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Dairy Market Impacts of US Milk Protein Imports and Trade Policy Alternatives

By

Phillip M. Bishop and Charles F. Nicholson

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Cornell Program on Dairy Markets and Policy

Department of Applied Economics and Management
College of Agriculture and Life Sciences
Cornell University
Ithaca, NY 14853-7801

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PREFACE

Phillip M. Bishop is a PhD Candidate, and Charles F. Nicholson is a Senior Research Associate in the Department of Applied Economics and Management at Cornell University. Nicholson is affiliated with the Cornell Program on Dairy Markets and Policy.

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SUMMARY

US imports of milk protein products, particularly certain Milk Protein Concentrates (MPC) have increased dramatically since 1995. Whereas in 1995 MPC imports were just 15.9 million pounds, by the year 2000 they had reached 116.1 million pounds—an increase of well over 600% in just five years. In 2000, the farm price of milk in the US had reached low levels by historical standards. The all-milk price that year was $12.40/cwt, down from $14.38/cwt the year before and $15.46/cwt the year before that. These two events, record high levels of MPC imports and low milk prices, led to a suspicion that MPC imports were responsible for the low prices. Although milk prices rebounded in 2001 and MPC imports declined, the issue of milk protein imports has continued to receive a good deal of attention during 2002 and 2003 when farmers faced low milk prices. Thus, the concern persists that MPC imports are generally having a large negative impact on milk prices. This research bulletin provides answers to two main questions:

- What has been the impact on the US dairy markets of recent increases in MPC imports, and
- What are the implications of likely policy options in the event that policy makers seek to limit MPC imports or mitigate their impact?

Our assessment of milk protein imports uses a model of the US dairy sector that includes all major US dairy pricing policies and specifies two regions: California and the rest of the US (largely areas regulated by Federal Milk Marketing Orders). The model is used to examine results for six scenarios:

1) A <u>Base Case</u> scenario for the year 2001 with current trade policy;
2) A <u>Chapter 4 MPC Import Ban</u> scenario that would prohibit the importation of any of the MPC products classified under Chapter 4 of the Harmonized Tariff Schedule. These are products containing more than 40% protein, for which imports grew most rapidly between 1995 and 2000;
3) A <u>Milk Protein TRQ Without Compensation</u> scenario that imposes Tariff Rate Quotas (TRQ) on imports of Chapter 4 MPC, MPC in Chapter 35 of the HTS (which contain more than 90% casein protein) and casein products. The TRQ are specified consistent with legislation currently before Congress (H.R. 1786 and S. 847). This scenario assumes that the US does not provide compensation to exporters of MPC and casein products, which would likely be required under the US' WTO commitments;
4) A <u>Milk Protein TRQ With Compensation</u> scenario which imposes the same TRQ as the previous scenario but provides compensation to exporters of MPC and casein products by increasing the amount of allowable imports under the TRQ for cheese by the dollar value equivalent of the reduction in MPC and casein product imports;

5) A Domestic Milk Protein Product Subsidy scenario that provides US manufacturers of MPC and casein with subsidies equal to the difference between landed import cost of these products and the return that processors could obtain selling NDM to the CCC;
6) A Tilt scenario that lowers the tilt from its average value of 93.3 cents/lb NDM in 2001 to 80 cents/lb. This scenario lowers the cost of NDM in US dairy markets, thus increasing incentives for its use, and reduces incentives to import MPC.

The results of each of the scenarios 2) through 6) are compared to the results of the base case 1) to evaluate the impacts of Chapter 4 MPC imports (scenario 2) and proposed policy alternatives (scenarios 3 through 6). It is important to note that the "milk protein" problem is viewed by some as an "import problem," by others as a "tilt problem" and by others (especially dairy farmers), as a "milk price problem." Thus, which policies are preferred by different groups will depend on their initial perceptions of the problem.

Key results of the six scenarios are:

- Imports of Chapter 4 MPC products have a modest impact on the US all-milk price, about \$0.08/cwt. Price impacts are larger in the rest of the US than in California.
- Restricting imports of milk protein products increases the value of protein in US markets, but reduces the value of butterfat. This occurs because there is not a one-to-one substitution of skim milk for use in domestic MPC manufacture and NDM production. Because there are still incentives to sell NDM to the government, there is an increased overall demand for domestically produced milk protein, which implies increased milk production, increased butterfat production, and reductions in the butter price, Class IV and Class II prices (Class 4a and Class 2 in California). Thus, restrictions on milk protein imports have *offsetting effects* on milk prices.
- The Domestic Milk Protein Production Subsidy scenario results in the highest all-milk price, but also the highest government expenditures.
- The Milk Protein TRQ Without Compensation scenario results in a higher milk price increase than prohibiting Chapter 4 MPC imports. However, if compensation is required by the WTO US all-milk prices will be *lower* than in the Base scenario. That is, US dairy farmers would likely be worse off under the TRQ with compensation scenario than under current policy in the 2001 base year. However, sensitivity analyses suggest that the price impacts of TRQs with compensation can be positive in low milk price years.
- The Tilt scenario, not surprisingly, results in the largest reduction in the all-milk price and dairy producer revenue. The lower purchase price for NDM results in the largest reduction in government expenditures (there are no NDM purchases by the CCC) and a decrease in imports of Chapter 4 MPC comparable to those achieved by a TRQ policy.

Imports of Chapter 4 MPC products have modest negative impacts on US milk prices. Two of the policy alternatives available to address these impacts, the reduction in the NDM purchase price and the imposition of TRQ (with compensation required by the WTO), will reduce milk prices more than the MPC imports themselves. Production subsidies for US manufacturers of MPC and casein can increase milk prices but may increase government costs depending on the amount of the subsidies. It is important to recognize that policies designed to influence protein values are likely to have effects on butterfat values as well, because any policy to increase prices will result in additional production of both of these milk components. Thus, restrictions on milk protein imports will increase protein values (and cheese prices) and reduce butterfat values (butter prices). This means that even policies designed to be highly restrictive of milk protein imports or highly supportive of domestic milk protein product manufacture will have smaller impacts on milk prices than would be supposed based only on consideration of supply and demand for protein.

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INTRODUCTION

Throughout the second half of the 1990s, US imports of milk protein concentrates (MPCs) increased dramatically. In 1990, imports of MPCs were quite small, less than 1.8 million pounds. By 1995, MPC imports had increased to 15.9 million pounds, and by the year 2000 they had reached 116.1 million pounds. Thus, MPC imports had grown well over 600% in just five years. One reason for this rapid growth is trade policy. As is the case with other milk protein products, but unlike almost all other dairy products entering the US, MPCs are not subject to import quotas and only miniscule tariffs are applied. As MPC imports peaked in 2000, the farm price of milk in the US reached a low level by historical standards. The all-milk price in 2000 was $12.31 per hundredweight (cwt), down from $14.35 the year before and $15.50 the year before that.

These two events, record high levels of MPC imports and low milk prices, led to a suspicion that MPC imports were responsible for the low prices. Although milk prices rebounded in 2001 and MPC imports declined, the issue of milk protein imports has continued to receive a good deal of attention during 2002 and 2003 when farmers faced low milk prices. Thus, the concern that MPC imports are generally having a large negative impact on milk prices persists.

It is the purpose of this research to quantitatively determine the impact of milk protein imports, especially MPC imports, on US dairy markets. In addition, it assesses the impacts of likely policy responses to the increasing quantity of MPC imports. This topic has not been adequately addressed to date, as previous efforts have tended to ignore important realities of the dairy production and processing system (*e.g.*, Bailey (2002), and to a lesser extent, Sumner and Balgatas (2003)). In particular, the fact that protein is just one component of whole milk means that it can be misleading to consider it in isolation. Dairy products are jointly produced from whole milk; hence there may be market impacts that result from a reallocation of other dairy components (fat and other nonfat, non-protein solids) as a result of changes in trade and domestic policies that affect milk proteins. Furthermore, the ability to reallocate in different ways than has previously been possible is highlighted by the case of MPCs. MPCs are a relatively new product innovation that has come about due to advances in filtration technology.

If MPC imports had not increased in recent years, the demand for imported milk protein would need to have been met from domestically produced milk. But this would have resulted in additional butter production, or some other change to the overall product mix, and in turn dairy product prices would have adjusted to maintain balance in the market place. In the presence of the multiple and potentially offsetting effects that follow from the joint production feature of dairy products, the end result for the producer price is difficult to predict.

Milk protein imports may lead to a lower milk price for farmers if they occur in significant quantities and substitute for domestically produced milk products, especially nonfat dry milk (NDM). However, through the Commodity Credit Corporation (CCC), the US Department of Agriculture (USDA) will purchase unlimited quantities of NDM at a predetermined price in order to support the farm price of milk at the legislated minimum. Hence, if the market price for

NDM is at the CCC purchase price, and NDM and milk proteins are perfect substitutes, then imports will have no effect at all on the farm price. Rather, they will simply increase CCC purchases and expenditures. A better understanding of the consequences of substitutability amongst dairy protein products is crucial in predicting the impacts of MPC imports on US dairy markets, and represents a goal of this research.

PREVIOUS RESEARCH

Nearly all of the previous research on the market impacts of milk protein imports has been undertaken since Chapter 4 MPC imports peaked in 2000 (see section below). Much of this research is descriptive (*e.g.*, reports quantities of imports and calculates their milk equivalent) or conceptual (e.g., graphical or mathematical analyses without development of an empirical model). One of the first studies of MPC imports was conducted by the General Accounting Office (GAO) in 2001 at the request of Congress following the increase in Chapter 4 MPC imports during the late 1990s. This report reviewed the basics of MPC manufacture, uses, and US imports, but did not provide an assessment of market impact. One month after the release of the GAO report, the National Milk Producers Federation (NMPF) released a report assessing milk protein imports (NMPF, 2001). This report calculated the "displacement" of NDM by milk protein imports, essentially calculating the amount of NDM equivalent, on a protein basis, for the milk protein in casein, caseinate, and MPC imports in 2000. NMPF also estimated that producer income would be $694 million higher over the seven years from 2002 to 2008 if casein and MPC imports were limited to 2001 levels. Although not presented in this way in the report, this is roughly equivalent to an impact of $0.06/cwt of farm milk. However, the methods used to generate this result were not described, and this study is not equivalent to an assessment of the impacts of MPC imports *per se* in any given year.

Bailey (2001) provided a further descriptive summary of milk protein imports, hypothesizing (but not demonstrating) that lower-cost imported milk protein used to make cheese could lower cheese prices and result in additional purchases of NDM by the CCC. Bailey (2002) developed an econometric model of MPC imports using quarterly data from 1996 to 2000. His results suggested that MPC and NDM are not perfect substitutes, but that MPC imports would displace NDM and result in higher purchases of NDM under the Dairy Price Support Program (DPSP). This research also concluded that because MPC and NDM were not perfect substitutes, MPC imports would not be eliminated if the purchase price of NDM were lowered. Balagtas *et al.* (2002) developed a conceptual (mathematical) model of US dairy markets that specified a high level of aggregation. Their conceptual model suggested that when the CCC is purchasing NDM, there are no farm-milk price effects from imports of "milk protein" imports (as distinguishable from the products casein or MPC). Harris (2002), Jesse (2003) and Sparks Companies (2003) reached similar conclusions about the effects of MPC imports when NDM was being purchased. However, these analyses assume essentially perfect substitution between NDM and all milk protein imports (which as Bailey (2002) noted, is unlikely to be appropriate), they ignore interrelationships among dairy product prices through the classified pricing formulas used by Federal Milk Marketing Orders (FMMOs), and demonstrate only limited awareness the joint-product nature of fat, protein and other solids in milk production. Moreover, they ignore the possibility that MPC imports may lead the government to modify the NDM purchase price in order to minimize government expenditures on NDM, a point raised by Jesse (2003).

Sumner and Balagtas (2003), in a paper prepared for public hearings held by the US International Trade Commission in December 2003, formulated a model incorporating supply and demand for protein and non-protein milk components. They specified a log differential form to examine percentage changes in equilibrium prices and quantities due to reductions in imported milk proteins. Under alternative assumptions about the share of protein imports, reductions in protein imports due to trade restrictions and the substitutability of domestic and imported milk proteins (*i.e.,* not products), they found that the all-milk price would increase between 0.03% and 0.58% if protein imports were restricted. At an all-milk price of $13.50/cwt, these results imply that imports of milk protein products reduce US all-milk prices by essentially zero to $0.08/cwt. However, it is not clear that this assessment adequately incorporated other government policy instruments (e.g., classified pricing and CCC purchases) due largely to high levels of product aggregation. Thus, the studies published to date offer relatively limited insights into the farm milk price and product price impacts of milk protein product imports, and none have assessed the impacts of specific policies that have been proposed to address them.

OBJECTIVES

The overall objective of this research is to estimate the impact of milk protein imports on US dairy markets and to analyze the likely policy responses that may emerge given concerns about the level of those imports and their impact. Specific objectives are as follows:

1) Quantitatively assess the impact of milk protein imports on the key outcomes in US dairy markets;
2) Compare and contrast three likely policy options that might be used to alleviate the impact of milk protein imports: new tariff rate quotas on milk protein products; production subsidies for domestic production of milk protein products so as to displace imports; and adjustment of the "tilt" of butter and NDM purchase prices under the dairy price support program;
3) Describe impacts of policy options on key variables, such as farm milk prices, producer revenues, costs and revenues associated with government programs in the dairy sector, wholesale prices in dairy markets, milk protein import quantities, consumer expenditures, CCC purchase quantities, and the use of MPC and NDM in dairy plants.

The development and documentation of a new dairy sector model that is capable of allowing these objectives to be met is a secondary goal of this research.

MILK PROTEIN PRODUCTS AND PRODUCTION TECHNOLOGIES

The typical composition of raw milk in the US is 3.65% fat, 3.30% protein 4.75% lactose (milk sugar), 0.65% minerals (calcium, etc.) and 87.75% water (WCDR, 2002). Of the 3.30% protein, 3.0% is true protein, which is composed of approximately 80% casein and 20% whey protein. Unless they have been denatured due to high temperature exposure, the whey proteins are water soluble. The dominant protein in milk, casein, is not soluble and can be extracted from milk by precipitation following treatment with rennet or acid.

Historically, whole milk has been manufactured into cheese products or separated into skim milk and cream, whereupon the cream has been used to produce fat-based products such as butter. The skim milk and the whey from cheese production were considered by-products of little value and were discarded or used as animal feed. As the nonfat portion of the milk began to be more highly valued, processes were developed to remove the water, thereby enabling the preservation of the remaining components. For example, skim milk was subject to evaporation, taking the total solids content from about 9% up to about 40%, and then dried to form Nonfat Dry Milk (NDM). Similarly, the by-product of cheese production, whey, was dried to produce a powdered product rich in lactose and whey protein.

Cheese making itself has become more sophisticated over time as well. It was long ago found that yields could be improved, as could the consistency of the finished cheese, if the raw milk used to make cheese was standardized to a specific casein-to-fat ratio through the addition of more protein to the milk and/or the removal of fat. The precise ratio depends on the variety of cheese being produced. Traditionally, standardization of cheese milk in the US has been accomplished by adding concentrated skim milk or reconstituted NDM. Indeed, approximately half of all NDM produced in the US is used to standardize milk for cheese making. If the cheese is a low fat variety, standardization may involve the removal of excess fat in the form of cream. Standardizing agents such as skim milk, concentrated skim milk, and NDM contain significant shares of lactose and whey protein, and because of their inherent solubility, much of both of these components is lost to the whey during the cheese making process. A stylized illustration of the modern cheese making process is shown in Figure 1.

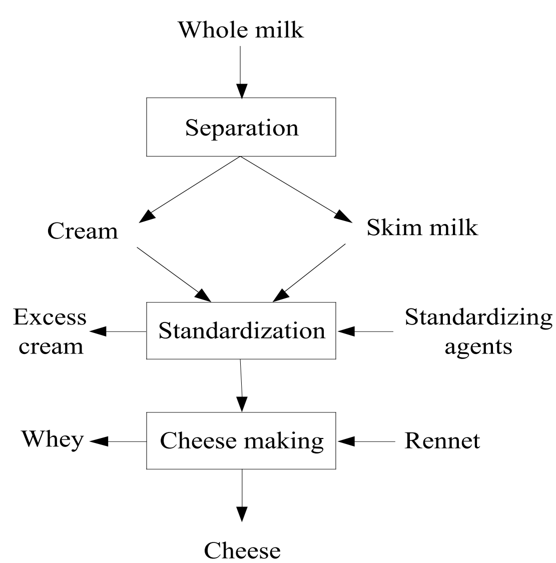

Figure 1. Stylized Illustration of the Cheese Making Process

A key process for some dairy product manufacturing is the extraction of protein from milk. The addition of rennet to milk when making cheese, for example, causes coagulation and the formation of curds and whey. At a pH of approximately 4.7, and aided by heat, casein forms an insoluble solid that becomes the curd. A related process is used to produce casein. Mineral acid or acid forming enzymes are added to skim milk in order to cause the (casein) protein to coagulate, which is then recovered by physically separating it from the whey using a screening or decanting procedure. The resulting curd is then washed and dried to produce casein – a fine, sand-like substance. In this form, casein is insoluble in water. Hence, it is often further processed into caseinate. By adding alkali substances, for example ammonium chloride, the casein is able to be neutralized and dissolved, and then dried in a similar manner to NDM. The alkali treatment results in caseinate being far more soluble in water than is casein. Figure 2 outlines the process for manufacturing casein and caseinate.

