Reduced fat	1.0	453.6	3.3%	1.9%	89.2%	5.5%
Low fat	1.0	453.6	3.4%	1.0%	90.0%	5.6%
Fat free	1.0	453.6	3.4%	0.2%	90.8%	5.6%
Buttermilk	1.0	453.6	3.3%	0.9%	90.1%	5.7%

[1]Conversion from reported units to metric tons.

Source: USDA National Nutrient Database for Standard Reference.

Appendix Table B – Model Specification

Define Feed Costs and Income Over Feed Costs:

FC = (cr_m_dbu_pri/56)*22.22+(sm_chi_m_dton_pri/2000)*2.52+(aprm_il_m_dton_pri /2000)*25.5

IOFC = (rm_allmilk_m_dcwt_pri/100)*65-fc

DEF_IOFC = iofc*100/cpi_all_unadj

Milk Production:

U.S. Milk Yield Per Cow:

(rm_usyield_m_lb_prd/days_in_month)*(100/ind_dailyaverage)

= 45.07 + 0.0753*trend + pdl(def_iofc,4,1)
(54.3) (11.0)

Parameters (student t) of the degree one polynomial are:
PDL01 = 0.0354 (1.148)
PDL02 = -0.0056 (-0.217)

AR(1) correction: $u_t = 0.84u_{t-1} + \varepsilon_t$
(13.3)

R2 = 0.985, DW = 1.993

U.S. Milk Cow Numbers:

(mc_us_m_thd_prd) = 7075.6 + 0.25*mc_us_m_thd_prd(-1)
(52.98)

pdl(def_iofc(-1),8,2) + pdl((mc_wi_slaugh_m_dcwt_pri(-1)*100/cpi_all_unadj(-1)),8,2)

- 0.0437 cwt2
(-0.56)

Parameters (student t) of the degree 2 polynomials are:

Deflated Income Over Feed Costs:
PDL01 = 4.036 (1.974)
PDL02 = 0.220 (0.428)
PDL03 = -0.280 (-1.392)

Deflated Slaughter Cow Prices:
PDL04 = -1.380 (-1.969)
PDL05 = -0.060 (-0.530)
PDL06 = 0.002 (0.036)

AR(2) correction: $u_t = 1.308*u_{t-1} - 0.338*u_{t-2} + \varepsilon_t$
(11.94) (-3.039)

R2 = 0.969, DW = 1.888

Milk Production Identity:

rm_usprd_m_mlb_prd = rm_usyield_m_lb_prd * mc_us_m_thd_prd / 1000

Price Linkage Equations: 4-week NASS

cz_nass_m_dlb_pri = 0.0603 + 0.952*cz_40blocks_m_dlb_pri
(1.639) (37.72)
R2=0.935, DW = 1.987

bt_nass_m_dlb_pri = -0.0237 + 1.0*bt_aa_m_dlb_pri
(-0.788) (47.0)
R2 = 0.957, DW = 2.083

nf_nass_m_dlb_pri = 0.1135 + 0.881*nf_west_m_dlb_pri
(3.482) (64.28)

AR(2) correction: $u_t = 1.228*u_{t-1} - 0.417*u_{t-2} + \varepsilon_t$
(13.06) (-4.38)
R2=0.994, DW = 2.15

wy_nass_m_dlb_pri = 0.0105 + 0.967*wy_west_m_dlb_pri
(1.918) (55.91)

AR(2) correction: $u_t = 0.906*u_{t-1} - 0.476*u_{t-2} + \varepsilon_t$

(10.03) (-5.23)

R2=0.991, DW=1.744

Price Linkage Equations: 2-week NASS

cz_nass_2w_dlb_pri = 0.058 + 0.956*cz_40blocks_m_dlb_pri(-1)

(1.171) (28.19)

R2=0.89, DW=2.08

bt_nass_2w_dlb_pri = 0.001 + 0.98*bt_aa_m_dlb_pri(-1)

(0.028) (34.9)

AR(1) correction: $u_t = -0.154u_{t-1} + \varepsilon_t$

(13.3)

R2=0.905, DW=1.975

nf_nass_2w_dlb_pri =0.01 + 0.97*nf_west_m_dlb_pri(-1)

(1.42) (44.28)

AR(2) correction: $u_t = 0.77*u_{t-1} - 0.353*u_{t-2} + \varepsilon_t$

(7.91) (-3.64)

R2=0.985, DW=1.916

wy_nass_2w_dlb_pri = 0.01 + 0.97*wy_west_m_dlb_pri(-1)

(1.416) (44.28)

AR(2) correction: $u_t = 0.77*u_{t-1} - 0.353*u_{t-2} + \varepsilon_t$

(7.91) (-3.64)

R2=0.985, DW=1.916

Federal Order Prices: 4-week Component Values

bf_fo_m_dlb_pri = (bt_nass_m_dlb_pri - 0.1202) * 1.20

pr_fo_m_dlb_pri = ((cz_nass_m_dlb_pri - 0.1682) * 1.383) + ((((cz_nass_m_dlb_pri - 0.1682) * 1.572) - bf_fo_m_dlb_pri * 0.9) * 1.17)

os_fo_m_dlb_pri = (wy_nass_m_dlb_pri - 0.1956) * 1.03

nf_fo_m_dlb_pri = (nf_nass_m_dlb_pri - 0.157) * 0.99

Federal Order Prices: 2-week Component Values

bf_fo_adv_dlb_pri = (bt_nass_2w_dlb_pri - 0.1202) * 1.20

pr_fo_adv_dlb_pri = ((cz_nass_2w_dlb_pri - 0.1682) * 1.383) + ((((cz_nass_2w_dlb_pri - 0.1682) * 1.572) - ((bt_fo_adv_dlb_pri - 0.1202) * 1.20) * 0.9) * 1.17)

nf_fo_adv_dlb_pri = (nf_nass_2w_dlb_pri - 0.157) * 0.99

os_fo_adv_dlb_pri = (wy_nass_2w_dlb_pri - 0.1956) * 1.03

Federal Order Prices: Class Prices

rm_c3s_adv_dcwt_pri = (pr_fo_adv_dlb_pri * 3.1) + (os_fo_adv_dlb_pri * 5.9)

rm_c4s_adv_dcwt_pri = nf_fo_adv_dlb_pri * 9

rm_c1s_adv_dcwt_pri = @iif(rm_c3s_adv_dcwt_pri >= rm_c4s_adv_dcwt_pri , rm_c3s_adv_dcwt_pri , rm_c4s_adv_dcwt_pri)

rm_c1m_m_dcwt_pri = (rm_c1s_adv_dcwt_pri * 0.965 + bf_fo_adv_dlb_pri * 3.5)

rm_c2bf_m_dcwt_pri = bf_fo_m_dlb_pri + 0.007

Price Linkage Equations: Other

Fluid whole milk price:

fl_fwh_m_dgl_pri = -0.57 + 0.0507*rm_c1m_m_dcwt_pri + 0.0154*cpi_all_unadj
(-1.155) (11.44) (5.93)

AR(1) correction: $u_t = 0.843 * u_{t-1} + \varepsilon_t$
(15.5)
R2=0.974, DW=2.042

Other Dairy CPI Index:

otherdairy_m_cpi = 25.05 + 2.37*cz_nass_m_dlb_pri + 0.477*cpi_all_unadj
(4.75) (2.43) (16.11)

+ 6.43*dumaug07
(6.47)

AR(1) correction: $u_t = 0.60 * u_{t-1} + \varepsilon_t$
(7.08)

R2=0.978, DW=2.016

Ice Cream Price, Half Gallon:

ic_m_dhalfgl_pri = 0.6072 + 0.029*bf_fo_adv_dlb_pri + 0.003*cpi_all_unadj
(2.74) (1.005) (2.45)

+ 0.694*ic_m_dhalfgl_pri(-1)
(8.36)

AR(1) correction: $u_t = -0.43 * u_{t-1} + \varepsilon_t$
(-4.03)

R2=0.509, DW=2.03

Retail Grade AA Butter Price:

bt_graa_m_dlb_pri = 2.45 + 0.476*bt_aa_m_dlb_pri(-1)
(15.58) (4.96)

AR(2) correction: $u_t = 0.645 * u_{t-1} + 0.178 * u_{t-2} + \varepsilon_t$
(6.34) 1.79)

R2=0.823, DW=2.024

Wholesale Mozzarella Cheese Price:

cz_mozz_m_dlb_pri = 1.457 + 0.414*cz_40b_m_dlb_pri
(17.86) (13.01)

AR(1) correction: $u_t = 0.936 * u_{t-1} + \varepsilon_t$
(21.20)

R2=0.962, DW=1.922

U.S. Average All-milk Price:

rm_am_m_dcwt_pri = 6.743 + 2.60*bf_fo_m_dlb_pri + 1.343*pr_fo_m_dlb_pri
(6.28) (9.01) (10.27)

+ 3.755*wy_west_m_dlb_pri
(2.88)

AR(1) correction: $u_t = 0.95*u_{t-1} + \varepsilon_t$
(26.20)
R2=0.979, DW=1.649

Demand: Fluid Milk Consumption

Fluid whole milk:
log((fl_whole_m_mlb_con/days_in_month)*(100/ind_d_fl_whole_m_mlb_con)*(1000000/pop_m_cap_macro))

= 20.15 - 0.214*log(fl_fwh_m_dgl_pri*100/cpi_all_unadj)
(23.71) (-4.56)

-2.26*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(-25.49)

+ 0.126*dumdec2004
(4.18)

R2=0.89, DW=1.183

Fluid Reduced Fat:
log((fl_redfat_m_mlb_con/days_in_month)*(100/ind_d_fl_redfat_m_mlb_con)*(1000000/pop_m_cap_macro))

= -2.97 – 0.0715*log(fl_fwh_m_dgl_pri*100/cpi_all_unadj)
(11.55) (-2.52)

+ 0.13*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(0.65)

+ 0.0014*trend
(5.23)

AR(2) correction: $u_t = -0.045*u_{t-1} - 0.194*u_{t-2} + \varepsilon_t$
(-0.495) (-2.41)
R2=0.678, DW=1.894

Fluid Lowfat:
log((fl_lowfat_m_mlb_con/days_in_month)*(100/ind_d_fl_lowfat_m_mlb_con)*(1000000/pop_m_cap_macro))
= 0.36 – 0.0724*log(fl_fwh_m_dgl_pri*100/cpi_all_unadj)
(0.115) (-1.37)

-0.3073*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(-0.94)

-0.0044*trend + 2.53E-05*trend*trend
(-1.71) (2.07)

AR(2) correction: $u_t = 0.201*u_{t-1} - 0.104*u_{t-2} + \varepsilon_t$
(2.22) (-1.46)
R2=0.236, DW=1.443

Fluid Fat Free:
log((fl_fatfree_m_mlb_con/days_in_month)*(100/ind_d_fl_fatfree_m_mlb_con)*(1000000/pop_m_cap_macro)) =

-0.023 - 0.05*log(fl_fwh_m_dgl_pri*1000/cpi_all_unadj)
(-0.01) (-1.35)

-0.2214*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(-1.03)

+ 0.0304*dumdec2004 + 0.0327*dumfatfree – 0.0057*trend + 2.46E-05*trend*trend
(1.46) (3.54) (-9.92) (7.08)

AR(1) correction: $u_t = 0.164*u_{t-1} + \varepsilon_t$
(1.57)

R2=0.855, DW=2.053

Buttermilk:
log((fl_bm_m_mlb_con/days_in_month)*(100/ind_d_fl_bm_m_mlb_con)*(1000000/pop_m_cap_macro))

= 0.62 – 0.56* log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(0.193) (-1.66)

– 0.0093*trend + 4.19E-05*trend*trend
(-11.01) (9.12)

R2=0.858, DW=1.079

Fluid Milk Components:

Protein:
fl_prot_m_mlb_con = 0.0322 * fl_whole_m_mlb_con + 0.033 * fl_redfat_m_mlb_con + 0.0337 * fl_lowfat_m_mlb_con + 0.034 * fl_fatfree_m_mlb_con + 0.0331 * fl_bm_m_mlb_con + 0.033 * fl_otherfluid_m_mlb_con

Milk Fat:
fl_milkf_m_mlb_con = 0.0325 * fl_whole_m_mlb_con + 0.0197 * fl_redfat_m_mlb_con + 0.0097 * fl_lowfat_m_mlb_con + 0.0018 * fl_fatfree_m_mlb_con + 0.0088 * fl_bm_m_mlb_con + 0.0197 * fl_otherfluid_m_mlb_con

Other Dairy Solids:
fl_ods_m_mlb_con = 0.0521 * fl_whole_m_mlb_con + 0.054 * fl_redfat_m_mlb_con + 0.0574 * fl_lowfat_m_mlb_con + 0.0562 * fl_fatfree_m_mlb_con + 0.0568 * fl_bm_m_mlb_con + 0.054 * fl_otherfluid_m_mlb_con

Define Other Fresh and Frozen Dessert Variables (Historical Data):