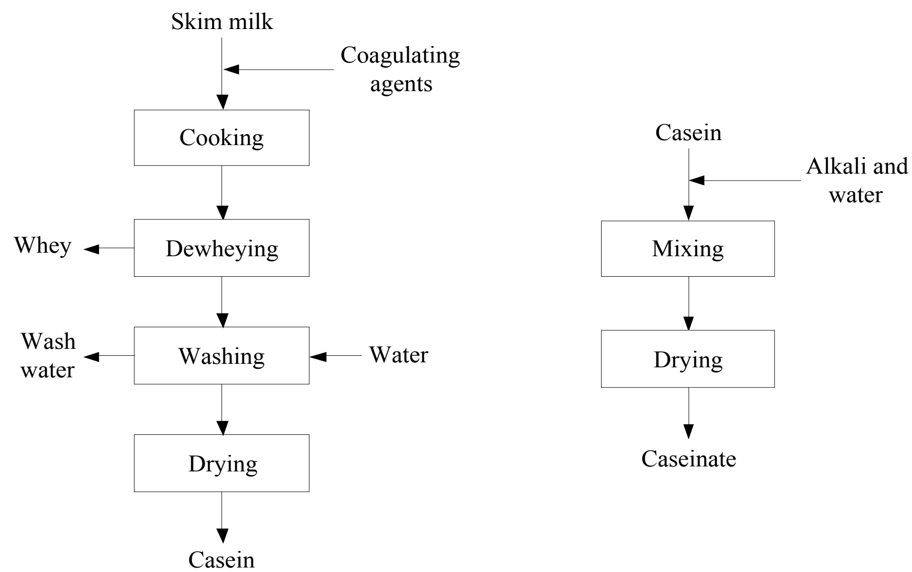

Figure 2. Stylized Illustration of Casein and Caseinate Manufacturing

From a purely technological standpoint, the ideal ingredient for standardizing cheese milk would be pure casein (WCDR, 2002). It is coagulated casein that forms the three dimensional lattice or backbone structure that traps fat, water, and minerals, and results in cheese curd. However, casein is too insoluble and the neutralizing agents in caseinate do not react well with rennet. These products are therefore difficult to use in cheese making and seldom ever are.

Milk protein concentrates are casein-abundant *and* soluble, and are therefore well suited for use in standardizing milk at cheese plants. Unlike the usual process for making casein, MPCs are produced via filtration techniques that are able to separate milk components according to size. In contrast to a product such as NDM, filtration enables the relative component shares of the solids portion to be dramatically altered. Because only the water is removed when skim milk is condensed or dried to produce NDM, the composition of the solids or non-water portion of these products is identical to that of skim milk.

The use of membranes as a separation technology in the dairy industry dates back to the 1960s, when the use of ultrafiltration (UF) for separating whey proteins from lactose was established. This development enabled cheese plant operators to further increase the value of the whey by-product by creating a range of products with protein contents varying from 34 to 75 percent. As ultrafiltration technology further developed, it was found that it was possible to apply it to cold whole milk. Hence, the use of cold ultrafiltered whole milk as a standardizing agent at cheese plants is now quite common. The proteins are not denatured by heat, and the presence of unwanted (non-retainable) soluble whey proteins and lactose is minimized. Depending on the degree of concentration, UF whole milk typically contains approximately 18 to 25 percent total solids, with over two-thirds of those solids being casein and fat, the two components that are desired and retained in cheese. NDM, on the other hand, contains over 50% lactose.

Ultrafiltration of whole milk or skim milk entails passing the milk along a filter or membrane containing minute pores. The larger molecules such as fat (in the case of whole milk) and casein are unable to pass through the membrane and are retained in what is called the retentate stream. Water and smaller components such as lactose, soluble whey proteins, and minerals may pass through the permeable membrane to become the so-called permeate stream. Under traditional filtration methods, the entire aqueous phase is forced under pressure through the filtering media, and the retained substances are removed from the filter once the flow has stopped. With ultrafiltration, the flow, while still under some pressure, is parallel to the filtering membrane rather than through it[1]. Hence, the process is not completely effective, *i.e.,* the retentate will still contain some of the smaller components such as lactose because not all of the milk will have come into contact with the membrane.

The degree of concentration is controlled through pore size and the length of time exposed to the membrane. To achieve solids concentration factors in the retentate greater than about five times, *i.e.,* 5X, a process called diafiltration is required. With diafiltration, additional water is added to the retentate stream which is then recirculated through the UF process. The added water "flushes" more of the smaller particles into the permeate stream. Milk protein concentrates (MPCs) are produced by drying ultrafiltered skim milk in much the same way that skim milk is dried to produce NDM. The protein content of the finished product is determined by the concentration that takes place during the ultrafiltration of the skim milk. It is possible to achieve a protein content in the finished product anywhere from 40 to more than 90 percent. Above about 65-70%, diafiltration is necessary.

It is important at this point to be clear about terminology. Ultrafiltered skim milk is sometimes referred to as "wet MPC" to distinguish it from the dried form. Throughout this bulletin, MPC will refer to the dry product. Wet MPC will be referred to as ultrafiltered skim milk.

It is also possible to manufacture MPCs via a process called co-precipitation. While this is technically similar to the process used to manufacture casein, the significant difference is that both the casein and the whey proteins are isolated from the whey. The result is an insoluble protein mixture. Products produced by co-precipitation are somewhat confusingly referred to as either MPCs or Milk Protein Isolates. They are also sometimes known as Total Milk Proteins (TMP). Figure 3 illustrates both the co-precipitation and ultrafiltration techniques for producing MPCs.

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[1] This form of filtration is sometimes referred to as Tangential Flow Filtration (TFF) as opposed to Normal Flow Filtration (NFF), where fluid is convected directly toward the filter media under applied pressure.

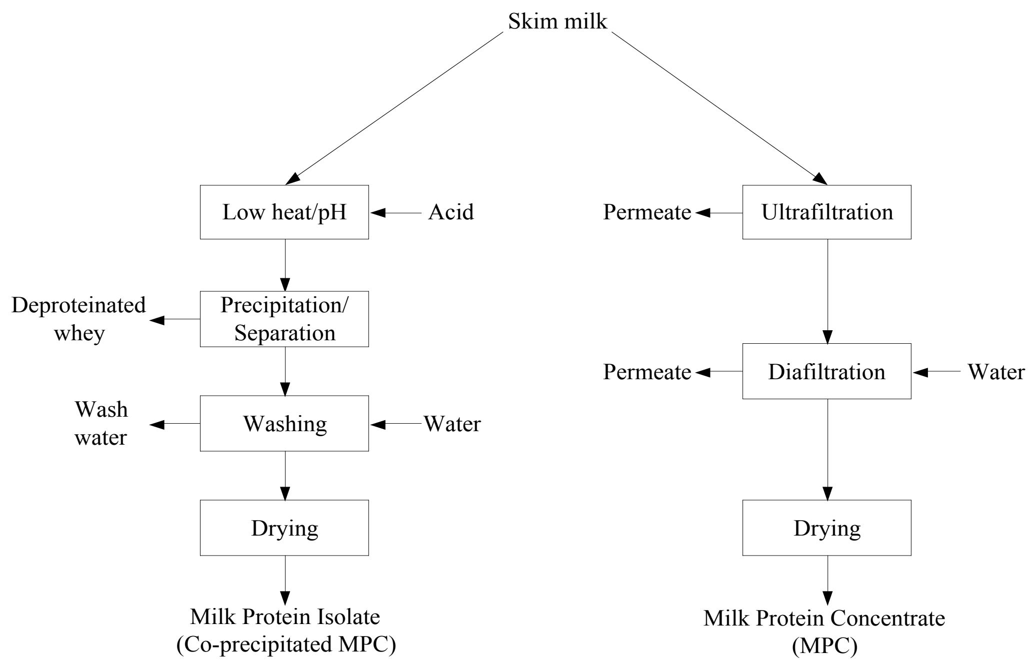

Figure 3. Stylized Illustration of Milk Protein Concentrate Manufacturing

New Zealand developed one of the first ultrafiltered MPC products in the early 1980s. It was MPC 56 (56% protein), and was developed as an ingredient for recombined white cheese in Europe (DCANZ, 2003). This product spawned an interest from a variety of food manufacturers ranging from dairy to bakery to nutritional applications. However, the relatively high lactose level of MPC 56 limited its use in nutritional applications. Since the 1980s, a wide range of MPC products have been engineered for use across a broad spectrum of food, beverage, and nutritional applications. Typically, the composition and production process is customized to meet the specific functional requirements of the customer using the product. Whereas a number of dairy exporting countries have produced and marketed MPC products since their inception in the 1980s, the first plant in the US to produce MPCs did not do so until very recently, early in 2003 in fact.

MILK PROTEIN IMPORTS

As noted in the introduction, US imports of milk protein products grew during the late 1990s, reaching a peak in 2000 (Figure 4). Imports of milk protein products can be usefully divided into four categories: casein, caseinates, high-protein MPCs and lower-protein MPCs. For the purposes of US trade policy, the first three of these products are classified in Chapter 35 (entitled "Albuminoidal Substances, Modified Starches; Glues; Enzymes") of the Harmonized Tariff Schedule (HTS), the detailed documentation of US quotas and tariffs. Lower-protein MPCs

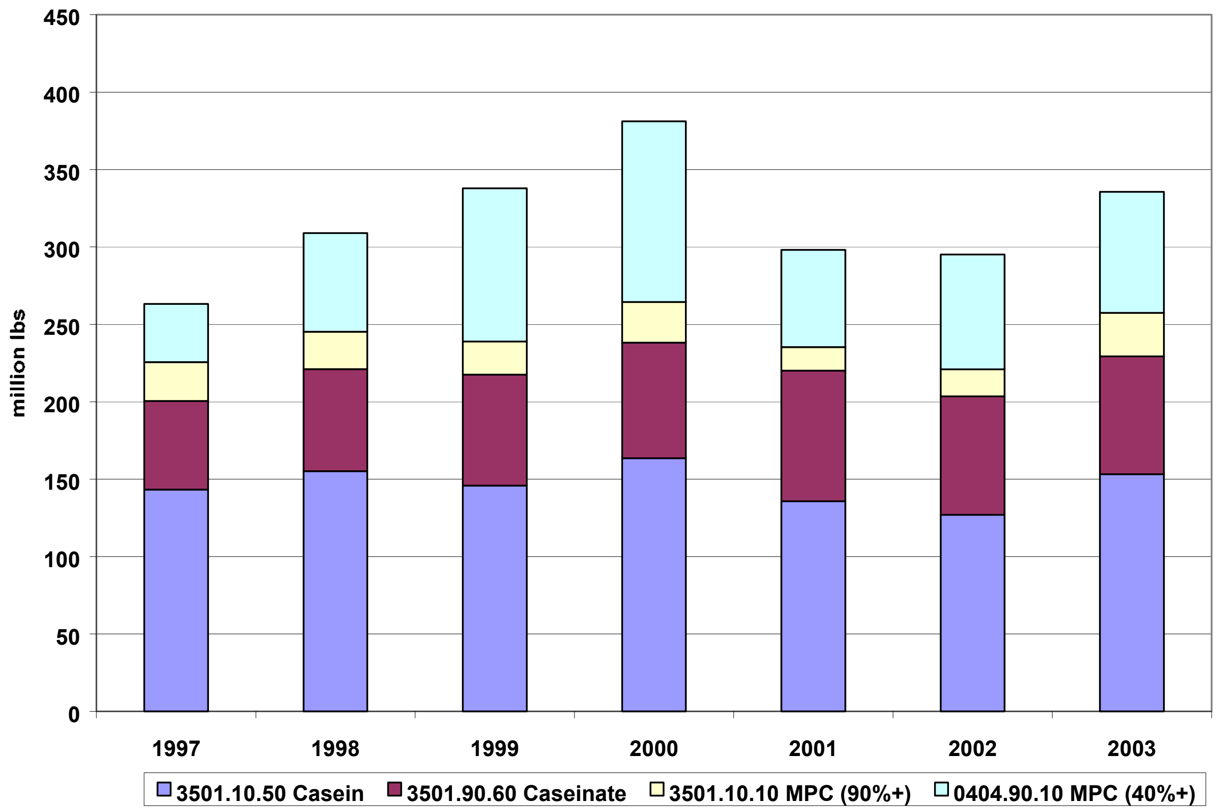

Figure 4. Milk Protein Imports, 1997-2003

Source: US International Trade Commission.

are located in Chapter 4 of the HTS, which includes most other dairy products. No quotas limiting imports exist for any of these products, and only very small tariffs are applied. Thus, milk protein products are largely free to enter the US, with import demand based primarily on relative prices for protein sources in the US and in world markets and a growing awareness of the functionality of these products in a wide variety of food and non-food uses. Casein and caseinates accounted for between 70 and 80% of the volume of milk protein products imported in the late 1990s and early 2000s, and accounted for an even larger share of imports on a milk-protein basis. Imports of these four milk protein products provided protein equal to between 5 and 6% of the amount of protein in US milk production (Figure 5). The protein in casein and caseinate imports accounted for about 4% of US milk protein production. As Bailey (2001) and others have noted, imports of Chapter 4 MPC imports peaked in 2000, when they provided protein equivalent to 1.3% of US milk protein production.

It is important to note that the MPC category in Chapter 4 is somewhat of a catch-all. It includes MPCs ranging in protein content from 40 to 90%[2], and does not specify the that the UF

[2] In the language of the HTS, Chapter 4 MPCs are "any complete milk protein (casein plus lactalbumin) concentrate that is 40 percent or more protein by weight."

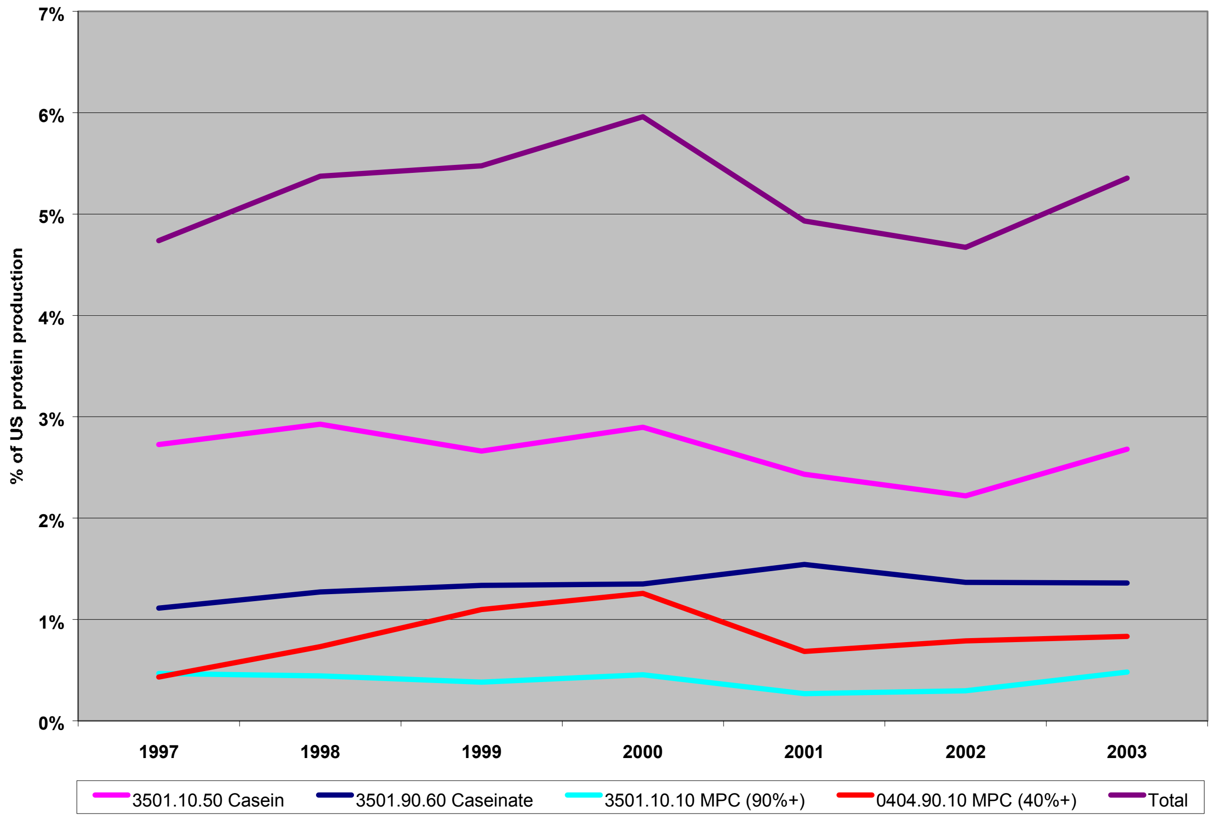

Figure 5. Milk Protein Imports as a Percentage of US Protein Production, 1997-2003

Source: US International Trade Commission and authors' calculations.

production process described above be used. As a result, in the late 1990s there were anecdotal reports that what were termed "dry blend MPCs" (mixtures of non-fat dry milk with casein sufficient to reach the 40% protein limit) were being imported. Although these products met the technical definition of a Chapter 4 MPC in the HTS, their functionality was usually quite different from MPCs made with the UF process. Moreover, dry blend MPCs looked a lot like a means for foreign exporters to circumvent US trade restrictions on nonfat dry milk imports (which were enacted to ensure that the Dairy Price Support Program would not become a support program for *world* nonfat dry milk prices). This was particularly the case because a number of major exporters (*e.g.*, the EU) provided hefty export subsidies for nonfat dry milk. It is in part for this reason that imports of Chapter 4 have become a major issue; imports of dry blend MPCs are viewed as "unfair exploitation" of a trade loophole that might significantly undermine a major domestic dairy policy. For the purposes of this analysis, however, it is important to keep in mind that Chapter 4 MPCs include a wide variety of products, and to date there has been very limited information about the types and uses of the products imported in this category. A forthcoming report from the US International Trade Commission (due out in May 2004) should shed considerable further light on the composition of milk protein imports and their uses.

MODEL DESCRIPTION

We now develop a model of the US dairy sector capable of addressing the objectives set out in the introduction. This section describes the conceptual underpinnings of the model and basic model characteristics. A detailed mathematical specification including variable definitions and equations is in Appendix A. Appendix B provides a detailed discussion of the data and related assumptions used in the model, and Appendix C describes model calibration and validation. Mathematically, the model is formulated as Mixed Complementarity Problem (MCP). It is written using the GAMS computer modeling language (Brook *et al.*, 1998) and is solved within the GAMS system using the PATH solver (Ferris and Munson, 2000).

CONCEPTUAL UNDERPINNINGS

As Ferris and Munson note, a fundamental mathematical problem is to find a solution to a square system of nonlinear equations. Newton's method, perhaps the most famous solution technique, has been extensively used in practice to calculate solutions to such systems. A generalization of the square system of nonlinear equations is the complementarity problem. The complementarity problem adds a "combinatorial twist" to the classic square system of nonlinear equations, thus enabling a broader range of situations to be modeled. For example, the complementarity problem can be used to model the Kuhn-Tucker (KT) optimality conditions for nonlinear programs, Walrasian equilibria, and bimatrix games.

In its simplest form, the combinatorial problem is to choose from 2n inequalities, a subset n that will hold as equalities. More formally, the nonlinear complementarity problem (NCP) can be specified as:

Given a nonlinear function $F:\Re^n \rightarrow \Re^n$, find $\mathbf{z} \in \Re^n$ such that

$$0 \le \mathbf{z} \text{ or } F(\mathbf{z}) \ge 0 .$$

Thus, only one of the inequalities is satisfied as an equality, or equivalently, for individual components, $z_i F(\mathbf{z}) = 0$. This property is typically referred to as z_i being complementary to $F_i(\mathbf{z})$. As an extension to this NCP, we may sometimes wish to specify certain intermediate variables, for example, y_i, where

$$y_i = f(\mathbf{z}) \quad \forall i = 1,\ldots,I .$$

Then, the NCP becomes:

Given a nonlinear function $F:\Re^n \rightarrow \Re^n$, find $\mathbf{z} \in \Re^n$ such that

$$0 \le \mathbf{z} \text{ or } F(\mathbf{z}) \ge 0$$

and

$$y_i = f(\mathbf{z})$$

The problem now involves a mixture of equations (for the *y*) and complementarity constraints. The *mixed* nature of this problem results in the name mixed complementarity problem (MCP). More formally, following Ferris and Munson (op. cit.), the mixed complementarity problem can be defined as:

$$\text{Given lower bounds } l \in \left\{\Re \cap \left\{-\infty\right\}\right\}^n \text{, upper bounds } u \in \left\{\Re \cap \left\{\infty\right\}\right\}^n ,$$

$$\text{and a function } F : \Re^n \rightarrow \Re^n , \text{ find } \mathbf{z} \in \Re^n$$

$$\text{such that precisely one of the following holds for each } i \in \left\{1,...,n\right\}$$

$$F_i\left(\mathbf{z}\right) = 0 \text{ and } l_i = z_i = u_i$$
$$F_i\left(\mathbf{z}\right) > 0 \text{ and } z_i = l_i$$
$$F_i\left(\mathbf{z}\right) < 0 \text{ and } z_i = u_i$$

Often in economic models, non-negativity constraints will be appropriate, implying that $l_i = 0$. Note also that if $l_i = z_i = u_i$, then the function $F_i(\mathbf{z})$ is unrestricted as precisely one of the three conditions in the MCP definition automatically holds.

In the typical simple spatial price equilibrium model with generalized per unit transfer costs, a nonlinear objective function is maximized subject to a set of constraints in order to calculate an equilibrium solution (Samuelson, 1952; Takayama and Judge, 1964). When the objective function is formulated in terms of inverse supply and demand functions, the model variables are the quantity produced in each region, the quantity demanded in each region, and the quantity shipped from each supply region to each demand region. The "dual" values, or shadow prices, in this formulation are the supply and demand prices in each region. Significantly, they are implied by the model but are not explicitly *in* the model.

In contrast, the MCP framework permits the construction of models with an explicit representation of both prices and quantities as variables. For example, the basic spatial price equilibrium (SPE) model would thus be expressed as an MCP:

$$\sum_j x_{i,j} \le Q_i^s \text{ or } P_i^s \ge 0$$
$$\sum_i x_{i,j} \ge Q_j^d \text{ or } P_j^d \ge 0$$
$$P_i^s \le g_i^s\left(Q_i^s\right) \text{ or } Q_i^s \ge 0$$
$$P_j^d \ge g_j^d\left(Q_j^d\right) \le \text{ or } Q_j^d \ge 0$$
$$P_j^d \le P_i^s + c_{i,j} \text{ or } x_{i,j} \ge 0$$

where:

Q_i^s is the quantity supplied in region *i*

Q_j^d is the quantity demanded in region *j*

P_i^s is the supply price in region *i*

P_j^d is the demand price in region *j*

$x_{i,j}$ is the quantity shipped from region *i* to region *j*

$c_{i,j}$ is the per unit generalized transfer cost from region *i* to region *j*

$g_i^s\left(Q_i^s\right)$ is the inverse supply function in supply region *i*

$g_j^d\left(Q_j^d\right)$ is the inverse demand function in demand region *j*

The MCP framework exploits the Kuhn-Tucker complementary slackness conditions to provide an explicit representation of both "primal" and "dual" variables in the model structure. Although primal-dual methods also exploit this complementarity, the MCP approach can be extended to create new problems for which no equivalent optimization problem exists. For example, Nicholson *et al.* (1994) have shown that the SPE model with discriminatory ad valorem tariffs (*i.e.,* tariffs on imports that differ by exporting region) cannot be directly solved using an optimization model, because the value of the tariff depends on the endogenously-determined supply price. In the MCP framework, this is easily handled by modifying the condition relating supply and demand prices as follows:

$$P_j^d \le \left(P_i^s + c_{i,j}\right)\left(1+\tau_{i,j}\right) \text{ or } x_{i,j} \ge 0$$

where τ represent ad valorem tariffs imposed by demand region *j* on imports from supply region *i*.

The essential points about the desirability of the MCP framework for the present application are that both price and quantity values can be simultaneously and directly constrained, and that the relationships among the variables need not conform to the first-order conditions of an underlying optimization problem. Indeed, such an underlying optimization problem may not even exist. Because both prices and quantities can be simultaneously constrained, policy instruments that target prices (*e.g.*, price supports and ad valorem tariffs) or quantities (*e.g.*, production subsidies) can be modeled simultaneously and directly. The MCP framework is also well suited to settings where regime switching occurs (*e.g.* tariff rate quotas). Finally, complementarity makes mute the issue of integrability (*e.g.*, the need for symmetry of cross-price terms in demand equations) which is a major restriction required by many of the algorithms for solving conventional optimization problems.

AN EMPIRICAL MODEL

For the purposes of constructing a model, the US dairy sector is conceived of as having three market levels: (1) supply, where farmers produce raw milk in response to its price; (2)

processing, where dairy plants receive raw milk and transform it into either intermediate products for shipment to some other dairy plant, or final products for shipment to end users outside of the dairy marketing channel; and (3) demand, where price-responsive end users such as food processors and final consumers purchase a range of dairy products.

In order to capture the crucially important joint production feature of the dairy sector, and to reliably address the issue of milk protein imports, three components are used to characterize milk and milk products. They are fat, protein, and other nonfat solids. Component balance at each plant type in each region for each component is assured, *i.e.,* all milk components must be used and production of dairy products is unable to occur without a supply of milk components. The main source of milk components is domestically produced raw milk, although dairy product imports can be a source of milk components also. Recognizing that milk components may pass through processing plants, and may be used to produce intermediate products, sales to US-based end users and exports represent the final destination of all milk components.

The model has nine intermediate products and 16 final products. There are 21 product types in total, *i.e.,* some may be both intermediate and final products. There are three regions – California, "Other US", and the rest of the world. The Other US region is all of the US except for Alaska, Hawaii, and California[3].

An innovative feature of this model is the structure of the production functions governing how the processing sector transforms raw milk (and intermediate products) into manufactured dairy products. Yield functions are employed, which are based on the physical process of separating cream and skim milk and the subsequent recombination in proportions necessary to produce products with desired attributes, *e.g.,* exogenously fixed moisture content or a minimum component composition. A consequence of adopting the yield function approach is that for many products and components, the composition turns out to be endogenous. Although this increases the nonlinearities in the model and therefore makes it more difficult to solve, it has the beneficial side effect of enabling us to avoid using potentially infeasible fixed coefficients production technologies. In other words, the composition of final products is a function of the quantity and composition of the various inputs used to produce it, and when these quantities are not known *a priori*, it is impossible to know with precision what the final composition will be.

All of the major dairy policy instruments are included in the model. For instance, import quotas and tariffs, both specific and *ad valorem*; export subsidies and quantitative restrictions on subsidized exports; and government product purchases under the dairy price support program are all modeled as explicit and distinct instruments. Similarly, the classified pricing rules of marketing orders, which determine the minimum prices that processors must pay for milk, are included in significant detail.

The model has at its core the basic characteristics of a traditional Samuelson-Takayama-Judge (STJ) spatial price equilibrium model, *i.e.,* a solution to the model requires that prices in one market are explicitly linked to prices in another as a strict equality, if a non-zero physical flow between the two markets exists. However, it departs from that STJ tradition in that it is formulated as an MCP. Whereas all NLPs may be recast as MCPs, the reverse is not the case.

[3] The dairy sector is practically non-existent in Alaska and Hawaii and is therefore ignored.

Hence, the MCP framework permits greater flexibility in terms of the economic structures that can be modeled. Besides avoiding the integrability issue associated with structures such as ad valorem tariffs, and gaining the advantage of being able to explicitly include both quantity and price variables in the model, there is one other more practical reason why the MCP formulation is desirable.

The model is highly nonlinear. For example, many of the regulated pricing constraints contain nonlinearities. The presence of a high number of nonlinearities makes solving the model more difficult using NLP solvers. This comes about because NLP solvers are unable to exploit second-order information, (*i.e.,* GAMS provides first order derivatives only to the chosen solver). An MCP is formulated in GAMS with explicit first order derivatives (that is more or less the definition of an MCP). Hence, GAMS then effectively provides second order derivatives to the solver. The ability to exploit this second order information greatly enhances the ability to solve large nonlinear problems. In order to obtain similar outcomes from NLP solvers, it is often necessary to overly constrain the model and/or bound the variables to restrict the domain over which the model is able to locate a solution.

SCENARIOS ANALYZED

To assess the impacts of milk protein imports, four scenarios are analyzed and compared to a base case scenario. The first scenario simply prohibits Chapter 4 MPC imports in order to gauge how those imports may have affected US dairy markets. In addition, three policy options aimed at addressing the "MPC problem" are examined and contrasted. As will become evident throughout the remainder of this bulletin, the interpretation of the outcome of these scenarios depends on how the "problem" is perceived; is it a milk protein import problem or is it a producer price problem?

The first policy response examined is the imposition of a Tariff Rate Quota (TRQ) on milk protein imports. Legislation proposing such TRQs is currently before Congress, and this scenario addresses the specific import levels and tariffs rates in the legislation[4]. If a TRQ were to be imposed on milk protein imports, it is highly likely that foreign exporters (of milk proteins to the US) would lodge a complaint with the World Trade Organization (WTO) and seek compensation under Article XXVIII of the General Agreement on Tariffs and Trade (1994). Hence, two variants of the TRQ proposal are examined: one without compensation and one with compensation. The second policy option considered is a cash subsidy to be paid by the government to processors for manufacturing Chapter 4 MPCs and casein. The third policy response is an adjustment to the so-called "butter-powder tilt," that is, changing the relative weightings on the price at which the government is prepared to purchase butter and NDM in order to support the farm price of milk. Specifically, we look at raising the butter price and lowering the NDM price, thereby removing the incentive that processors have to continue producing NDM when the production of MPCs might otherwise be profitable.

In addition to the scenarios just outlined, several other scenarios are examined to explore the sensitivity of the model's results to certain assumptions and parameters. Extensive experimentation with the model has revealed that there are three main areas where the results, while remaining qualitatively similar, might change somewhat. The three areas are: MPC

[4] H.R. 1160 and S. 560.

processing costs; the use of 2001 (a relatively high milk price year) as a base period; and supply and demand elasticities, particularly the import supply elasticities. Each of these cases will be discussed in some detail.

Because imports of Chapter 4 MPCs have grown more rapidly than other milk protein imports over the past decade, and because it is these products, especially the low protein variants, that are likely to be most substitutable with NDM, careful attention is paid throughout the analysis to this class of milk protein imports.

BASE SCENARIO

The base scenario represents the US market and trade policy conditions existing in 2001. It is important that the base case adequately represent those market outcomes, so that it can serve as a reliable basis for comparison with the outcomes predicted under the four policy scenarios. Aspects of the base case solution, model calibration and validation are presented in Appendix C. The information in that Appendix demonstrates that the predicted model outcomes closely replicate the observed 2001 market outcomes for nearly all sectors and market levels. Accordingly, it is appropriate and reasonable to compare the outcomes of the policy scenarios with this base scenario. Some additional discussion of assumptions in the base scenario, particularly the treatment of products imported as Chapter 4 MPCs, is merited here.

Although the Customs Bureau places all Chapter 4 MPC imports into a single HTS classification (0404.90.10), this product category contains an array of products with protein contents ranging from 40% to more than 90%. Three distinct products, MPC 42, MPC 56, and MPC 70, are used to represent Chapter 4 imports in the model. That is, MPCs with a low, medium, and high protein content, respectively. One difficulty, however, is that while we know the total quantity of Chapter 4 MPC imports in the 2001 reference year, we do not know the quantity associated with each of the three Chapter 4 MPC product groups in the model. Thus, we assume in the base scenario that each category accounts for one third of the total Chapter 4 imports.

Furthermore, when deriving the quantity with which to calculate the parameters in the final demand function for the low protein product, MPC 42, the one-third share is further reduced because we assume that 30% of it is used within the dairy sector, specifically at cheese plants either in the production of starter or, where permissible, as a milk standardizing agent. In other words, in the jargon of our model, we assume that 10% (30% of one third) of all Chapter 4 imports are used as an intermediate product. Thus, of the 62.8 million pounds (28,469 metric tons) of Chapter 4 imports in 2001, 20.9 million lbs are used to calibrate each of the final demand functions for MPC 56 and MPC 70. The reference quantity for MPC 42 final demand is only 14.7 million lbs while the remaining 6.3 million lbs of Chapter 4 MPC imports is assumed to be used in cheese plants.

The model is configured to allow MPC 42 to be substitutable with NDM in final demand. The degree of substitution is governed by the NDM-MPC 42 cross-price elasticity term in the demand function, which, in the base scenario, is set equal to 0.5. All other milk protein products are assumed not to be substitutable for NDM in final demand uses. The sensitivity of this assumption is examined later in this chapter. All three Chapter 4 products are substitutable with NDM in intermediate uses, primarily cheese plants, and the choice of how much of each is used is determined endogenously by the model. In other words, the relative prices and composition of NDM, MPC 42, MPC 56, and MPC 70 will dictate how much of each, if any, is to be used.