Other Fresh Production:
of_ofresh_m_mlb_prd =
(yg_yogurt_m_tlb_prd+cm_sourcream_m_tlb_prd+ct_cotcream_m_tlb_prd+ct_cotcurd_m_tlb_prd+ct_cotlow_m_tlb_prd)/1000

Frozen Dessert Production:
ic_fdairy_m_mlb_prd =
(ic_reghard_m_tga_prd+ic_lfhard_m_tga_prd+ic_lfsoft_m_tga_prd+ic_nfhard_m_tga_prd+ic_sherbet_m_tga_prd+ic_otherfrozen_m_tga_prd+ic_watjuices_m_tga_prd+ic_fyogurt_m_tga_prd)*(4.5/1000)

Define Other Fresh and Frozen Dessert Milk Components (Historical Data):

Other Fresh Protein:
of_prot_m_mlb_prd =
(0.0525*yg_yogurt_m_tlb_prd + 0.0316*cm_sourcream_m_tlb_prd + 0.1249*ct_cotcream_m_tlb_prd+ 0.173*ct_cotcurd_m_tlb_prd + 0.1239*ct_cotlow_m_tlb_prd)/1000

Other Fresh Milk Fat:
of_milkf_m_mlb_prd =
(0.0155*yg_yogurt_m_tlb_prd+0.2096*cm_sourcream_m_tlb_prd+0.0451*ct_cotcream_m_tlb_prd+ 0.004*ct_cotcurd_m_tlb_prd+0.0102*ct_cotlow_m_tlb_prd)/1000

Other Fresh Other Dairy Solids:
of_ods_m_mlb_prd =
(0.0813*yg_yogurt_m_tlb_prd + 0.0493*cm_sourcream_m_tlb_prd + 0.0404*ct_cotcream_m_tlb_prd + 0.025*ct_cotcurd_m_tlb_prd + 0.0411*ct_cotlow_m_tlb_prd)/1000

Frozen Dessert Protein:
ic_prot_m_mlb_prd =
(0.18*ic_reghard_m_tga_prd + 0.195*ic_lfhard_m_tga_prd + 0.195*ic_lfsoft_m_tga_prd + 0.2*ic_nfhard_m_tga_prd+ 0.05*ic_sherbet_m_tga_prd + 0.18*ic_otherfrozen_m_tga_prd + 0.2*ic_watjuices_m_tga_prd + 0.225*ic_fyogurt_m_tga_prd)*0.2*4.5/1000

Frozen Dessert Milk Fat:
ic_milkf_m_mlb_prd =
(0.6*ic_reghard_m_tga_prd + 0.25*ic_lfhard_m_tga_prd + 0.25*ic_lfsoft_m_tga_prd + 0.0125*ic_nfhard_m_tga_prd+ 0.1*ic_sherbet_m_tga_prd + 0.5*ic_otherfrozen_m_tga_prd + 0.2*ic_watjuices_m_tga_prd + 0.25*ic_fyogurt_m_tga_prd)*0.2*4.5/1000

Frozen Dessert Other Dairy Solids:
ic_ods_m_mlb_prd =
(0.22*ic_reghard_m_tga_prd + 0.555*ic_lfhard_m_tga_prd + 0.555*ic_lfsoft_m_tga_prd + 0.7875*ic_nfhard_m_tga_prd+ 0.85*ic_sherbet_m_tga_prd + 0.32*ic_otherfrozen_m_tga_prd + 0.6*ic_watjuices_m_tga_prd + 0.525*ic_fyogurt_m_tga_prd)*0.2*4.5/1000

Class II Consumption:

Other Fresh:
log((of_ofresh_m_mlb_prd/days_in_month)*(100/ind_d_of_m_mlb_prd)*(1000000/pop_m_cap_macro))

= -28.89 – 0.7064*log(otherdairy_m_cpi*100/cpi_all_unadj)
(-19.24) (-3.70)

+ 2.978*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(25.50)

R2=0.882, DW=1.267

Frozen Desserts:
log((ic_fdairy_m_mlb_prd/days_in_month)*(100/ind_d_fd_m_mlb_prd*(1000000/pop_m_cap_macro))

= -4.194 - 0.323* log(ic_m_dhalfgl_pri*100/cpi_all_unadj)
(-1.53) (-4.60)

+ 0.181*log(disp_inc_m_bdl_macro*100*1000000000/(pop_m_cap_macro*cpi_all_unadj))
(0.63)

-0.0011*trend - 2.53E-06*trend*trend
(-1.506) (-0.618)

R2=0.548, DW=1.718

Other Fresh Components (for Simulation):

Other Fresh:
of_prot_m_mlb_prd = 0.0695 * of_ofresh_m_mlb_prd
of_milkf_m_mlb_prd = 0.0547 * of_ofresh_m_mlb_prd
of_ods_m_mlb_prd = 0.0641 * of_ofresh_m_mlb_prd

Frozen Dessert:
ic_prot_m_mlb_prd = 0.0365 * ic_fdairy_m_mlb_prd
ic_milkf_m_mlb_prd = 0.0903 * ic_fdairy_m_mlb_prd
ic_ods_m_mlb_prd = 0.0732 * ic_fdairy_m_mlb_prd

Define the Supply of Manufacturing Milk Components:

Protein:
mm_prot_m_mlb = rm_prot_m_mlb_prd - fl_prot_m_mlb_con - of_prot_m_mlb_prd - ic_prot_m_mlb_prd

Milk Fat:
mm_milkf_m_mlb = rm_milkf_m_mlb_prd - fl_milkf_m_mlb_con - of_milkf_m_mlb_prd - ic_milkf_m_mlb_prd

Other Solids:
mm_ods_m_mlb = rm_ods_m_mlb_prd - fl_ods_m_mlb_con - of_ods_m_mlb_prd - ic_ods_m_mlb_prd

Define American Cheese Variables:

Production:
cz_amer_m_mlb_prd = cz_amer_m_tlb_prd/1000
Imports:
cz_amer_m_mlb_imp = cz_amer_m_mt_imp*(2204.6/1000000)
Ending Stocks:
cz_amer_m_tlb_est = cz_totamer_m_tlb_est-cz_gst_m_tlb_est
= cz_amer_m_tlb_est/1000
cz_amer_m_mlb_est = cz_amer_m_tlb_est/1000
Exports:
cz_amer_m_mlb_exp = cz_amer_m_mt_exp*(2204.6/1000000)
Consumption:
cz_amer_m_mlb_con = cz_amer_m_mlb_est(-1)+cz_amer_m_mlb_imp+cz_amer_m_mlb_prd-cz_amer_m_mlb_est-(cz_amer_m_tlb_grm/1000)-(cz_amer_m_mlb_exp-cz_deiprm_m_tlb_grm/1000)