The CCC purchase price for NDM is 93.3 cents per lb, the monthly weighted average of the purchase prices that actually existed in 2001. The direct payments representation of the Milk Income Loss Contract (MILC) program is not operational in the base scenario as this program did not come into being until 2002. Parameters for all other dairy policy instruments–TRQs on imports, export subsidies, classified pricing–are set as described in Appendix B.

NO CHAPTER 4 MPC IMPORTS

This scenario is identical to the base scenario except that all Chapter 4 MPC imports are prohibited and MPC processing costs are lowered (see subsequent explanation). Other protein imports such as casein, caseinate, and Chapter 35 MPCs are still allowed to occur. The purpose of this scenario is to ascertain the impact that Chapter 4 imports have on the US dairy industry, particularly on such key variables as the producer price of milk, producer revenues, and CCC purchases of NDM.

Under our assumptions about substitutability among protein products, demand for MPCs by the non-dairy sector, (that is, what is considered in the model as final demand) must continue to be satisfied in the absence of imports. Hence, under this scenario, the US dairy sector must begin producing some quantity of MPCs. The nonfat solids required to produce MPCs domestically will come primarily from one of two sources: either more raw milk will be produced or skim milk will be diverted from production of some other product, most likely NDM, into MPC production. It is possible that some combination of both these effects will occur. The more that skim milk is diverted from other products such as NDM into MPC production; the lower will be the positive impact on the price of raw milk from prohibiting Chapter 4 imports. Conversely, if the supply of skim milk for MPC production derives substantially from an increase in the supply of raw milk, then the effect will be to increase the price of raw milk, *i.e.,* the price must increase in order to generate the required quantity response. Under this situation, the value of protein relative to the other components in milk will increase; an effect which will have the consequence of raising the price of milk for cheese manufacturers and therefore reducing cheese production. CCC purchases of NDM would be expected to decline under this scenario.

Both NDM and MPC production result in fat, or cream, as a by-product. Excess cream will be used to produce butter and to the extent that butter production increases, its price will decrease and this will feed back through the classified pricing formulas to have an offsetting (*i.e.,* negative) effect on the price of raw milk, although the net outcome of prohibiting Chapter 4 MPC imports may still be an increase in the price of raw milk.

PROPOSED TRQ, WITH AND WITHOUT COMPENSATION

The first policy option considered is the TRQ proposal currently before Congress. This calls for a quota of 34.9 million lbs (15,818 metric tons) on Chapter 4 MPCs, a rather trivial within quota tariff rate of 16.8 cents per 100 lbs (0.37 cents per kilogram), and a significantly greater over quota tariff rate of $70.76/100 lbs ($1.56 per kg). Similarly, the Chapter 35 TRQ specifies a quota of 119.2 million lbs (54,051 metric tons), a within quota tariff rate of 16.8 cents per 100 lbs, and an over quota tariff rate of $97.98/100 lbs, or $2.16 per kg. Unlike the Chapter 4 TRQ which applies only to MPCs, the Chapter 35 TRQ applies more broadly to milk proteins, *i.e.,* the sum of casein, caseinate, and MPC imports.

If imports over and above the quota amounts are successfully prevented, these proposed TRQs will represent a reduction from 2001 import levels of 44% or 27.9 million lbs in the case of

Chapter 4 MPCs, and 49% or 116.2 million lbs for Chapter 35 milk proteins. Apart from reductions in MPC processing costs and imposing the TRQs, the configuration of the model is the same as for the base scenario.

The imposition of a new TRQ in the US is likely to be challenged at the WTO by milk protein exporting countries. If such a complaint were made and upheld, it is likely that the WTO would insist that the US offer compensation to the affected parties. Consequently, in addition to the "without compensation" scenario just described, a second TRQ scenario is examined where the US must compensate affected milk protein exporters by offering increased market access for some other product. Specifically, we assume that the compensation takes the form of a proportional increase in the import quotas of the two cheese categories included in the model. This form of compensation is in keeping with the type of compensation scheme envisioned by the WTO. Alternative arrangements could conceivably extend to granting an aggrieved country market access in some entirely unrelated commodity. However, analysis of such arrangements is beyond the scope of this model.

The model predicts that when TRQs on milk protein products are imposed without compensation, the value of milk protein product imports declines by $347 million. Using the model-generated import supply prices from that scenario, *i.e.,* the price received by the aggrieved exporter, it is estimated that allowing an additional $347 million worth of cheese imports requires the following increases in import quotas: the cheddar cheese quota must be increased from 37 million lbs to 75.1 million lbs and the other cheese quota must be increased from 251.7 million lbs to 481.2. These changes in quota quantities permit an allowable increase in the value of cheese imports in proportion to the initial size of the import quotas.

The result of the TRQ without compensation scenario is expected to be similar to the previous scenario where only Chapter 4 imports were prohibited, *i.e.,* the direction of changes in key variables would be the same although the magnitudes may be more pronounced. On the one hand, the proposed TRQ reduces Chapter 4 imports by a lesser amount than the complete prohibition case. But on the other, it extends to a range of milk protein products, the Chapter 35 products, which were not restricted at all in the previous scenario. Because the volume of casein imports far exceeds that of Chapter 4 MPCs, and they are now to be subject to import restrictions, one would expect the quantitative impacts of this scenario to be somewhat greater than was the case where Chapter 4 imports were prohibited.

Whereas the TRQ places a limit on the overall level of Chapter 35 imports, relative price changes will determine how the import quota burden is shared amongst the individual Chapter 35 products. However, because the model is not configured to allow caseinate or Chapter 35 MPC production in the US, the demand prices for these products will not fall. In fact, unless casein carries the entire burden of the quota restriction, these prices will likely increase, leading to reduced imports and reduced demand.

Expected outcomes for the TRQ with compensation case are a little more difficult to anticipate. In the first instance, it is reasonable to expect cheese imports to increase dramatically and this will have the effect of lowering cheese prices, reducing cheese production, and depressing the value of protein. The impact on the price of fat, however, is difficult to predict and it could either mitigate or exacerbate the outcomes already outlined. For example, if the domestic production of MPCs and casein requires skim milk solids in greater quantities than are released by lower cheese production, then those nonfat solids will have to come from a whole milk source, and this will lead to excess cream and therefore a decrease in the price of butter and fat. On the other hand, lower cheese production, especially the lower fat content other cheese category, might deny the butter sector a source of fat which would lead to butter price increases. It is not possible to know a priori which of these two effects will dominate. This point reinforces the need to model the dairy sector in a manner that reflects the joint production possibilities of dairy processing, and recognizes the value and costs of dealing with by-products.

CASEIN AND MPC PRODUCTION SUBSIDIES

An alternative policy to address MPC imports is a domestic production subsidy[5]. Specifically, we assume that a per-unit subsidy is offered to processors of casein and MPC 42, the low-protein content MPC product. Apart from the subsidy on casein and MPC 42, and the lowered MPC processing costs, the configuration of the model for this scenario is identical to the base scenario.

The subsidy amount is calculated so that processors should be indifferent between selling NDM at 93.3 cents per lb (the CCC purchase price) and receiving the subsidy on casein or MPC 42 production at the US market and import prices observed in 2001[6]. Using the base scenario import prices of casein and MPC 42, the domestic price of NDM, and the respective yields of casein and MPC 42 from NDM, a cash subsidy of 98 cents per lb of casein and 6.3 cents per lb of MPC 42 is calculated. The arithmetic of the subsidy calculation depends on the relative composition of NDM vis-à-vis casein.

Whilst the composition of manufactured products in this model is endogenous and depends, in the case of casein and MPCs, on the composition of the skim milk from which it is made, casein contains about 92% protein (casein) and NDM about 34% protein, of which about 80% is casein. Hence the casein yield from one lb of NDM is 0.296, *i.e.,* (0.34*0.8)/0.92 = 0.296. The landed price of imported casein in the base scenario is $2.18/lb and the domestic market price of NDM is $0.93/lb. Thus, the NDM equivalent price at which US processors could afford to produce casein is $3.16/lb (*i.e.*, $0.93/0.296). The calculated subsidy is 3.16 - 2.18 = 0.98. If the figures are not rounded for the convenience of presentation, the subsidy is 97.7 cents per lb. No adjustment is made for any value that might attach to the lactose and other components in skim milk that are lost to the whey during the casein manufacturing process.

For MPC 42, the calculation is slightly different. When skim milk is used to produce MPCs, it is first ultrafiltered and then dried. The protein retention factor emanating from this process for MPC 42 has previously been calculated to be 98.25% (see Table B7, Appendix B). Thus, the MPC 42 yield from one lb of NDM is 0.795, *i.e.,* (0.34*0.9825)/0.42 = 0.795. The landed price of imported MPC 42 in the base scenario is $1.11/lb and with NDM at $0.93/lb, the NDM equivalent price at which US processors could afford to produce MPC 42 is $1.17/lb (*i.e.,* $0.93/0.795). Hence, the required subsidy is 1.17 - 1.11 = 0.06. In the absence of rounding, the subsidy is 6.3 cents per lb. As with the casein subsidy calculation, no adjustment is made for any value that might be derived from the permeate stream.

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[5] The Alliance for Western Milk Producers, for example, has floated the idea of using price support funds to subsidize the cost of producing and marketing MPC and casein in the US, http://www.dairyline.com/archives/2002/Mar2002.htm. In April 2004, legislation (H.R. 4223) was introduced to the House requiring the CCC to support, *i.e.*, subsidize, the development of a domestic casein and milk protein concentrate industry. The bill is currently with the House Committee on Agriculture.

[6] Note that use of observed prices may overstate the amount of the subsidy required to reduce imports to the extent that other market prices are influenced by the subsidy.

It is also possible to use the model structure to calculate the subsidy levels so that the import quantities of casein and Chapter 4 MPCs are identical to those arising under the TRQ without compensation scenario. Such subsidies are found to be 89 cents per lb for casein, 18.9 cents for MPC 42, 16.5 cents for MPC 56, and 21.8 cents per lb for MPC 70. Because the model is not configured to permit domestic production of caseinate or Chapter 35 MPCs, no TRQ equivalent subsidy is calculated for these two products. Thus, the subsidy levels that limit imports of MPC 42 and casein to the same amounts as the TRQs are larger than those required to stimulate domestic production of these products. Detailed results for this scenario are not reported.

Clearly the domestic production of casein and MPCs would be expected to rise with the aid of the subsidy (production of both products is zero in the base scenario). This in turn would tend to render protein more valuable, which would drive up the price of cheese. At the same time, it is likely to depress the butter price and therefore the value of fat as well, because cream, a by-product of both casein and MPC production, will be in excess supply.

Since the model permits no substitution between casein and NDM in final demand, nor does it allow casein to be used as an input within the dairy sector, the casein production subsidy would be expected to drive down the casein price and therefore increase the quantity demanded. Whether this draws skim away from NDM production, and thereby reduces CCC purchases of NDM, or drives up the price of raw milk to elicit a greater supply of raw milk will depend on the degree to which the CCC purchasing constraint is binding. In other words, if in the absence of the subsidy the unsupported price of NDM is well below the CCC purchase price, then it will take a considerable elevation of the underlying market price before it surpasses the purchase price level, at which point government purchases would cease.

BUTTER-POWDER TILT

The third policy option to be considered is a change in the tilt of the CCC purchase prices. These product purchase prices are determined such that the legislated milk price of $10.10 per cwt at 3.67% butterfat can be supported. However, by altering the relative weights given to the value of the fat and the non-fat components in milk, a range of product purchase prices can be determined, all consistent with the same milk support price. Some dairy industry analysts have argued that the Secretary of Agriculture should take a more aggressive stance towards tilting purchase prices whenever CCC purchases of NDM and MPC imports rise.

In the base scenario we use an NDM purchase price of 93.3 cents per lb and a butter price of 85.5. These are the average CCC purchase prices that prevailed in 2001, *i.e.,* the purchase prices were in fact tilted in May 2001. Under the tilt scenario we lower the NDM purchase price to 80 cents and raise the butter price to 105 cents per lb.

When the market price of NDM is equal to the CCC purchase price for NDM, the result of tilting prices as described above is easy to predict. NDM purchases by the CCC will go down and may even be driven to zero. But this will also cause the farm price of milk to unambiguously decline. Although a reduction in CCC purchases will generally be viewed as a positive outcome, a lower producer price will not be so universally applauded. Indeed, if it is argued that MPC imports are resulting in downward pressure on producer prices and increased government NDM purchases, then tilting may go some way to addressing the government purchasing problem, but it certainly will not raise the producer price of milk. The US may begin to produce MPCs under this scenario although such an outcome is by no means assured.

A NOTE ON MPC PROCESSING COSTS

The MPC processing costs are lower in all scenarios than they are for the base scenario. An ultrafiltration (UF) operation processing 10 million pounds of raw milk per month is assumed in the base scenario. This is a small scale operation and results in combined UF and drying costs sufficiently high that the model does not have the US producing MPC in the 2001 base case – the outcome actually observed in 2001.

A recent survey of operating costs in UF plants, albeit based on a very small sample, suggests that capacities of 50 to 60 million pounds per month would be required to fully exploit economies of scale (Mark Stephenson, Cornell Program on Dairy Markets and Policy, Cornell University, personal communication). We presume that as US dairy processors make greater use of ultrafiltration technology, the plants will get larger, the institutional knowledge associated with operating such plants will expand, and the per unit processing costs will decline.

Although the analysis undertaken with the model is of a comparative static nature, it is envisioned that the transition from the base scenario equilibrium to the counterfactual scenario equilibrium would play out over the medium term, *i.e.,* three to five years. Hence, under all but the base case scenario, we base the processing costs on a UF operation of 30 million pounds per month. As part of the sensitivity analysis, we lower the costs even further, basing them on a UF plant that processes 50 million pounds per month.

RESULTS AND DISCUSSION

OVERVIEW OF SCENARIO RESULTS

A broad overview of the results is provided by Tables 1 through 10. Additional results such as production levels and prices for all products are in Appendix D. The first point to note is that Chapter 4 MPC imports have a limited effect on the producer price of milk (Table 1). When MPC imports are prohibited, the overall all-milk price rises by $0.08/cwt. Increases are $0.09/cwt in the Other US region and $0.04/cwt in California. Producer revenues increase by $182 million, or about 0.7 percent. Cheddar cheese prices increase $0.02/lb, and butter prices fall about $0.07/lb. This fall in the butter price is due to the combined effects of an increase in demand for milk proteins, higher milk prices, a larger quantity of milk produced, and more butterfat available. Thus, the butter price must fall to clear the market. In this scenario (and others) an increase in the demand for domestic milk proteins typically results in additional milk production and a decrease in the butter price (Table 2). The decrease in the butter price and a powder price maintained at 93.3 cents/lb by the DPSP implies a decrease in the Class IV price, which will offset to some degree the increase in the Class III price associated with the higher cheese prices.

A key effect is the increase in demand for milk protein, which arises because there is continued demand for milk protein to make sales of NDM to the CCC. Note that CCC purchases of NDM decline by about 31 million lbs, but the skim milk made available by this cutback doesn't come close to being sufficient to produce the 483.3 million lbs of MPCs that the US produces and uses at cheese plants, let alone the MPC produced to satisfy final demands. The disinclination of skim milk to simply be diverted from NDM to MPC production is an outcome that is repeated to some extent in all of the scenarios except for the tilt. With the CCC purchase price of NDM at 93.3 cents/lb, demand for NDM by the CCC remains strong, despite the impacts in the MPC market. Under these conditions, skim milk does not simply divert from NDM production to MPC

Table 1. Model Results, by Scenario

Variable	Scenario					
	Base	No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
All-milk price, $/cwt						
Other US	15.26	15.35	15.44	15.13	15.60	15.03
California	13.79	13.83	13.95	13.63	14.47	13.42
All US	14.96	15.04	15.13	14.83	15.36	14.70
Producer revenues, $ million	24,762	24,944	25,144	24,465	25,675	24,180
Use in cheese plants, million lbs						
NDM	386.7	409.3	460.4	465.7	0.0	408.5
Chapter 4 MPCs	20.6	483.3	499.0	480.7	849.5	6.0
Wholesale product prices, $/lb						
Cheddar cheese	1.47	1.49	1.55	1.49	1.62	1.44
Butter	1.63	1.56	1.33	1.43	1.05	1.69
NDM	0.93	0.93	0.93	0.93	0.93	0.85
CCC purchases of NDM, mil. lbs.	259.9	229.1	115.4	63.3	253.0	0.0
Protein imports, million lbs						
Chapter 4 MPCs	76.4	0.0	34.9	34.9	60.2	38.9
Chapter 35 MPCs	15.3	15.3	13.2	13.2	15.3	15.3
Casein	135.8	135.8	32.6	32.5	21.2	135.8
Net govt. program costs[1], $mil.	309.3	295.0	191.3	111.7	514.7	49.8
Domestic sales, $ million	29,967	30,216	30,456	29,709	30,833	29,421

[1] Import tariff revenue less the cost of CCC purchases, export subsidies, and production subsidies (*i.e.,* Casein and MPC).

Table 2. Model Results, Change from Base Scenario

Variable	Base Scenario	Scenario				
		No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		(Change from Base Scenario)				
All-milk price, $/cwt						
Other US	15.26	0.09	0.18	-0.13	0.34	-0.23
California	13.79	0.04	0.16	-0.16	0.68	-0.37
All US	14.96	0.08	0.17	-0.13	0.40	-0.26
Producer revenues, $ million	24,762	182	382	-297	913	-582
Use in cheese plants, million lbs						
NDM	386.7	22.6	73.7	79.0	-386.7	21.8
Chapter 4 MPCs	20.6	462.7	478.4	460.1	828.9	-14.6
Wholesale product prices, $/lb						
Cheddar cheese	1.47	0.02	0.08	0.02	0.15	-0.03
Butter	1.63	-0.07	-0.30	-0.20	-0.58	0.06
NDM	0.93	0.00	0.00	0.00	0.00	-0.08
CCC purchases of NDM, mil. lbs.	259.9	-30.8	-144.5	-196.6	-6.9	-259.9
Protein imports, million lbs						
Chapter 4 MPCs	76.4	-76.4	-41.5	-41.5	-16.2	-37.5
Chapter 35 MPCs	15.3	0.0	-2.1	-2.1	0.0	0.0
Casein	135.8	0.0	-103.2	-103.3	-114.6	0.0
Net govt. program costs[1], $mil.	309.3	-14.3	-118.0	-197.6	205.4	-259.5
Domestic sales, $ million	29,967	249	489	-258	866	-546

[1] Import tariff revenue less the cost of CCC purchases, export subsidies, and production subsidies (*i.e.,* Casein and MPC).

production. In fact, when production of MPCs (or casein) is encouraged, the raw input is usually whole milk diverted from either cheese or fluid plants (or both), or from an increase in the raw milk supply. (This is discussed further subsequently.) In either case, when whole milk is used to make MPCs, excess cream results, which in turn has a depressing effect on the price of butter (Tables 2 and 7). This effect exists in all but the tilt scenario; the price of SNF never changes (because NDM is stuck at 93.3 cents) and the price of fat always declines. This translates into price increases for Class III and 4B milk (Table 9), *i.e.,* milk for cheese, and price decreases for Class IV and 4A, *i.e.,* butter-powder.

The policy of imposing new TRQs for milk protein products without compensation has effects qualitatively similar to those when Chapter 4 MPC imports are prohibited. As suggested previously, the quantitative impacts are larger than for the scenario prohibiting MPC imports because a wider range of imported milk protein products is affected by the TRQs. The all-milk price increases by $0.17/cwt, with roughly equal increases in California and the rest of the US (Table 2). Imports of MPCs and casein fall to roughly one-third of the level in the base scenario, and purchases of NDM by the CCC fall by more than 50%. Net government program costs fall by $118 million, or nearly 40%. When the imposition of TRQs is accompanied by compensation in the form of additional access for cheddar and other cheese imports, the all-milk price *decreases* compared to the base. This result arises because the increase in the cheese price is less than for the case without compensation due to increased access to imports, and therefore does not compensate for the decrease in the butter price of $0.20/lb. CCC purchases of NDM are markedly reduced, as are net government costs. The key point is that in this case TRQs will not make dairy producers better off if compensation is required.

Subsidies to US manufacturers of casein and MPCs have effects similar to those of TRQs without compensation. The US average all-milk price increases by $0.40/cwt, with larger increases in California than in the Other US region (Tables 1 and 2) Cheddar cheese prices increase, butter prices decrease, and milk protein product imports fall to about 40% of the amounts predicted in the base scenario. Thus, subsidies of the amounts assumed would be effective at addressing concerns about both farm milk prices and milk protein imports. In fact, they may be "too effective" given that processing costs would fall as MPC and casein manufacturers gain experience and process larger volumes, a smaller subsidy than those assumed would be necessary to make manufacturers indifferent between NDM production and casein or MPCs. Thus, the subsidies assumed for this analysis may overstate the need for subsidy, which is one reason that the cheese prices and all-milk prices increase more under this scenario than others. However, the subsidies would not reduce government expenditures; net government program costs would increase by about $205 million. This occurs largely because the production subsidies cost the government $192 million (Table 3), and the reduction in expenditures by the CCC on NDM is minimal (given the higher milk price and larger milk supply).

A change in the butter-powder tilt results in qualitatively different outcomes than the other policies. The tilt causes a lower all-milk price, lower cheese prices, and higher butter prices. Under the market conditions of 2001, the model predicts that NDM purchase price of $0.80/lb would eliminate purchases of NDM by the CCC. This reduces net government expenditures by nearly $260 million, largely due to changes in NDM purchases (Tables 2 and 3). This policy option is relatively less effective in reducing imports of milk protein products. Changing the tilt does reduce Chapter 4 MPC imports by about half, but it has essentially no impact on imports of casein, caseinates, or Chapter 35 imports.

Table 3. Government Dairy Program Revenue and Costs, by Scenario

Revenue or Cost	Scenario					
	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ With Compensation	Casein & MPC Subsidy	Tilt
Import tariff revenue						
Cheddar cheese	5.0	5.0	5.0	11.0	6.5	5.0
Other cheese	32.0	32.0	32.0	55.9	32.0	32.0
Butter	14.6	1.2	0.9	0.9	0.9	32.1
All other imports	4.8	4.4	3.7	4.1	3.0	4.5
Total	56.4	42.6	41.6	71.8	42.3	73.6
Production subsidies						
Casein	0.0	0.0	0.0	0.0	139.6	0.0
MPC 42	0.0	0.0	0.0	0.0	52.5	0.0
Total	0.0	0.0	0.0	0.0	192.1	0.0
CCC purchases of NDM	242.2	213.8	107.7	59.0	236.1	0.0
Export subsidies						
Cheddar cheese	3.6	3.6	3.6	3.6	3.6	3.6
Butter	3.6	3.9	5.2	4.5	8.9	3.4
NDM	116.3	116.3	116.3	116.3	116.3	116.3
Total	123.5	123.8	125.1	124.4	128.8	123.3
Total revenue	56.4	42.6	41.6	71.8	42.3	73.6
Total costs	365.7	337.6	232.8	183.5	557.0	123.3
Net costs[1]	309.3	295.0	191.2	111.7	514.7	49.8

[1] Import tariff revenue less the cost of CCC purchases, export subsidies, and production subsidies (*i.e.,* Casein and MPC).

All of the policies (TRQs, subsidies and Tilt) are at least somewhat successful at reducing milk protein imports; TRQs and subsidies lower them by about half on a protein basis (Table 4). They also result in the US producing MPCs, most of which is used in cheese plants. Of the three options most likely to be feasible (TRQs with compensation, subsidies, and tilt), the ultimate outcomes are either 1) higher producer prices and higher government costs, or 2) lower producer prices and lower government costs[7]. The scenarios can be ranked according to the change in the all-milk price (Table 5), which indicates that a subsidy program of the assumed amounts increases farm milk prices the most. Subsidies also have the highest producer price impact when adjusted for government costs, $0.28/cwt above the adjusted base price of $14.78/cwt. The rankings of the policy alternatives' impact on the all-milk price are the same with and without consideration of net of government dairy program costs (Table 5).

ESTIMATED REGIONAL IMPACTS

Although the model explicitly includes only two regions, it is important to consider potential regional differences in impacts of the various policy outcomes. A rough estimate of relative regional impacts can be constructed by assuming that the proportion of class utilization in each region remains the same as in 2001, and using the changes in predicted class prices under each of the policy scenarios to calculate a change in the blend price. This ignores the potential for changes in utilization that may occur, as well as changes in over-order premiums, but it provides some indication of how impacts may differ due to regional differences in class utilization. In all scenarios except the tilt, policies affecting milk protein product imports provide greater benefits to regions with high class III or class I utilization (or both; Table 6). For example, the estimated impact on the blend price of prohibiting Chapter 4 MPC imports is $0.23/cwt in the Upper Midwest (high Class III utilization) and $0.21/cwt in Florida (high Class I utilization). Similar but somewhat larger effects occur under the TRQ without compensation and subsidy scenarios, where the regions with higher Class III or I utilization gain most. Regions with Class I utilization gain because the Class III prices is the "higher of" and is therefore the mover for the Class I price. (If Class IV were the mover, regions with higher Class I utilization would see less benefit.) Perhaps more importantly, under the TRQ with compensation scenario, regions with higher Class III or I utilization are likely to see an overall increase the blend price, whereas other regions are likely to see lower blend prices (Table 6). The tilt scenario results in relatively equal decreases in blend prices across regions due to decreases in both the cheese and butter prices. Thus, as is the case for many other dairy policy issues, regional impacts will differ, and this is likely to influence how dairy producers in different regions view the policy options.

PRODUCT PRICES, COMPONENT VALUES AND CLASS PRICES

Key determinants of market outcomes are the classified pricing regimes in the FMMOs and California[8]. Although classified prices and product prices are determined simultaneously in the model, it is easiest to start with the product prices used to compute component values and commodity reference prices (Table 7). These results then feed into the determination of component prices by class (Table 8), which in turn are used to calculate class prices of raw milk, *i.e.,* the minimum price that processors in each class must pay for raw milk (Table 9).

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[7] The TRQ without compensation scenario will result in higher milk prices and lower government expenditures, but is unlikely to be feasible under the US' WTO obligations.

[8] The classified pricing arrangements are summarized in Appendix A.

Table 4. Protein in Imports and Domestically Produced Milk Proteins, by Scenario

Variable	Scenario					
	Base	No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
Protein in raw milk supply, mil lbs	5,131.3	5,140.4	5,151.1	5,115.3	5,180.9	5,099.4
	(As a % of protein in raw milk)					
Protein in Chapter 4 & 35 imports	5.0	4.2	2.5	2.5	2.8	4.7
Protein in NDM manufactured in the US	8.6	8.5	8.1	7.8	5.9	7.0
Protein in casein manufactured in the US	0.0	0.0	1.6	1.6	2.3	0.0
Protein in MPCs manufactured in the US	0.0	4.6	4.4	4.2	6.9	0.3
Protein in cheddar and other cheese, mil lbs	1,939.7	1,927.0	1,899.4	1,880.6	1,866.4	1,953.2
	(As a % of protein in cheese manufactured in the US)					
Protein in all Chapter 4 & 35 imports	13.3	11.3	6.7	6.8	7.7	12.2
Protein in imports retained in cheese	0.3	0.0	0.4	0.4	0.5	0.1
Protein in US NDM retained in cheese	5.1	5.4	6.2	6.3	0.0	5.3
Protein in US MPCs retained in cheese	0.0	7.9	7.9	7.7	13.8	0.0

Table 5. Scenarios Ranked According to All-Milk Price Impact

	All-Milk Only	All-Milk Price Net of Costs[1]
Base scenario, $/cwt	*14.96*	*14.78*
	(Change from Base Scenario, $/cwt)	
Subsidy on casein and MPC	+0.40	+0.28
TRQ without compensation	+0.17	+0.24
No Chapter 4 imports	+0.08	+0.09
TRQ with compensation[2]	-0.13	-0.02
Tilt	-0.26	-0.10

[1]All-milk price net of government dairy program costs, *i.e.* producer revenue + import tariff revenue - CCC purchases - production subsidies - export subsidies, all divided by the quantity of raw milk supplied.

[2] Compared with the base case scenario (see Table 2).

Finally, the class prices are weighted according to the utilization of milk in each class to yield blend prices, which, when added to the over-order premiums, give the all-milk price (Table 10). Tracking the changes in component values and utilization by scenario is useful in analyzing the mechanism by which the impact of each scenario is transmitted throughout the dairy marketing system.

It is also helpful to refer to the dual or first-order inequalities when disentangling the process by which a new equilibrium is attained following a shock. Wholesale product prices enter into the component price formulas. At the end of the classified pricing process, the blend price inclusive of over-order premiums emerges, which becomes the price that farmers respond to (*i.e.,* equation (24) in Appendix A). Also coming out of the classified pricing process is the minimum class price (at test) that processors must pay for milk. This price, when adjusted for the cost of shipping milk from supply points to plants, places a constraint on the basic milk fractions used at plants (equation (26) in Appendix A). In other words, if the class price declines, then this allows the value of the milk fractions, skim milk and cream, to decline as well. In fact, if a raw milk shipment occurs, then by complementary slackness, the value of the cream and the skim milk at the plant must decline too, as the condition would then hold as a strict equality. It is at this point that components are “reassembled” into manufactured dairy products according to the yield-based production functions and shipped out, either to another plant or to satisfy final demand[9].

[9] The relevant first-order conditions on this activity are equations (33) and (35) for intermediate products, and (34) and (37) for final products in Appendix A.

Table 6. Estimated Change in Regional Blend Price from Base Scenario

Marketing Area	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ With Compensation	Casein & MPC Subsidy	Tilt
FMMO Markets					
Northeast	0.12	0.30	-0.07	0.63	-0.39
Appalachian	0.12	0.30	-0.07	0.63	-0.39
Southeast	0.15	0.42	-0.01	0.88	-0.38
Florida	0.21	0.65	0.11	1.33	-0.36
Mideast	0.17	0.50	0.03	1.03	-0.37
Upper Midwest	0.23	0.74	0.15	1.50	-0.36
Central	0.20	0.61	0.08	1.24	-0.37
Southwest	0.17	0.50	0.03	1.03	-0.37
Arizona-Las Vegas	0.10	0.23	-0.10	0.51	-0.39
Western	0.11	0.28	-0.08	0.61	-0.39
Pacific Northwest	0.06	0.07	-0.18	0.19	-0.40
California	0.05	0.21	-0.11	0.59	-0.33

Note: Estimated regional changes in blend price equal the change in class price times the average annual class utilization in 2001, except for California, for which actual model results are reported. This calculation assumes constant proportional utilization, which is unlikely to be the case in the face of major policy changes for milk proteins.

Table 7. Product Prices and Derived Basic Component Values Used in Classified Pricing Formulas, Change from Base Scenario

Variable	Base Scenario	Scenario				
		No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		(Change from Base Scenario)				
National product prices, $/lb[1]						
Cheddar cheese	1.47	0.02	0.08	0.02	0.15	-0.03
Dry whey products	0.27	0.00	-0.02	-0.01	-0.02	-0.01
Butter	1.63	-0.07	-0.30	-0.20	-0.58	0.06
NDM	0.93	0.00	0.00	0.00	0.00	-0.08
California NDM price, $/lb[1]	0.93	0.00	0.00	0.00	0.00	-0.08
Component prices, $/cwt[2]						
Fat	185.01	-8.91	-36.74	-24.31	-71.04	6.76
SNF	77.78	0.00	0.00	0.00	0.00	-8.32
Protein	211.65	19.14	74.17	37.01	143.17	-18.30
Other SNF solids	13.70	0.00	-1.74	-1.05	-1.84	-0.73
Miscellaneous values used in California						
Commodity reference price, $/lb	1.49	0.02	0.06	0.01	0.13	-0.03
Commodity reference price (Cheese), $/lb	1.48	0.02	0.07	0.01	0.13	-0.03
Commodity reference price (Butter/powder), $/lb	1.49	-0.03	-0.13	-0.08	-0.24	-0.06
Class 4B product value, $/lb	1.33	0.02	0.07	0.01	0.14	-0.03
Class 1 carrier price, $/cwt	0.02	0.00	0.01	0.00	0.01	0.00

[1] FOB prices, at plants.
[2] Only relevant to the Other US region, *i.e.,* FMMOs.

Table 8. Component Values by Price Class, Change from Base Scenario

Variable	Base Scenario	Scenario: No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		(Change from Base Scenario)				
Fat price, $/cwt						
Class I	187.70	-8.91	-36.74	-24.31	-71.04	6.76
Class II	185.71	-8.91	-36.74	-24.31	-71.04	6.76
Class III	185.01	-8.91	-36.74	-24.31	-71.04	6.76
Class IV	185.01	-8.91	-36.74	-24.31	-71.04	6.76
Class 1	183.90	-8.80	-36.20	-24.00	-70.00	6.60
Class 2/3	182.60	-8.70	-36.10	-23.90	-69.90	6.70
Class 4B	178.80	-8.80	-36.10	-23.90	-69.90	6.70
Class 4A	178.80	-8.80	-36.10	-23.90	-69.90	6.70
SNF price, $/cwt						
Class II	85.55	0.00	0.00	0.00	0.00	-8.32
Class 1	77.90	4.10	16.70	7.90	32.70	-4.70
Class 2/3	85.60	0.00	0.00	0.00	0.00	-9.20
Class 4B	77.40	6.00	23.10	11.30	44.60	-5.80
Class 4A	78.50	0.00	0.00	0.00	0.00	-9.20
Skim price, $/cwt						
Class I	10.06	0.59	2.20	1.09	4.33	-0.61
Class II	7.70	0.00	0.00	0.00	0.00	-0.75
Class III	7.37	0.59	2.20	1.09	4.33	-0.61
Class IV	7.00	0.00	0.00	0.00	0.00	-0.75

Note: Classes I, II, III, and IV refer to the Other US region (FMMOs); Classes 1, 2/3, 4B, and 4A refer to California.