Define Other Cheese Variables:

Production:
cz_resid_m_mlb_prd = (cz_total_m_tlb_prd - cz_amer_m_tlb_prd - cz_mozz_m _tlb_prd)/**1000**
cz_mozz_m _mlb_prd = cz_mozz_m_tlb_prd/**1000**
cz _misc_m_mlb_prd = cz_resid_m_mlb_prd + cz_mozz_m_mlb_prd
Imports:
cz_ misc_m_mlb_imp = (cz_total_m_mt_imp - cz_amer_m_mt_imp)*(**2204.6**/**1000000**)

Ending Stocks:
cz_misc_m_mlb_est = (cz_total_m_tlb_est - cz_amer_m_tlb_est)/**1000**
Exports:
cz_misc_m_mlb_exp = (cz_total_m_mt_exp - cz_amer_m_mt_exp)*(**2204.6**/**1000000**)
Consumption:
cz_misc_m_mlb_con = cz_misc_m_mlb_est(-1)+ cz_misc_m_mlb_prd
+ cz_misc_m_mlb_imp - cz_misc_m_mlb_est - cz_misc_m_mlb_exp

Define Butter Variables:

Ending Stocks:
bt_bt_m_mlb_est = (bt_total_m_tlb_est – bt_gst_m_tlb_est)/1000
Imports:
bt_bt_m_mlb_imp = (mf_milkf_m_mt_imp +
fp_milkf_m_mt_imp)*(**2204.6**/**1000000**)/**0.8111**
Production:
bt_bt_m_mlb_prd = bt_bt_m_tlb_prd/**1000**
Exports:
bt_bt_m_mlb_exp = mf_milkf_m_mt_exp*(**2204.6**/**1000000**)/**0.811**
Consumption:
bt_bt_m_mlb_con =
bt_bt_m_mlb_est(-1) + bt_bt_m_mlb_imp + bt_bt_m_mlb_prd
- bt_bt_m_mlb_est - (bt_bt_m_tlb_grm/**1000**) - (bt_bt_m_mlb_exp -
bt_bt_deiprm_m_tlb_grm/**1000**)

Define Nonfat Dry Milk (Skim Milk Powder) Variables:

Ending Stocks:
nf_nfsm_m_mlb_est = nf_nfm_m_tlb_est/**1000**
Imports:
nf_nfsm_m_mlb_imp = dp_smp_m_mt_imp *(**2204.6**/**1000000**)
Production:
nf_nfsm_m_mlb_prd = (nf_nfm_m_tlb_prd + nf_smp_m_tlb_prd)/1000
Exports:
nf_nfsm_m_mlb_exp = dp_smp_m_mt_exp*(**2204.6**/**1000000**)
Consumption:
nf_nfsm_m_mlb_con =
nf_nfsm_m_mlb_est(-1) + nf_nfsm_m_mlb_imp + nf_nfsm_m_mlb_prd

- nf_nfsm_m_mlb_est - (nf_nfm_m_tlb_grm/**1000**) - (nf_nfsm_m_mlb_exp - nf_deiprm_m_tlb_grm/**1000**)

Define Dry Whey Variables:

Ending Stocks:
wy_dry_m_mlb_est = (wy_dryh_m_tlb_est + wy_drya_m_tlb_est)/**1000**
Imports:
wy_dry_m_mlb_imp = lw_dryh_m_mt_imp*(**2204.6**/**1000000**)
Production:
wy_dry_m_mlb_prd = (wy_dryh_m_tlb_prd + wy_drya_m_tlb_prd)/**1000**
Exports:
wy_dry_m_mlb_exp = lw_dryh_m_mt_exp*(**2204.6**/**1000000**)
Consumption:
wy_dry_m_mlb_con =
wy_dry_m_mlb_est(-1) + wy_dry_m_mlb_imp + wy_dry_m_mlb_prd
- wy_dry_m_mlb_est - wy_dry_m_mlb_exp

Cheese Production:

American Cheese Production:

log(cz_amer_m_mlb_prd/days_in_month) = -0.341
(-1.07)

+0.429*log(mm_prot_m_mlb/days_in_month) + 0.376*log(ind_d_cz_amer_m_mlb_prd)
(15.45) (5.02)

+ 0.0488*log((10.53*(1-0.005)*cz_40b_m_dlb_pri+0.26508*rm_c2bf_m_dcwt_pri)
(2.99)

/(4.48*bt_aa_m_dlb_pri+8.13*nf_west_m_dlb_pri))

R2=0.828, DW=0.826

Mozzarella Cheese Production:

(cz_mozz_m_mlb_prd/days_in_month) = -1.253 + 0.019*trend
(-1.82) (12.23)

+ 7.633*ind_d_cz_mozz_m_mlb_prd
(11.33)

AR(1) correction: $u_t = 0.638*u_{t-1} + \varepsilon_t$
(7.94)

R2=0.941, DW=1.924

Residual Cheese Production:

(cz_resid_m_mlb_prd/days_in_month) = -1.515 + 0.019*trend
(-3.71) (14.96)

+ 0.059*ind_d_cz_resid_m_mlb_prd
(15.27)

AR(2) correction: $u_t = 0.247*u_{t-1} + 0.253*u_{t-2} + \varepsilon_t$
(2.47) (2.57)

R2=0.923, DW=2.106

Define Miscellaneous Cheese Production:

cz_misc_m_mlb_prd = cz_resid_m_mlb_prd + cz_mozz_m_mlb_prd

Define Cheese Production Components:

cz_total_prot_m_mlb = (0.2301 * cz_amer_m_mlb_prd + 0.2426 * cz_mozz_m_mlb_prd + 0.222 * cz_resid_m_mlb_prd)
cz_total_milkf_m_mlb = (0.2929 * cz_amer_m_mlb_prd + 0.1592 * cz_mozz_m_mlb_prd + 0.2755 * cz_resid_m_mlb_prd)
cz_total_ods_m_mlb = (0.074 * cz_amer_m_mlb_prd + 0.0604 * cz_mozz_m_mlb_prd + 0.0621 * cz_resid_m_mlb_prd)

Define Milk Components After Cheese Production:

mmcz_prot_m_mlb = mm_prot_m_mlb - cz_total_prot_m_mlb
mmcz_milkf_m_mlb = mm_milkf_m_mlb - cz_total_milkf_m_mlb

mmcz_ods_m_mlb = mm_ods_m_mlb - cz_total_ods_m_mlb

Other Dairy Product Production:

Butter:

log(bt_bt_m_mlb_prd/days_in_month) = -0.959
(-7.99)