Table 9. Minimum Class Prices and Utilization, Change from Base Scenario

Variable	Base Scenario	Scenario: No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		(Change from Base Scenario)				
Class price, $/cwt[1]						
Class I	16.28	0.26	0.83	0.20	1.69	-0.35
Class II	13.93	-0.31	-1.29	-0.85	-2.49	-0.49
Class III	13.59	0.26	0.83	0.20	1.69	-0.35
Class IV	13.23	-0.31	-1.29	-0.85	-2.49	-0.49
Class 1	15.36	0.15	0.65	0.07	1.29	-0.31
Class 2/3	13.84	-0.31	-1.27	-0.84	-2.45	-0.57
Class 4B	12.99	0.22	0.75	0.15	1.44	-0.27
Class 4A	13.09	-0.31	-1.27	-0.84	-2.45	-0.57
Utilization, %						
Class I	37.52	-0.32	-0.65	-0.20	-1.13	0.27
Class II	7.90	-0.02	0.03	0.04	0.09	0.02
Class III	45.81	-5.11	-7.44	-7.77	-10.00	0.05
Class IV	8.78	5.45	8.06	7.93	11.04	-0.33
Class 1	19.04	-0.07	-0.25	0.05	-0.64	0.32
Class 2/3	4.61	0.02	0.09	0.10	0.13	0.15
Class 4B	54.68	0.36	3.41	4.42	8.61	3.09
Class 4A	21.67	-0.30	-3.25	-4.57	-8.10	-3.56

Note: Classes I, II, III, and IV refer to the Other US region (FMMOs); Classes 1, 2/3, 4B, and 4A refer to California.
[1] At standard test.

Table 10. Over-Order Premiums, Blend Prices, and All-Milk Price, Change from Base Scenario

Variable	Base Scenario	Scenario				
		No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		(Change from Base Scenario)				
OOPs, $/cwt						
Other US	0.37	0.00	-0.02	0.01	0.00	0.12
California	0.18	-0.01	-0.05	-0.04	0.10	-0.04
Blend price, $/cwt[1]						
Other US	14.59	0.11	0.26	-0.10	0.46	-0.37
California	13.50	0.06	0.25	-0.09	0.68	-0.34
Weighted average	14.37	0.10	0.26	-0.09	0.50	-0.36
Blend price, $/cwt[2]						
Other US	14.89	0.09	0.20	-0.14	0.33	-0.35
California	13.61	0.05	0.21	-0.11	0.59	-0.33
Weighted average	14.64	0.08	0.20	-0.13	0.38	-0.35
All-milk price, $/cwt[2]						
Other US	15.26	0.09	0.18	-0.13	0.34	-0.23
California	13.79	0.04	0.16	-0.16	0.68	-0.37
Weighted average	14.96	0.08	0.17	-0.13	0.40	-0.26

[1] At standard test.

[2] At actual test. The blend price at actual test plus OOPs equals the all-milk price.

COMPONENT REALLOCATION EFFECTS

A result that is observed repeatedly in all of these scenarios except the tilt is that skim milk generally does not divert from NDM production to MPC production, whenever some action is taken that encourages MPC production. In this section, the changes that take place at cheese plants under the subsidy scenario are examined closely and compared with the base scenario, in order to understand the how the joint production feature of the dairy sector manifests itself. Of particular interest are the inflows and outflows at cheese plants for both scenarios (Table 11).

Under the subsidy scenario, 849.5 million lbs of MPCs are used at cheese plants, up from 20.6 million lbs in the base scenario. Of the 849.5 million lbs, all but 2.8 of it are produced in the US. Yet CCC purchases of NDM decline by only 6.9 million lbs, *i.e.,* the skim milk for the MPC production clearly doesn't come out of the NDM being purchased by the CCC. The price of cheddar cheese increases by $0.15/lb, whereas the other cheese price increases by $0.14/lb under the casein and MPC subsidy scenario. This leads to a significant increase in the value of protein in the Other US region and in the SNF value in California (Tables 7 and 8) and with it the Class III and 4B price of milk (Table 9). The Class IV and 4A prices decline dramatically with the $0.58/lb drop in the butter price.

The dramatic increase in the price that cheese processors must pay results in a decrease in the amount of raw milk shipped to cheese plants. Specifically, raw milk flows into cheddar plants fall from 38,610 million lbs to 36,820 million lbs, or by 4.6%. Other cheese plants see a drop in raw milk in the intake of 21.4% (Table 11). The milk used to produce MPCs is being diverted from cheese plants, and Class I plants as well, as it happens. Because it is whole milk that is being sent to MPC plants, a large excess of cream is generated, which in turn depresses the butter price.

The policy also affects the amount of cream leaving other cheese plants. In the base scenario, 19.2% of the fat in raw milk entering other cheese plants is shipped away in the form of cream. Equivalently, of the fat in the cheese produced, 145.6% of that amount arrives at the plant in the form of raw milk (Table 11). But under the subsidy scenario, the shipment of cream away from other cheese plants ceases. Instead, dry protein in the form of MPC is added to the milk, *i.e.,* a high milk price coupled with a low fat value means that the way to exploit the low fat price is to add dry protein. 18.7% of the protein retained in the finished cheese comes from MPC 42, all of which was produced in the US. Similarly, at cheddar plants, 9.2% of the protein retained in the finished cheese comes from MPC 42, while the NDM that was being used in the base scenario at cheddar plants ceases to be so used.

These changes result in cheddar cheese production declining by 5.1%, slightly more than the 4.6% decline in raw milk received at plants. Although raw milk shipments to other cheese plants fell by 21.4%, cheese production only declined by 2.3%, *i.e.,* from 4,176 million lbs to 4,079 million lbs. There is also a regional shift in cheese production predicted (Appendix Table D4). Under the subsidy scenario Class III utilization falls by 10 percentage points, whereas in California the Class 4B utilization increases by nearly 9 percentage points (Table 9). Overall, cheese production decreases. The regional reallocation is a consequence of the different pricing formulas. Whereas the Class III price of milk increased in the Other US region by $1.69/cwt, the increase in the Class 4B price in California, while still dramatic, was only $1.44/cwt.

Table 11. Reallocation of Component Sources and Uses at Cheese Plants, Base Scenario Compared with Subsidy Scenario

Variable	Cheddar Cheese		Other Cheese	
	Base	Subsidy	Base	Subsidy
Raw milk to plants, million lbs	38,610	36,820	40,870	32,100
Fat in raw milk, million lbs	1,407	1,338	1,495	1,175
Protein in raw milk, million lbs	1,197	1,140	1,269	997
Cheese production, million lbs	3,922	3,720	4,176	4,079
Fat in cheese, million lbs	1,311	1,247	1,027	1,003
Protein in cheese, million lbs	1,000	949	940	918
	(As % of fat in all cheese produced)			
Fat in raw milk to plants	107.3	107.3	145.6	117.1
Fat in NDM retained in cheese[1]	0.2	–	–	–
Fat in US MPC 42 retained in cheese[1]	–	0.2	–	0.5
Fat in imported MPC 42 retained in cheese	0.0	0.0	–	–
	(As % of protein in all cheese produced)			
Protein in raw milk to plants	119.7	120.2	135.1	108.7
Protein in NDM retained in cheese[1]	9.8	–	–	–
Protein in US MPC 42 retained in cheese[1]	–	9.2	–	18.7
Protein in imported MPC 42 retained in cheese	0.6	0.9	–	–
	(As % of like component in cream shipped out of plants)			
Fat in raw milk received at plants	–	–	19.2	–
Protein in raw milk received at plants	–	–	1.1	–

Note: Retention factor for fat and protein in cheddar cheese vat is 0.93 and 0.749, respectively. At other cheese plants it is 0.85 and 0.749 for fat and protein, respectively.

[1]All such use was sourced from US plants.

The question still remains, however: why not simply divert skim milk from NDM into MPC production? The answer is straightforward: the CCC is holding up the price of NDM, making it worthwhile for processors to continue producing it (see the Class 4A SNF price and the Class IV skim price (Table 8); these prices don't change while the CCC is buying NDM). In fact, the Class IV and 4A prices drop because of the decrease in the butter price, and this means that milk for powder production is less expensive than before. Although the butter price has dropped, the combined return on butter and powder (NDM) given the lower milk price means that it is still profitable to satisfy the demands of the CCC. The tilt scenario, on the other hand, by allowing the price of NDM to fall does enable skim milk to divert away from NDM production, although not very much of it goes to MPC production, because little MPC is required. However, the tilt also lowers the producer price.

SENSITIVITY ANALYSES

MPC PROCESSING COSTS

As US processing plants begin to make greater use of ultrafiltration technology, it is reasonable to assume that per unit processing costs will decline. Already there are a number of plants in the US that operate ultrafiltration units in order to make use of ultrafiltered milk in the cheese vat, and a plant in New Mexico has recently begun drying ultrafiltered milk to make MPCs. Nevertheless, the use of ultrafiltration for cheese milk and MPC production is a relatively recent innovation. Thus, it is appropriate to examine the impacts of scenarios under alternative assumptions about MPC processing costs. As explained earlier, the processing costs for MPC production are based on an ultrafiltration plant capacity of 30 million lbs per month. The scenarios are now repeated, based on a plant capacity of 50 million lbs per month, *i.e.,* with lower MPC processing costs. This change lowers the processing cost for all of the MPC products. For example, the unit cost of processing one pound of dried MPC 42 decreases from 13 cents in the scenarios reported previously to 10 cents when UF plant utilization is increased to 50 million lbs per month.

With lower processing costs, MPC becomes even more preferred to NDM as a standardizing agent in cheese plants. Under the No Chapter 4 MPC imports scenario, overall effects are similar to those using higher MPC processing costs, but some subtle differences are worth noting. The all-milk price increases by somewhat less than with higher MPC processing costs, $0.06/cwt compared to $0.08/cwt (Table 12). In this case, however, there is an increase of $0.07/cwt in the other US and a decrease in California of $0.02/cwt. There is a smaller increase in the cheese price (due to a smaller increase in the Class III price and lower costs of producing and using MPCs in the cheese vat) and a smaller decrease in the butter price (due to less milk being produced, hence less butterfat). CCC purchases of NDM decline more with lower MPC processing costs, again due to less additional milk being produced.

Under the TRQ scenarios, the all-milk price increases by more (without compensation) and decreases by less (with compensation) when MPC processing costs are lower. This result is somewhat counter-intuitive based on conventional economic logic, which suggests that a decrease in processing costs should decrease cheese prices and milk prices, as noted in the previous paragraph. The effect of lower processing costs is to encourage additional domestic production of MPCs (especially for use in the cheese vat), despite the fact that lower processing costs are offset to a certain extent by an increase in the milk price and the protein price. On net there is a decrease in the price of domestically produced MPCs, a large decrease in NDM use in cheese making, and a small decrease in imports of high-protein MPCs. Overall, there is an increase in the demand for domestic proteins with the lower processing costs in the presence of the TRQs. The increase in domestic demand for milk proteins essentially drives the increase in the milk prices. Given the larger increase in demand for domestic proteins with lower processing costs, there is a larger decrease in the butter price, because the overall effect is to increase the all-milk price, milk supplies and cream. Greater milk supplies result in an increase in NDM purchases (without compensation) and a smaller decrease in NDM purchases (with compensation), thus increasing net government expenditures (Table 12). This scenario illustrates quite well the need for adequate product disaggregation to examine the effects of product-specific trade policy changes in the dairy industry.

Table 12. Model Results Using Lower MPC Processing Costs, Change from Base Scenario

Variable	Base Scenario	No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
		Scenario				
		(Change from Base Scenario)				
All-milk price, $/cwt						
Other US	15.26	0.07	0.28	-0.10	0.33	-0.22
California	13.79	-0.02	0.57	0.07	0.70	-0.35
All US	14.96	0.06	0.34	-0.06	0.40	-0.24
Producer revenues, $ million	24,762	122	761	-139	907	-543
Use in cheese plants, million lbs						
NDM	386.7	-386.7	-386.7	-386.7	-386.7	-119.8
Chapter 4 MPCs	20.6	300.8	821.1	813.6	829.7	96.5
Wholesale product prices, $/lb						
Cheddar cheese	1.47	0.01	0.13	0.05	0.15	-0.02
Butter	1.63	-0.02	-0.49	-0.38	-0.57	0.05
NDM	0.93	0.00	0.00	0.00	0.00	-0.08
CCC purchases of NDM, mil. lbs	259.9	-74.6	23.5	-45.3	-28.3	-259.9
Protein imports, million lbs						
Chapter 4 MPCs	76.4	-76.4	-41.5	-41.5	-27.2	-42.1
Chapter 35 MPCs	15.3	0.0	-2.1	-2.1	0.0	0.0
Casein	135.8	0.0	-103.1	-103.3	-113.7	0.0
Net govt. program costs1, $mil.	309.3	-62.9	41.0	-63.7	184.5	-256.2
Domestic sales, $ million	29,967	97	873	-119	830	-507

[1] Import tariff revenue less the cost of CCC purchases, export subsidies, and production subsidies (*i.e.* Casein and MPC).

The all-milk and product price results for the subsidy and tilt scenarios are quite similar to those with higher MPC processing costs. There are minor differences in CCC purchases of NDM with lower MPC processing costs. However, under the tilt scenario, there are marked shifts in the intermediate products used in cheese production. MPC use increased from 6.0 million lbs under higher processing costs to 117.1 million lbs under lower processing costs, and NDM use declined from 408.5 to 266.9 million lbs). In other words, MPC use increases relative to NDM when the price of NDM is not held above the market clearing price by the DPSP. Under these conditions, skim milk is diverted directly from NDM production into MPC production.

LOW PRICE MARKET CONDITIONS

It was noted previously that 2001 was a year in which the all-milk price was relatively high by historical standards. This then raises the question: how would the results differ had a period more representative of "typical" market conditions been used as the reference point for the base scenario?[10] This question can be examined using the model by shifting the raw milk supply curves to the right and repeating the analysis of each of the scenarios. Specifically, the raw milk supply functions are shifted such that the quantity supplied in each region increases by 5% over the base scenario. Total US milk production in 2002 was actually 2.6% greater than it was in 2001, although the state of California experienced a 5% year on year increase. Hence, an overall annual increase of 5% seems a reasonable test.

The Milk Income Loss Contract (MILC) program financially compensates dairy producers when milk prices fall below a specified level, and was introduced late in 2002 (see equations (71) and (72) in Appendix A). The all-milk price in 2002 was almost $3.00/cwt less than it was in 2001. Because the MILC program is now a feature of low price periods, we include it in the simulation to consider the impact of milk protein imports during times of low producer prices. The revised base scenario is labeled "Low Price Base" (Table 13). For the sake of comparison, the results for the original base scenario are shown as well. The low price base year results in an all-milk price of $13.12/cwt, $1.84/cwt lower than the regular base scenario. Compared to the 2001 scenario, producer revenues are 8% lower in the low base price year, cheddar cheese prices are $0.12/lb lower, and butter prices are $0.60/lb lower. CCC purchase of NDM are increased markedly, and net government program costs are nearly $1 billion larger than in the high price year, including $542 million in MILC payments. (It is important to not that higher government expenditures are not due to milk protein imports; they results from much larger NDM purchases and MILC payments. In fact, across all scenarios, imports of milk proteins barely change compared to when milk prices are much higher.) Thus, market conditions are much different in the low price base scenario than in the 2001 base scenario.

Despite the contrast in overall dairy market conditions, the impacts of milk protein concentrate imports and the policies designed to address them generally are similar in low price and high price years (Table 13). For example, prohibiting Chapter 4 MPC imports increases the US all-milk price $0.05/cwt in the low price year, which is just a bit lower than the $0.08/cwt in the 2001 base year. Similarly, milk and product prices increase under the TRQ without compensation scenario and subsidy scenario compared to the low price base, and decrease under the tilt scenario.

[10] It is not uncommon to hear US dairy market commentators lament that there is no longer such a thing as a "typical" year; prices seem to be permanently unpredictable.

Table 13. Results Under Low Milk Price Market Conditions, Change from Low Price Base Scenario

Variable	Base Scenario	Low Price Base Scenario	Scenario				
			No Chapter 4 MPC Imports	TRQ Without Compen-sation	TRQ With Compen-sation	Casein & MPC Subsidy	Tilt
			(Change from Low Base Price Scenario)				
All-milk price, $/cwt							
Other US	15.26	13.42	0.04	0.24	0.16	0.36	-0.42
California	13.79	11.96	0.05	0.32	0.22	0.40	-0.21
All US	14.96	13.12	0.05	0.26	0.18	0.37	-0.37
Producer revenues, $ million	24,762	22,788	89	516	335	750	-725
Use in cheese plants, million lbs							
NDM	386.7	1,110.3	-956.0	-954.3	-956.4	-1110.3	-671.1
Chapter 4 MPCs	20.6	24.9	745.7	728.6	729.2	862.7	-22.7
Wholesale product prices, $/lb							
Cheddar cheese	1.47	1.35	0.01	0.06	0.05	0.08	-0.06
Butter	1.63	1.03	-0.03	-0.12	-0.11	-0.14	0.39
NDM	0.93	0.93	0.00	0.00	0.00	0.00	-0.80
CCC purchases of NDM, mil. lbs	259.9	629.0	-63.6	-87.4	-99.8	-115.7	-437.5
Protein imports, million lbs							
Chapter 4 MPCs	76.4	80.5	-80.5	-45.6	-45.6	-19.6	-48.9
Chapter 35 MPCs	15.3	15.3	0.0	-2.1	-2.1	0.0	0.0
Casein	135.8	135.8	0.0	-102.9	-103.0	-113.1	-11.6
Net govt. program costs1, $mil.	309.3	1,248.8	-116.3	-352.4	-314.8	-246.0	-5.9
Domestic sales, $ million	29,967	28,305	64	494	309	538	-798

Note: All scenarios except the Base Scenario include MILC payments.

[1] Import tariff revenue less the cost of CCC purchases, export subsidies, production subsidies (*i.e.* Casein and MPC), and MILC payments.

However, there are three qualitatively important differences in the effects of the policy options when milk prices are lower. First, milk prices are higher under the TRQ with compensation than in the low price base scenario, which contrasts with the lower prices under this scenario when milk prices are higher. This increase results from the interaction of the TRQs for milk protein imports, the TRQs for other cheese and decreased incentives to import cheese when US cheese prices are lower. In the 2001 base scenario, the TRQ for other cheese (252 million lbs) is completely filled. In the low price base scenario, in contrast, the TRQ for other cheese is not filled. Only 193 million lbs of other cheese are imported because US cheese market prices are now $0.12/lb lower than in the 2001 base scenario. The TRQs imposed on milk protein products in the "TRQ without compensation" scenario increase US cheese prices by $0.07/lb, and imports of other cheese increase to completely fill the other cheese TRQ that was not binding in the low price base scenario. When the TRQ for both of the cheeses is increased to provide compensation in the "TRQ with compensation" scenario, there is only a small increase in other cheese imports compared to the increase when US milk supplies are tighter due to lower US market prices for cheese. The smaller amount of additional imports under the with compensation scenario results in much less negative impact on US cheese and Class III prices than in the 2001 scenarios, a smaller decrease in the butter price, and an increase in all-milk prices compared to the low price base scenario. Overall, our analysis suggests that the TRQ with compensation scenario benefits dairy producers under some dairy market supply and demand conditions, but not under others. In high price years, the policy will reduce all-milk prices relative to not having TRQs, and in low price years, the TRQs will be effective at increasing producer milk prices.

Second, the tilt scenario results in a larger reduction in milk prices when milk supplies are relatively plentiful. The reason for this is straightforward: under 2001 market conditions, the market for NDM reached an equilibrium at about $0.85/lb, whereas with the additional milk supplies, the market price is still being supported by the DPSP, with about 190 million lbs of NDM purchased by the CCC at a lower price of $0.80/lb.

Third, the effects of the scenarios on government expenditures are different when milk prices are lower. In contrast to the 2001 scenario, a casein and MPC production subsidy reduces government expenditures rather than increasing them. The production subsidies cost the government $192 million, but have the effect of reducing MILC payments by $350 million and CCC purchases of both NDM and butter by $209 million. Although this result is fortuitous in this case, in general it will be costly to simultaneously provide direct payments to producers (as in MILC) and to support prices through product purchase programs (DPSP). In general, the policy options result in larger reductions in net government costs when milk supplies are larger (*e.g.*, the reduction in government expenditures if MPC imports were prohibited is $14 million in the 2001 scenario and $116 million under lower milk prices). These larger reductions are primarily the result of the much higher level of government expenditure on CCC purchases and MILC in the low price base scenario. As a percentage of expenditures in the base case, the reductions are larger only for the scenarios banning Chapter 4 MPC imports and as mentioned, for the casein and MPC production subsidy. The percentage reduction in net government costs is lower for the TRQ scenarios, and is in fact minimal for the tilt scenario when milk supplies are large.

Finally, the pattern of domestic production of milk protein products is somewhat different compared with the earlier scenarios. Under the case where Chapter 4 MPC imports are prohibited, for example, 770.6 million lbs of MPCs are produced domestically and used in cheese plants; whereas earlier the comparable figure was 483.3 million lbs. The increased MPC use in cheese plants is at the expense of NDM.

SUPPLY AND DEMAND ELASTICITIES

Models of the type used for this research depend on previously-estimated elasticities to determine the price responsiveness of supply and demand behavior. We did not estimate any of the elasticities used in this research; they were either from the literature or, in the case of the import supply elasticities, assumed, as described in Appendix B. Different estimation techniques and data sets can give rise to a range of elasticity estimates all of which in principle reflect the same underlying behavior. The estimates selected for use in the present study are within the range that many economic researchers would consider reasonable. If there is any bias in the estimates, it is likely that the elasticity values used are too low, i.e., that the supply and demand elasticities are more inelastic than current reality. Use of more inelastic supply and demand curves would tend to cause our estimates of price impacts to be slightly exaggerated, due to the scope for greater price changes rather than quantity changes.

To assess the potential for bias in the results due to the elasticity estimates used, the model was run with a variety of elasticity values. For the purposes of this document, it suffices to discuss how outcomes of the policy scenarios varied when all supply and demand elasticities are increased by 50%. Under the scenario where Chapter 4 MPC imports were prohibited, for example, the overall all-milk price rose by $0.08/cwt. When all supply and demand elasticities, including import supply elasticities are increased by 50%, the overall all-milk price rises by just $0.04/cwt. Although this represents a 50% decline in the measured impact, it is half of a rather small quantity. Changes in wholesale product prices are generally within one cent of what was previously observed. CCC purchases of NDM are 221.5 million lbs, whereas when the elasticities were not increased by 50%, NDM purchases by the CCC were 229.1 million lbs, a minor difference. Imports of other milk protein products, *e.g.,* casein and Chapter 35 MPCs, scarcely changed when all elasticities were doubled. Findings such as these strongly suggest that our general conclusions do not hinge upon the choice of elasticity estimates.

SUBSTITUTION POSSIBILITIES

It is relevant to include a few additional remarks about the substitution possibilities amongst the protein products in the model. The model has been configured to allow NDM and MPC (MPC 42, MPC 56, and MPC 70) to be substitutes in intermediate uses, where relative protein values and intensities will determine the actual choice. Furthermore, MPC 42 and NDM are able to substitute for one another in final demand. However, as has previously been noted, we have no basis other than anecdotal evidence for setting parameters for demand quantities and cross-price elasticities for NDM and MPC 42 in final demand. For example, we do not know what share of the Chapter 4 MPC imports belong to each of the low, medium, and high protein categories. Nor do we know how much of each, if any, is used within the dairy processing system versus final uses. We don't even know with any certainty what the average protein content of each of the three Chapter 4 groupings ought to be. Fortunately, the assumptions used in for these quantities make no practical difference to the results of the scenarios. For instance, changing the low-medium-high shares from one third each to something like 10%-80%-10% or 60%-20%-20% or any number of other combinations makes a difference that is almost undetectable. Similarly, changing the high protein content from 70% to 80% or even 85% makes no discernable difference. This is an important result, because it indicates that detailed information about the types and uses of MPC imports *is not crucial to assessing their market impacts*.

The cross-price elasticity governing the substitution of NDM and MPC 42 in final demand is set at 0.5. This reflects our contention that NDM and low protein content MPCs, *i.e.,* MPC 42, are probably close substitutes. If the elasticity were set equal to one, then a 1% change in the price of NDM would be associated with a 1% change (in the same direction) in the demand for MPC 42. Running the model with this parameter set equal to one causes very little to change in any of the solutions. Some minor reallocation of NDM and MPC 42 takes place but literally nothing else changes. But this is in large part due to the binding CCC purchasing constraint, *i.e.,* the NDM price is unable to fall. Running the tilt scenario while setting the NDM-MPC 42 cross price elasticity equal to an unrealistically high value of 10, say, results in CCC purchases of about 227 million lbs of NDM, *i.e.,* the \$0.80/lb purchase price becomes binding, and MPC imports decline by about 25%. But once again, little else changes significantly, *e.g.,* wholesale product prices are within one cent or so of what they were using the cross-price value of 0.5.

One aspect of protein substitutability we have not explored is the degree to which NDM and some of the other milk protein products, *i.e.,* casein, caseinate, and the Chapter 35 MPCs, are able to be substituted for one another. Although our general knowledge of dairy processing practices enables us to be reasonably certain that these products are not used within the dairy manufacturing sector, at least not extensively, we have much less confidence about the applicability of their use in place of NDM in non-dairy uses. For this research we have assumed that these products are not able to be substituted with NDM. Unfortunately, there is presently no publicly available information to enlighten us. However, that should change in May 2004 when the result of a US International Trade Commission investigation into milk protein imports and uses is released.

CONCLUSIONS

THE RESEARCH PROBLEM AND FINDINGS

This research addresses two main questions: (a) what has been the impact on the US dairy sector of recent increases in MPC imports, and (b) in the event that policy makers seek to do something about MPC imports, what are the implications of policy options that might be employed?

A detailed policy model of the US dairy sector was constructed to answer these questions. The model was formulated and solved as a Mixed Complementarity Problem (MCP), facilitating the inclusion of features of the dairy sector that are crucially important to the MPC issue. Specifically, the model had to be capable of capturing the joint production characteristic of dairy processing. This was accomplished by representing milk and dairy products on a component basis. Fat, protein, and other nonfat solids were the three components used. Furthermore, explicit inclusion of these three basic milk components enabled them to be independently and simultaneously priced. This in turn permitted the classified pricing rules to be reliably modeled.

Regarding the first question, our model predicts that milk protein imports in the form of Chapter 4 MPCs have had a very modest impact on the US dairy sector. They have resulted in the all-milk price being at most about \$0.08/cwt lower than it otherwise would have been (although impacts in some regions will be larger). This is less than the observed monthly variation in the all-milk price, and is about 30 to 40 times less than the annual variation seen in recent years.

This suggests that the large variation in milk prices observed in the last 15 years has much more to do with the underlying dynamics of changes in farm milk supply and product demand than with milk protein imports (see Nicholson and Fiddaman, 2003). In 2001 terms, this represents an annual loss of about $180 million in producer revenue, about $70 million less than the savings to end users from having access to imported MPCs. The protein contained in Chapter 4 MPCs represents less than 1% of the protein contained in the US milk supply, so on that basis alone it is not surprising that the farm price impacts are relatively minor.

However, the more significant reason for the modest impact has to do with joint production. In the absence of MPC imports, and in the presence of a binding CCC purchase price for NDM, the US dairy sector would have to meet that demand for milk protein. It would do so by increasing milk supply a little and by diverting milk from other uses, primarily cheese production. In both cases, the end result would be the production of excess fat, which would decrease the price of butter and therefore have a depressing effect on the farm price of milk.

To some extent, MPC imports appear to play a balancing role in the protein market, *i.e.,* they enable the balance between the supply of and demand for milk proteins to be maintained without resulting in the production of unwanted fat, which has an all-milk price depressing effect. However, the overall the impact of MPC imports remains slightly negative so the market balancing argument is appropriate only up to a point.

We examine three policy options to address the impact of milk protein imports. The first is a tariff rate quota on casein and MPC products. Although it effectively curtails protein imports and results in an increase in the producer price, *i.e.,* $0.17/cwt, government purchases of NDM continue. However, such a policy is likely to be challenged and if cheese import quotas are increased in order to compensate aggrieved milk protein exporters, the producer price actually declines by $0.13. This comes about because the additional fat and protein that is able to enter the US in the form of cheese imports limits the protein price increase that the TRQ on milk proteins would otherwise bring about, and also causes the price of fat to go down. In the case of the TRQ without compensation, the protein price increase is sufficient to more than offset the fat price decline.

The second policy analyzed is a subsidy to encourage domestic production of protein products; MPCs and casein. Whereas it results in a producer price increase of $0.40/cwt, government purchases of NDM barely change and this adds to the cost of the program.

The final policy scenario is to alter the butter-powder price tilt. This successfully reduces imports of Chapter 4 MPCs by almost one half but also results in a lower producer price of milk. Therein lays the conundrum facing policy makers: what should be the response, if any, to the damage done by milk protein imports? Stated differently, is the problem to be defined as one of unwanted milk protein imports, low milk prices, or government expenditure? The policy responses can address some but not all of these concerns.

A key finding of this research is that any attempt to encourage MPC or casein production in the US will be subject to offsetting effects on milk prices if the NDM purchase price is high enough for purchases to occur. In these cases, skim milk will simply not divert from NDM production to MPC or casein. Instead, the protein products will be made from whole milk which results in excess fat, which in turn puts downward pressure on producer prices.

CONTRIBUTIONS AND LIMITATIONS OF THIS STUDY

This research has made a contribution in that the question of how MPC imports affect US dairy markets has been rigorously analyzed for the first time. The mechanism by which prices are determined and markets equilibrate in the dairy sector has been used to explain how a single component of milk cannot be treated in isolation. The joint production reality is inescapable: if milk production is somehow encouraged to increase in order to satisfy a demand for protein, then an excess of fat will ensue. These two outcomes will have opposing, although not necessarily equal, effects on the price of milk. Moreover, the difficulty of actually mitigating the impact has been highlighted. It is very difficult to design a policy response that is able to limit imports in a WTO-compliant manner, maintain the farm price of milk, and not increase the burden on taxpayers. However, this research would imply that it may not be necessary to do so, because the impact of Chapter 4 MPC imports on milk prices is small. Although a number of analysts have suggested that the impact is likely to be small (or even zero), the perception has persisted for several years now that MPC imports have been doing significant damage to the US dairy sector.

In addition to evaluating the impact of MPC imports more completely than previous research, a significant output of this research has been the construction of a new model of the dairy sector. The major innovation of this model is the yield-based production functions used to represent the processing of dairy products and explicit inclusion of product pricing formulas underlying classified pricing in FMMOs and California. Processing intermediaries use raw milk from producers and intermediate products from other dairy plants or from imported sources as inputs into the production process. The yield-based functions govern the manner in which the various inputs are combined to produce a mix of by-products, intermediate products, and final products. This approach has done away with the need for the usual fixed coefficients technology in this type of model. As a result, the model is easier to calibrate and is better able to be validated.

The model could be employed to address a wide range of US dairy policy issues. It could be also be further disaggregated and used to undertake analyses of regional policy and structural issues. In addition, more countries could be added to make it a useful tool for trade liberalization studies.

The addition of more countries would overcome the major weakness of the model – the trade sector. Presently the import supply curves are a relatively unsophisticated means of delivering imports to the US. The supply of imports is disconnected from factors that influence the supply those products in the exporting countries. The addition of more countries, each with their own set of supply and demand conditions and policies, would alleviate this problem.

FURTHER RESEARCH

It has already been noted that the US ITC will soon be releasing a study of how milk proteins are used in the US, both within the dairy sector and the broader food, beverage, and nutrition sector. The ITC study has benefited from the ability of the ITC to seek sources of information not normally collated and reported by any other federal agency. It may transpire that our assumptions regarding the absence of substitution possibilities between NDM and other milk protein products, besides Chapter 4 MPCs, is incorrect. If this is so, then it would be prudent to revise this work in light of that information, although we would anticipate no significant change to the findings. Further substitution possibilities would make the impact of milk protein imports on the dairy sector greater than is reported herein.

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APPENDIX A: DETAILS OF MODEL STRUCTURE

MATHEMATICAL SPECIFICATION OF THE EMPIRICAL MODEL

A detailed mathematical description of the MCP model is now presented. We begin by describing the sets or indices upon which the variables, parameters, and equations are defined. Table A1 shows the primary indices, whereas Table A2 reports the secondary indices, *i.e.,* subsets and mapping arrangements. All of the variables are then listed and defined, and following that the model's parameters are defined. Finally, we get to the algebraic specification of the model.