+0.937*log(mmcz_milkf_m_mlb/days_in_month)
(8.92)

-0.136*log((10.53*(1-0.005)*cz_40b_m_dlb_pri+0.26508*rm_c2bf_m_dcwt_pri)
(-3.16)

/(4.48*bt_aa_m_dlb_pri+8.13*nf_west_m_dlb_pri))

+ 0.0046*ind_d_bt_butter_m_mlb_prd + 0.001*trend
(6.74) (4.01)

R2=0.937, DW=1.445

Nonfat Dry Milk:

(nf_nfsm_m_mlb_prd/days_in_month) =

-0.136*log((10.53*(1-0.005)*cz_40b_m_dlb_pri+0.26508*rm_c2bf_m_dcwt_pri)
(NA)

/(4.48*bt_aa_m_dlb_pri+8.13*nf_west_m_dlb_pri))

0.301 + 0.245*(mmcz_prot_m_mlb/days_in_month)
(3.64) (3.81)

+ 0.0084*ind_d_nf_nfmsmp_m_mlb_prd – 0.136*dum2007m05
(10.06) (-3.35)

AR(2) correction: $u_t = 0.934*u_{t-1} - 0.202*u_{t-2}+\varepsilon_t$
(9.06) (-1.92)

R2=0.904, DW=1.936

Dry Whey:

(wy_dry_m_mlb_prd/days_in_month) = -0.392
(-1.08)

+ 0.039*((cz_amer_m_mlb_prd+cz_mozz_m_mlb_prd+cz_resid_m_mlb_prd)
(2.60)

/days_in_month) + 0.025*ind_d_wy_dryha_m_mlb_prd – 0.001*trend
(8.77) (-0.52)

AR(2) correction: $u_t = 0.639 * u_{t-1} + 0.21 * u_{t-2} + \varepsilon_t$
(6.41) (2.21)

R2=0.847, DW=2.017

Domestic Consumption:

Butter:

(log((bt_bt_m_mlb_con/days_in_month)*(100/
ind_d_bt_butter_dcd_m_mlb)*(1000000/pop_m_cap_macro))

= -17.44 - 0.15*log(bt_aa_m_dlb_pri*100/cpi_all_unadj))
(-6.32) (NA)

+ 0.083*log(mr_m_cpi(-1)*100/cpi_all_unadj)
(0.29)

+ 1.321*log(disp_inc_m_bdl_macro*100*1000000000
(5.18)

/(pop_m_cap_macro*cpi_all_unadj))

-0.157*dumbtclow + 0.153*dumbtchigh
(-7.07) (5.31)

AR(2) correction: $u_t = 0.086 * u_{t-1} + 0.232 * u_{t-2} + \varepsilon_t$
(0.82) (2.23)

R2=0.616, DW=2.06

American Cheese:

log((cz_amer_m_mlb_con/days_in_month)*(100/ind_d_cz_amer_dcd_m_mlb)*(1000000/pop_m_cap_macro))

= -5.585 -0.033*log(cz_40b_m_dlb_pri*100/cpi_all_unadj) +
(-6.84) (-1.78)

0.236*log(disp_inc_m_bdl_macro*100*1000000000
(2.79)

/(pop_m_cap_macro*cpi_all_unadj)) -0.0097*unempl_percent_unadj_mac
(-2.48)

+ 0.065*dumamczhigh -0.089*dumamczlow
(5.43) (-5.35)

R2=0.449, DW=1.81

Miscellaneous Cheese:

log((cz_misc_m_mlb_con/days_in_month)*(100/ind_d_cz_misc_dcd_m_mlb)*(1000000/pop_m_cap_macro))

= -16.48 – 0.026*log(cz_mozz_m_dlb_pri*100/cpi_all_unadj)
(-22.29) (-0.73)

+ 1.404*log(disp_inc_m_bdl_macro*100*1000000000
(18.35)

/(pop_m_cap_macro*cpi_all_unadj)) -0.008*unempl_percent_unadj_mac
(-2.25)

AR(2) correction: u_t = -0.032*u_{t-1} - 0.132*u_{t-2}+ε_t
(-0.30) (-1.25)

R2=0.745, DW=1.966

Nonfat:

log((nf_nfsm_m_mlb_con/days_in_month)*(1000000/pop_m_cap_macro))

= -12.39 -0.205*log(nf_west_m_dlb_pri*100/cpi_all_unadj)
(-1.21) (-1.18)
+ 0.73*log(cz_40b_m_dlb_pri*100/cpi_all_unadj)
(3.36)

+ 0.789*log(disp_inc_m_bdl_macro*100*1000000000
(0.75)

/(pop_m_cap_macro*cpi_all_unadj)) – 2.35*dumoct04 – 0.775*dumnfclow
(-9.35) (-6.12)

AR(1) correction: u_t = 0.248*u_{t-1} + ε_t
(2.40)

R2=0.634, DW=2.005

Dry Whey:

log((wy_dry_m_mlb_con/days_in_month)*(100/ind_d_wy_dryha_dcd_m_mlb)*(1000000/pop_m_cap_macro))

= 28.17 – 0.374*log(wy_west_m_dlb_pri*100/cpi_all_unadj)
(3.42) (-4.74)

- 3.526*log(disp_inc_m_bdl_macro*100*1000000000
(-4.18)

/(pop_m_cap_macro*cpi_all_unadj))

AR(1) correction: $u_t = 0.337*u_{t-1} + \varepsilon_t$
(3.39)

R2=0.715, DW=1.997

Wholesale Price Equations:

American Cheese:

cz_40b_m_dlb_pri = 0.499 - 0.004*dseadtrd_est_cz
(4.11) (-2.91)

+ 1.44E-05*dseadtrd_est_cz*dseadtrd_est_cz + 0.793*cz_40b_m_dlb_pri(-1)
(2.18) (15.19)

+ 0.348*cz_pri_dummy3 – 0.374*cz_pri_dummy4
(5.40) (-4.65)

R2=0.888, DW=1.827

where:

trd_stk_cz = 439.1045 + 1.102899 * trend - 80
cz_amer_m_mlb_est_sa = cz_amer_m_mlb_est / cz_amer_m_mlb_est_sf
dseadtrd_est_cz = cz_amer_m_mlb_est_sa - trd_stk_cz

Butter:

bt_aa_m_dlb_pri = 2.21 - 0.5*bt_aa_m_dlb_pri(-1) – 0.026*bt_bt_m_mlb_prd_sa
(1.98) (NA) (-1.33)

+ 8.11E-05*bt_bt_m_mlb_prd_sa*bt_bt_m_mlb_prd_sa
(0.95)

- 0.000147*bt_bt_m_mlb_imp + 0.000703*(bt_bt_m_mlb_con+bt_bt_m_mlb_exp)
(-0.06) (1.12)

+ 0.354*dummy1 – 0.227*dummy2 + 0.0027*trend
(6.99) (-2.66) (3.15)

R2=0.545, DW=1.438

where:

bt_bt_m_mlb_prd_sa = bt_bt_m_mlb_prd / bt_bt_m_mlb_prd_sf

Nonfat:

nf_west_m_dlb_pri = -1.015 + 0.762*exr_eurodol_pri
(-5.25) (4.60)

+ 0.000528*nf_eu_euromt_pri
(21.30)

R2=0.940, DW=0.500

Dry Whey:

wy_west_m_dlb_pri = 0.124 - 0.25*wy_west_m_dlb_pri(-1)
(4.39) (NA)

+ 0.246* nf_west_m_dlb_pri
(9.83)

- 0.391*wy_dry_m_mlb_est/(wy_dry_m_mlb_con+wy_dry_m_mlb_exp))/wy_stks_use_sf
(-6.14)

- 0.038*dumccc + 0.089*dum2006
(-2.36) (5.30)

R2=0.746, DW=0.511

Market Clearing Identities:

American Cheese:

cz_amer_m_mlb_est = cz_amer_m_mlb_est(-1) + cz_amer_m_mlb_imp + cz_amer_m_mlb_prd - cz_amer_m_mlb_con - (cz_amer_m_tlb_grm / 1000) - (cz_amer_m_mlb_exp - cz_deiprm_m_tlb_grm / 1000)

Other Cheese:

cz_misc_m_mlb_est = cz_misc_m_mlb_est(-1) + cz_misc_m_mlb_imp + cz_misc_m_mlb_prd - cz_misc_m_mlb_con - cz_misc_m_mlb_exp

Butter:

bt_bt_m_mlb_est = bt_bt_m_mlb_est(-1) + bt_bt_m_mlb_imp + bt_bt_m_mlb_prd - bt_bt_m_mlb_con - (bt_bt_m_tlb_grm / 1000) - (bt_bt_m_mlb_exp - bt_deiprm_m_tlb_grm / 1000)

Nonfat:

nf_nfsm_m_mlb_est = nf_nfsm_m_mlb_est(-1) + nf_nfsm_m_mlb_imp + nf_nfsm_m_mlb_prd - nf_nfsm_m_mlb_con - (nf_nfm_m_tlb_grm / 1000) - (nf_nfsm_m_mlb_exp - nf_deiprm_m_tlb_grm / 1000)

Dry Whey:

wy_dry_m_mlb_est = wy_dry_m_mlb_est(-1) + lw_dryh_m_mt_imp * (2204.6 / 1000000) + wy_dry_m_mlb_prd - wy_dry_m_mlb_con - lw_dryh_m_mt_exp * (2204.6 / 1000000)

Appendix Table C: Variable Description List

Endogenous Variables:

Variable Names	Descriptions
BF_FO_ADV_DLB_PRI	Butterfat price, 2-week advanced, monthly, $/lb.
BF_FO_M_DLB_PRI	Butterfat price, 4-week average, monthly, $/lb.
BT_AA_M_DLB_PRI	Butter price, CME Grade AA, monthly, $/lb.
BT_BT_M_MLB_CON	Butter domestic consumption, monthly, mil lbs.
BT_BT_M_MLB_EST	Butter commercial ending stocks, monthly, mil lbs.
BT_BT_M_MLB_EXP	Butter exports, definition, monthly, mil lbs.
BT_BT_M_MLB_IMP	Butter imports, definition, monthly, mil lbs.
BT_BT_M_MLB_PRD	Butter production, monthly, mil lbs.
BT_BT_M_MLB_PRD_SA	De-seasonalized butter production, monthly, mil lbs.
BT_GRAA_M_DLB_PRI	Retail Grade AA butter price, monthly, $/lb.
BT_NASS_2W_DLB_PRI	Butter price, NASS, 2-week average, monthly, $/lb.
BT_NASS_M_DLB_PRI	Butter price, NASS, 4-week average, monthly, $/lb.
CZ_40BLOCKS_M_DLB_PRI	Cheese price, CME 40 lb block, monthly, $/lb.
CZ_AMER_M_MLB_CON	American cheese domestic consumption, monthly, mil lbs.
CZ_AMER_M_MLB_EST	American cheese ending stocks, monthly, mil lbs.
CZ_AMER_M_MLB_EST_SA	De-seasonalized American cheese ending stocks, monthly, mil lbs.
CZ_AMER_M_MLB_EXP	American cheese exports, identity, monthly, mil lbs.
CZ_AMER_M_MLB_IMP	American cheese imports, identity, monthly, mil lbs.
CZ_AMER_M_MLB_PRD	American cheese production, monthly, mil lbs.
CZ_MISC_M_MLB_CON	Misc cheese consumption, monthly, mil lbs.
CZ_MISC_M_MLB_EST	Misc cheese ending stocks, monthly, mil lbs.
CZ_MISC_M_MLB_EXP	Misc cheese exports, identity, monthly, mil lbs.
CZ_MISC_M_MLB_IMP	Misc cheese imports, identity, monthly, mil lbs.
CZ_MISC_M_MLB_PRD	Misc cheese production equals residual plus mozz, monthly, mil lbs.
CZ_MISC_M_MLB_PRD	Misc cheese production, identity, monthly, mil lbs.
CZ_MOZZ_M_DLB_PRD	Mozzarella cheese production, monthly, mil lbs.
CZ_MOZZ_M_DLB_PRI	Wholesale mozzarella price, monthly, $/lb.
CZ_NASS_2W_DLB_PRI	Cheese price, NASS, 2-week average, monthly, $/lb.
CZ_NASS_M_DLB_PRI	Cheese price, NASS, 4-week average, monthly, $/lb.
CZ_RESID_M_MLB_PRD	Cheese, residual production, monthly, mil lbs.
DEF_IOFC	Deflated income over feed costs, $/cow/day
DSEADTRD_EST_CZ	De-seasonalized, detrended monthly American cheese ending stocks.
FC	Daily feed cost for a milking cow, $/cow/day
FL_BM_M_MLB_CON	Fluid consumption, buttermilk, monthly, mil lbs.
FL_FATFREE_M_MLB_CON	Fluid consumption, fat free, monthly, mil lbs.
FL_FWH_M_DGL_PRI	Retail city average fluid milk price, whole milk, monthly, $/gal.

FL_LOWFAT_M_MLB_CON	Fluid consumption, low fat, monthly, mil lbs.
FL_MILKF_M_MLB_CON	Fluid milk consumption, milk fat content, monthly, mil lbs.
FL_ODS_M_MLB_CON	Fluid milk consumption, other dairy solids content, monthly, mil lbs.
FL_PROT_M_MLB_CON	Fluid milk consumption, protein content, monthly, mil lbs.
FL_REDFAT_M_MLB_CON	Fluid consumption, reduced fat, monthly, mil lbs.
FL_WHOLE_M_MLB_CON	Fluid consumption, whole milk, monthly, mil lbs.
IC_FDAIRY_M_MLB_PRD	Frozen dessert production production, monthly, mil lbs.
IC_M_DHALFGL_PRI	Retail ice cream price, monthly, dollars per half gal.
IC_MILKF_M_MLB_PRD	Frozen dessert milk fat content, monthly, mil lbs.
IC_ODS_M_MLB_PRD	Frozen dessert other solids content, monthly, mil lbs.
IC_PROT_M_MLB_PRD	Frozen dessert protein content, monthly, mil lbs.
IOFC	Income over feed costs for a milking cow, $/cow/day
MC_US_M_THD_PRD	U.S. estimated milk cows, monthly, thousand head.
MM_MILKF_M_MLB	Manufacturing supply of components, milk fat, monthly, mil lbs.
MM_ODS_M_MLB	Manufacturing suppy of components, other solids, monthly, mil lbs.
MM_PROT_M_MLB	Manufacturing supply of components, protein, monthly, mil lbs.
MMCZ_MILKF_M_MLB	Supply of components after cheese producion, milk fat, monthly, mil lbs.
MMCZ_ODS_M_MLB	Suppy of components after cheese production, other solids, monthly, mil lbs.
MMCZ_PROT_M_MLB	Supply of components after cheese production, protein, monthly, mil lbs.
NF_FO_ADV_DLB_PRI	Nonfat solids price, 2-week advanced, monthly, $/lb.
NF_FO_M_DLB_PRI	Nonfat solids price, 4-week average, monthly, $/lb.
NF_NASS_2W_DLB_PRI	Nonfat price, NASS, 2-week average, monthly, $/lb.
NF_NASS_M_DLB_PRI	Nonfat price, NASS, 4-week average, monthly, $/lb.
NF_NFSM_M_MLB_CON	Nonfat/skim domestic consumption, monthly, mil lbs.
NF_NFSM_M_MLB_EST	Nonfat/skim ending stocks, monthly, mil lbs.
NF_NFSM_M_MLB_EXP	Nonfat/skim exports, monthly, mil lbs.
NF_NFSM_M_MLB_IMP	Nonfat/skim imports, monthly, mil lbs.
NF_NFSM_M_MLB_PRD	Nonfat/skim production, monthly, mil lbs.
NF_WEST_M_DLB_PRI	Nonfat price, AMS Western mostly, monthly, $/lb.
OF_MILKF_M_MLB_PRD	Other fresh milk fat content, monthly, mil lbs.
OF_ODS_M_MLB_PRD	Other fresh other dairy solids content, monthy, mil lbs.
OF_OFRESH_M_MLB_PRD	Other fresh dairy product production, monthy, mil lbs.
OF_PROT_M_MLB_PRD	Other fresh protein content, monthly, mil lbs.
OS_FO_ADV_DLB_PRI	Other solids price, 2-week advanced, monthly, $/lb.
OS_FO_DLB_PRI	Other solids price, 4-week average, monthly, $/lb.
OTHERDAIRY_M_CPI	CPI other dairy index, monthly, 1982-84=100.
PR_FO_ADV_DLB_PRI	Protein price, 2-week advanced, monthly, $/lb.
PR_FO_M_DLB_PRI	Protein price, 4-week average, monthly, $/lb.
RM_ALLMILK_M_DCWT_PRI	All-milk price, $/cwt.

RM_AM_M_DCWT_PRI	U.S. average all-milk price, $/cwt.
RM_C1M_M_DCWT_PRI	Class I price, monthly, $/cwt.
RM_C1S_ADV_DCWT_PRI	Advanced Class I solids price, monthly, $/cwt.
RM_C2BF_M_DCWT_PRI	Class II butterfat price, monthly, $/cwt.
RM_C3S_ADV_DCWT_PRI	Advanced Class III solids price, monthly, $/cwt.
RM_C4S_ADV_DCWT_PRI	Advanced Class IV solids price, monthly, $/cwt.
RM_USPRD_M_MLB_PRD	U.S. estimated milk production, monthly, million pounds.
RM_USYIELD_M_LB_PRD	U.S. estimated milk yield per cow, monthly, pounds.
TRD_STK_CZ	Trend in American cheese commercial ending stocks.
WY_DRY_M_MLB_CON	Dry whey domestic consumption, mil lbs.
WY_DRY_M_MLB_EST	Dry whey ending stocks, monthly, mil lbs.
WY_DRY_M_MLB_EXP	Dry whey exports, monthly, mil lbs.
WY_DRY_M_MLB_IMP	Dry whey imports, monthly, mil lbs.
WY_DRY_M_MLB_PRD	Dry whey production, monthly, mil lbs.
WY_NASS_2W_DLB_PRI	Dry whey price, NASS, 2-week average, monthly, $/lb.
WY_NASS_M_DLB_PRI	Dry whey price, NASS, 4-week average, monthly, $/lb.
WY_WEST_M_DLB_PRI	Dry whey price, AMS Western mostly, monthly, $/lb.

Exogenous Variables:

Variable Names	Descriptions
APRM_IL_M_DTON_PRI	Premium alfalfa hay prices, Illinois, NASS, $/ton.
BT_BT_DEIPRM_M_TLB_GRM	Butter DEIP exports, monthly, thou lbs.
BT_BT_M_MLB_PRD_SF	Monthly seasonal index, butter production.
BT_BT_M_TLB_GRM	Butter government removals, monthly, thou lbs.
CM_SOURCREAM_M_TLB_PRD	Sour cream production, monthly, thou lbs.
CPI_ALL_UNADJ	Consumer price index, all, 1982-84=100.
CR_M_DBU_PRI	Corn price, NASS, $/bu.
CT_COTCREAM_M_TLB_PRD	Cottage cheese, regular, monthly, thou lbs.
CT_COTCURD_M_TLB_PRD	Cottage cheese, curd, monthly, thou lbs.
CT_COTLOW_M_TLB_PRD	Cottage cheese, lowfat, monthly, thou lbs.
CZ_AMER_M_MLB_EST_SF	Monthly seasonal index, american cheese ending stocks.
CZ_AMER_M_MT_EXP	American cheese exports, monthly, mt.
CZ_AMER_M_MT_EXP	American cheese exports, monthly, mt.
CZ_AMER_M_MT_IMP	American cheese imports, monthly, mt.
CZ_AMER_M_MT_IMP	American cheese imports, monthly, mt.
CZ_AMER_M_TLB_GRM	American cheese government removals, thou lbs.
CZ_DEIPRM_M_TLB_GRM	American cheese DEIP exports, monthly, thou lbs.
CZ_TOTAL_M_MT_EXP	Total cheese exports, monthly, mt.
CZ_TOTAL_M_MT_IMP	Total cheese imports, monthly, mt.
DAYS_IN_MONTH	Days in the month.

DISP_INC_M_BLD_MACRO	U.S. disposable personal income, bil $.
DP_SMP_M_MT_EXP	Dry protein, skim milk powder, exports, monthly, mt.
DP_SMP_M_MT_IMP	Dry protein, skim milk powder, imports, monthly, mt.
DUM_DEC2004	Dummy variable, December 2004=1.
DUM2006	Dummy = 1, Feb 2006 - Dec 2009.
DUM2007M05	Dummy variable, equals 1 for May 2007.
DUMAMCZHIGH	Dummy = 1, Jan 2001, Sep 2002, Apr, May, Aug, & Nov 2004.
DUMAMCZLOW	Dummy =1, Jan 2000, Sep 2001, Jul 2004, Sep 2007.
DUMAUG07	Dummy variable, August 2007=1.
DUMCCC	Dummy = 1, Jan 1997 - May 2001.
DUMFATFREE	Dummy variable, fat free fluid milk consumption, equals 1 in months 2005-present.
DUMMY1	Dummy =1, Sep & Oct 1998, Nov 2000, May-Sep 2001, Mar-May 2004.
DUMMY2	Dummy = 1, Sep-Nov 2003.
DUMNFCLOW	Dummy =1, Apr 2000, Nov 2002, Dec 2004, Nov 2007.
DUMOCT04	Dummy = 1, Oct 2004.
DUMTCHIGH	Dummy = 1, Oct 2002, Apr 2004, Aug 2006, Jul 2007.
DUMTCLOW	Dummy = 1, Jan 2001, Apr 2002, May 2003, Aug 2003, Jan 2004, Dec 2007, Mar 2008.
EXR_EURODOL_PRI	Exchange rate, dollars per euros, monthly.
FP_MILKF_M_MT_IMP	Imports from food preparations, milk fat concent, monthly, mt.
IC_FYOGURT_M_TGA_PRD	Frozen yogurt production, monthly, thou gal.
IC_LFHARD_M_TGA_PRD	Ice cream production, lowfat hard, monthly, thou gal.
IC_LFSOFT_M_TGA_PRD	Ice cream production, lowfat soft, monthly, thou gal.
IC_NFHARD_M_TGA_PRD	Ice cream production, nonfat hard, monthly, thou gal.
IC_OTHERFROZEN_M_TGA_PRD	Other frozen dessert production, monthly, thou gal.
IC_REGHARD_M_TGA_PRD	Ice cream production, regular hard, monthly, thou gal.
IC_SHERBET_M_TGA_PRD	Sherbet production, monthly, thou gal.
IC_WATJUICES_M_TGA_PRD	Frozen water and juice production, monthly, thou gal.
IND_D_BT_BUTTER_DCD_M_MLB	Monthly seasonal index, daily butter consumption.
IND_D_BT_BUTTER_M_MLB_PRD	Monthly seasonal index, daily butter production.
IND_D_CZ_AMER_DCD_M_MLB	Monthly seasonal index, daily american cheese consumption.
IND_D_CZ_AMER_M_MLB_PRD	Monthly seasonal index, daily american cheese production.
IND_D_CZ_MISC_DCD_M_MLB	Monthly seasonal index, daily miscellaneous cheese consumption.
IND_D_CZ_RESID_M_MLB_PRD	Monthly seasonal index, daily residual cheese production.
IND_D_DZ_MOZZ_M_MLB_PRD	Monthly seasonal index, daily mozzarella cheese production.
IND_D_FD_M_MLB_PRD	Monthly daily average index of frozen dessert production.
IND_D_FL_BM_M_MLB_CON	Monthly daily average index of butter milk consumption.
IND_D_FL_FATFREE_M_MLB_CON	Monthly daily average index of fluid fat free consumption.
IND_D_FL_LOWFAT_M_MLB_CON	Monthly daily average index of fluid low fat consumption.
IND_D_FL_REDFAT_M_MLB_CON	Monthly daily average index of fluid reduced fat consumption.

IND_D_FL_WHOLE_M_MLB_CON	Monthly daily average index of fluid whole milk consumption.
IND_D_NF_NFMSMP_M_MLB_PRD	Monthly seasonal index, daily nonfat production.
IND_D_OF_M_MLB_PRD	Monthly daily average index of other fresh production.
IND_D_WY_DRYHA_DCD_M_MLB	Monthly seasonal index, daily human dry whey consumption.
IND_D_WY_DRYHA_M_MLB_PRD	Monthly seasonal index, daily dry whey production.
IND_DAILYAVERAGE	Seasonal index, milk yield per cow, average=100.
LW_DRYH_M_MT_EXP	Dry whey exports, for human consumption, monthly, mt.
LW_DRYH_M_MT_IMP	Dry whey imports, for human consumption, monthly, mt.
MC_WI_SLAUGH_M_DCWT_PRI	Milk cow slaughter prices, Wisconsin, cents/lb.
MF_MILKF_M_MT_EXP	Exports from butter products, milk fat content, monthly, mt.
MF_MILKF_M_MT_IMP	Imports from butter products, milk fat content, monthly, mt .
MR_M_CPI	Margarine CPI index, 1982-84=100.
NF_DEIPRM_M_TLB_GRM	Nonfat dry milk DEIP removals, monthly, thou lbs.
NF_EU_EUROMT_PRI	EU border price for skim milk powder, Northern Europe, monthly, euros/mt.
NF_NFM_M_TLB_GRM	Nonfat dry milk government removals, monthly, thou lbs.
POP_M_CAP_MACRO	U.S. resident population.
SM_CHI_M_DTON_PRI	Soybean meal price, Chicago, Feedstuffs, $/ton.
TREND	Monthly trend, Januanary 1997=1, February 1997=2, etc.
UNEMPL_PERCENT_UNADJ_MAC	U.S. unemployment rate, percent.
YG_YOGURT_M_TLB_PRD	Yogurt production, monthly, thou lbs.