Table A1. Primary Indices on which the Model is Defined

Description	Symbol	Entities[1]
Region	I, J, K	Other US (OTH) California (CAL) Rest of World (ROW)
Products	P	Fluid milk (FLU) Ice cream (ICM) Yogurt (YOG) Cottage cheese (COT) Cheddar cheese (CHE) Other cheese (OCH) Dry whey products (DWH) Butter (BUT) Nonfat dry milk (NDM) Casein (CAS) Caseinate (CTE) Chapter 35 MPCs (MPC>90%) Evaporated, condensed and other dry products (ECD) Chapter 4 MPCs with 42% protein (MPC 42) Chapter 4 MPCs with 56% protein (MPC 56) Chapter 4 MPCs with 70% protein (MPC 70) Cream (CRM) Skim milk (SKM) Ice cream mix (MIX) Fluid whey (FWH) Buttermilk (BMK)
Milk components	C	Fat (F) Protein (P) Other nonfat solids (S)

Description	Symbol	Entities[1]
Milk pricing classes	CL	Other US: Class I (I) Class II (II) Class III (III) Class IV (IV) California: Class 1 (1) Class 2/3 (2/3) Class 4B (4B) Class 4A (4A)
Levels in TRQ schedule	QL	Within quota (W) Over quota (O)
Levels in export schedule	XL	Subsidized (D) Unsubsidized (U)

[1] Set element label in parentheses.

Table A2. Secondary Indices on which the Model is Defined

Description	Symbol	Entities[1]
US regions	US	OTH, CAL
Final products	FP	FLU, ICM, YOG, COT, CHE, OCH, DWH, BUT, NDM, ECD, CAS, MPC>90%, CTE, MPC 42, MPC 56, MPC 70
Intermediate products	IP	NDM, MPC 42, MPC 56, MPC 70, CRM, SKM, MIX, FWH, BMK
Raw milk receiving plants	REC	FLU, YOG, COT, CHE, OCH, NDM, ECD, CAS, MPC 42, MPC 56, MPC 70}
Basic milk fractions	BF	CRM, SKM
Cheese varieties	CHS	CHE, OCH
Chapter 35 products	C35	CAS, CTE, MPC>90%
Chapter 4 milk protein concentrate products	MPC	MPC 42, MPC 56, MPC 70
Fat	FAT	F
Protein	PRT	P
Solids not fat	SNF	P,S
Mapping of intermediate products to origin plants	IPFR	J-IP-FP
Mapping of interplant shipment possibilities	IPX	J′-J-IP-FP′-FP

VARIABLES

The conditions that restrict the range over which the variables are defined, *i.e.,* the secondary indices, are omitted from the variable descriptions as such conditions can be seen from the equation listing.

Table A3. Variable Definitions

Variable	Definition
QS_i	Quantity of milk supplied in supply region *i*.
$QSM_{j,p}$	Quantity of imports of intermediate and final product *p* supplied to the US by region *j*, the rest of the world.
$XRM_{i,j,fp,cl}$	Quantity of raw milk shipped from supply region *i* to plant type *fp* and class *cl* in region *j*. Product types map uniquely into class types.
$QMFSEP_{j,fp,ip}$	Quantity of basic milk fractions, cream and skim milk, separated from raw milk received at plant type *fp* in region *j*.
$QMFUSE_{j,fp,ip}$	Quantity of basic milk fractions, cream and skim milk, used at plant type *fp* in region *j*.
$QUSEMIX_{j,fp,ip}$	Quantity of basic milk fractions, cream and skim milk, used to make ice cream mix at NDM plants in region *j*.
$QIP_{j,ip,fp}$	Quantity of intermediate product *ip* produced at plant type *fp* in region *j*.
$QFP_{j,fp}$	Quantity of final product *fp* processed in region *j*.
$XIP_{j,j',ip,fp,fp'}$	Quantity of intermediate product *ip* shipped from plant type *fp* in region *j* to plant type *fp'* in region *j'*.
$XIPM_{j,j',p,fp,ql}$	Quantity of imported intermediate product *p* shipped from region *j* to plant type *fp* in region *j'* under quota level *ql*.
$XFP_{j,k,fp}$	Quantity of final product *fp* shipped from region *j* to demand region *k*.
$XFPM_{j,k,p,ql}$	Quantity of imports of final product *p* shipped from region *j* (the rest of the world) to US demand region *k* under quota level *ql*.
$XFPX_{j,k,fp,xl}$	Quantity of exports of final product *fp* shipped from US region *j* to rest of world demand region *k* under export subsidy regime *xl*.
$XFPG_{j,fp}$	Quantity of final product *fp* shipped from region *j* to the CCC under the dairy price support program.
$QD_{k,fp}$	Quantity of final product *fp* demanded in demand region *k*.
PS_i	Marginal value of raw milk at supply point *i*.
$PMFS_{j,fp,ip}$	Marginal value of cream and skim milk at point of separation in plant type *fp* in region *j*.
$PMFU_{j,fp,ip}$	Marginal value of cream and skim milk at the point they are processed into manufactured products at plant type *fp* in region *j*.
$PMIXUSE_j$	Marginal value of cream and skim used in ice cream mix in region *j*.
$PMIXSPEC_{j,fp}$	Marginal value of the required composition of ice cream mix in region *j*.
$PFPLT_{j,fp}$	Marginal (internal) value a unit of manufactured product at plant type *fp* in region *j*. This is the value before processing costs are applied.

Variable	Definition
$PFPLT_{j,fp}^{BMK}$	Marginal value of buttermilk at butter plant in region *j*.
$PMINREQ_{j,c,fp}$	Marginal value of the minimum composition requirement on component *c* in product type *fp* in region *j*.
$PIPFOB_{j,ip,fp}$	Wholesale price (ex plant) of intermediate product *ip* produced at plant type *fp* in processing region *j*.
$PFPFOB_{j,fp}$	Wholesale price (ex plant) for final product *fp* in processing region *j*.
$PSM_{j,p}$	Supply price of imported intermediate or final product.
$PEXS_{fp,xl}$	Marginal value of quantitative restriction on subsidized exports of product *fp* under export subsidy level *xl*.
$PFPCIF_{k,fp}$	Wholesale price (cif) for final product *fp* in demand region *k*.
$PQR_{p,ql}$	Price of the import quota constraint (*i.e.,* a quota rental value) on product type *p* under quota level *ql*.
$PQR4_{ql}$	Price of the (proposed) import quota constraint on Ch. 4 MPC imports under quota level *ql*.
$PQR35_{ql}$	Price of the (proposed) import quota constraint on Ch. 35 milk protein imports (casein, caseinates, and MPCs) under quota level *ql*.
$PRFAT$	Price of butterfat as determined by the FMMO pricing formulas.
$PRSNF$	Price of SNF as determined by the FMMO pricing formulas.
$PRPROT$	Price of protein as determined by the FMMO pricing formulas.
$PROS$	Price of other nonfat solids as determined by the FMMO pricing formulas.
$PRFATCL_{j,cl}$	Class price of butterfat in region *j*.
$PRSKMCL_{j,cl}$	Class price of skim milk in region *j* (not relevant in California).
$PRSNFCL_{j,cl}$	Class price of SNF in region *j*.
$CRPCH_{j}$	Commodity reference price for cheese from California pricing formulas.
$CRPBP_{j}$	Commodity reference price for butter/powder from California pricing formulas.
CRP_{j}	Commodity reference price for Class 1 from California pricing formulas.
$PVCL4B_{j}$	Class 4B product value price from California pricing formulas.
$PCL1CAR_{j,cl}$	Class 1 fluid carrier price from California pricing formulas.
$PRCLA_{j,cl}$	Minimum class price for class *cl* in region *j* at actual test.
$PRCLS_{j,cl}$	Minimum class price for class *cl* in region *j* at standard test.
$OOPD_{j}$	Over-order premium (or deduct) in processing region *j*.
$PCLASSA_{j,cl}$	Actual cost to processors of milk used class *cl* in region *j* at actual test, including premiums or deducts.
$PCLASSS_{j,cl}$	Actual cost to processors of milk used class *cl* in region *j* at standard test, including premiums or deducts.
$PBLENDA_{j}$	Blend price of milk in region *j* at actual test.
$PBLENDS_{j}$	Blend price of milk in region *j* at standard test.

Variable	Definition
$BLACT_j$	Blend price including over-order premiums in region *j* at actual test. This is the all-milk price in region *j*.
$TOTUTIL_j$	Total utilization of cream, skim milk, and interplant shipments in region *j*.
$CLASSUTIL_{j,cl}$	Utilization of cream, skim milk, and interplant shipments by class *cl* in region *j*.
DP_j	Direct payments under MILC program per cwt of milk in region *j*.
PEM_j	Proportion of milk in processing region *j* eligible for direct payments.

PARAMETERS

Table A4. Parameter Definitions

Parameter	Definition
$\rho_{j,ip}$	Milk fraction (cream and skim milk) share parameter in region *j*, *i.e.,* the volume of cream and skim, respectively, separated from a unit of raw milk.
$\delta_{j,ip}$	Share parameters for cream and skim milk, respectively, when combined to make ice cream mix.
$\theta^{RM}_{i,c}$	Proportion of component *c* in raw milk in milk supply region *i*.
$\theta^{IP}_{j,c,ip}$	Proportion of component *c* in intermediate product *ip* in region *j*.
$\theta^{H_2O}_{j,ip}$	Moisture content of intermediate product *ip* in region *j*.
$\theta^{H_2O}_{j,fp}$	Moisture content of final product *fp* in region *j*.
$\theta^{SALT}_{j,fp}$	Salt content of final product *fp* in region *j*.
θ^{CS}_{j}	Total solids content in concentrated skim milk in region *j*.
$\psi\, j,c,fp$	Retention factor of component *c* used when processing final product *fp* in region *j*.
$\gamma_{j,fp,c}$	Required minimum proportion of component *c* in final product *fp* processed in region *j*.
$xvol_{fp,xl}$	Quantitative restriction on subsidized exports of final product *fp* under export subsidy level *xl* (set *xl* contains two levels – subsidized and unsubsidized). There is no effective restriction on unsubsidized exports.
$qlvl_{p,ql}$	Import quota quantity for (intermediate or final) product *p* under TRQ regime *ql*.
$qlvl4_{ql}$	Import quota quantity for (intermediate or final) Chapter 4 MPC imports under TRQ regime *ql*.
$qlvl35_{ql}$	Import quota quantity for Chapter 35 protein imports (casein, caseinates, and MPCs) under TRQ regime *ql*.
α_i	Inverse raw milk supply parameter in region *i*.
ε_i	Raw milk supply flexibility in region *i*.
$\kappa_{j,p}$	Parameter in inverse import supply function.
$\lambda_{j,p}$	Import supply function flexibility for product *p*.
$\beta_{k,fp}$	Inverse wholesale demand parameter for final product *fp* in region *k*.
$\eta_{k,fp}$	Final product *fp* demand flexibility in region *k*.
σ^{NM}_{k}	Cross-price elasticity between NDM and MPC 42 in final demand in region *k*.
$tcas_{i,j,fp}$	Per unit transportation cost of assembling raw milk from region *i* at plant type *fp* in region *j*.
$tcip_{j,j',ip,fp,fp'}$	Per unit transportation cost of shipping intermediate products from plant type *fp* in region *j* to plant type *fp'* in region *j'*.

Parameter	Definition
$tcfp_{j,k,fp}$	Per unit transportation cost of distributing final product *fp* from processing region *j* to demand region *k*.
$pcip_{j,ip}$	Per unit cost of processing intermediate product *ip* in region *j*.
$pcfp_{j,fp}$	Per unit cost of processing final product *fp* in region *j*.
$psub_{j,p}$	Per unit production subsidy on (intermediate and final) product *p* in region *j*.
$xsub_{fp,xl}$	Per unit export subsidy for final product *fp* under export subsidy level *xl*.
$tar_{p,ql}$	Per unit import tariff on product *p* under quota level *ql*.
$\tau_{p,ql}$	Ad valorem import tariff on product *p* under quota level *ql*.
$cldiff_{j,cl}$	Class differentials by region.
$cccpp_{fp}$	CCC purchase price for product *fp*.
$propem_j$	Initial proportion of milk in region *j* eligible to receive direct payments.
$qs0_i$	Reference quantity of raw milk supply by region.

EQUATIONS AND INEQUALITIES

The equations and inequalities that comprise the MCP model can be grouped into four classes:

1) Primal or quantity-based inequalities;
2) Dual or value-based inequalities (more or less the first-order conditions of the underlying optimization nonlinear program, for the parts of the model where such an optimization problem exists);
3) Inequality constraints on price variables;
4) A set of strict equalities that define the classified pricing formulas in both the Federal Milk Marketing Orders (FMMOs), *i.e.,* the Other US region, and in California.

The inequalities and equations in each of these four classes are now listed. A brief description follows each algebraic expression. Each inequality is uniquely paired with its complementary variable, which is shown in square brackets. The algebraic expressions in the fourth group, the strict equalities, require no complementary variable.

PRIMAL INEQUALITIES

$$QS_i \geq \sum_{j \in US} \sum_{fp \in REC} \sum_{cl} XRM_{i,j,fp,cl} \quad \forall i \in US \tag{1}$$

Raw milk assembly [PS_i]: The quantity of raw milk supplied at region *i*, *QS*, must be at least as great as the sum of all shipments, *XRM*, from the supply region to processing plants in region *j*. Plants are defined according to the type of final product they produce as well as the price classification under the relevant classified pricing regime, *cl*.

$$\rho_{j,ip} \left(\sum_{i \in US} \sum_{cl} XRM_{i,j,fp,cl} \right) \geq QMFSEP_{j,fp,ip} \quad \forall j \in US, fp \in REC, ip \in BF \tag{2}$$

Volume of milk fractions separated from raw milk [$PMFS_{j,fp,ip}$]: The basic milk fractions are cream and skim milk. The amount of raw milk received at a plant multiplied by the basic milk fraction share parameter, ρ , is greater than or equal to the volume of each fraction separated, *QMFSEP*. The share parameters are calculated using an independent system of simultaneous equations, solving for the volume and composition of the cream and skim milk fractions assuming the separated cream contains 40% butterfat and the composition of the raw milk is known. If the model was more spatially disaggregated, leading to the possibility of raw milk arriving at plants from multiple supply locations, each with milk of a different composition, then the share values would need to be determined endogenously.

$$\begin{aligned} &QMFSEP_{j,fp,ip} \geq QMFUSE_{j,fp,ip} + QUSEMIX_{j,fp=NDM,ip=MIX} + \\ &QIP_{j,fp,ip} \quad \forall j \in US, fp \in REC, ip \in BF \end{aligned} \tag{3}$$

Volume of milk fractions used at the receiving plant [$PMFU_{j,fp,ip}$]: The cream and skim milk separated at plants can either be used for processing into a final product at that plant, *QMFUSE*, or it can be shipped away to be used at some other plant, *QIP*. In the case of NDM plants, the cream and skim milk may also be used to prepare ice cream mix, *QUSEMIX*. This constraint says that the quantity of cream and skim milk separated at a plant must be at least as great as the sum of the quantities used in final products, to make ice cream mix, and that which is shipped to other plants.

$$QUSEMIX_{j,fp=NDM,ip=CRM} + \left(\frac{\left(1-\theta_{j,ip=SKM}^{H_2O}\right)}{\theta_j^{CS}} \right) QUSEMIX_{j,fp=NDM,ip=SKM} \geq QIP_{j,ip=MIX,fp=NDM} \quad \forall j \in US \tag{4}$$

Determine the volume of ice cream mix [$PMIXUSE_j$]: The volume of cream and concentrated skim milk used to produce ice cream mix at NDM plants must be greater than or equal to the volume of ice cream mix produced. This is nothing more than a conservation of mass balance constraint. Concentrated skim milk is calculated as the volume of skim milk used in ice cream mix times one minus the water content of skim milk divided by the exogenously specified desired total solids content of the concentrated skim milk.

$$QUSEMIX_{j,fp,ip\in BF} \geq \delta_{j,ip\in BF} \cdot QIP_{j,ip=MIX,fp} \quad \forall j \in US, fp = NDM \tag{5}$$

Determine the composition of ice cream mix [$PMIXSPEC_{j,fp}$]: The proportions of cream and skim milk combined to generate ice cream mix are selected such that the finished ice cream has a predetermined fat content. This equation constrains the previous one to ensure that at NDM plants, the correct proportions, δ, of cream and skim milk are combined when manufacturing ice cream mix. The value of δ is calculated using an independent system of simultaneous equations and is based on the desired fat content of the ice cream mix (volume basis), which in turn yields ice cream of the desired fat content.

Equations 6 through 14 are production functions that determine the yield of manufactured products. The complementary variable in each case is $PFPLT_{j,fp}$. While there are subtle differences in these functions across the various products, in essence they state that whatever comes into a plant, be it cream or skim milk separated at the plant, or shipments of intermediate products from some other plant, or imported dry ingredients such as MPC, either the combined volume of those inputs or the combined quantity of the milk components contained in those inputs, will determine the output yield. Most of these production functions relate to final products. However, in the case of NDM and MPCs, the production process used to produce the intermediate product form is identical to that of the final product form. Hence the production functions for NDM and MPCs relate to both intermediate and final product manufacturing. We have already seen the process by which the intermediate products cream, skim milk, and ice cream mix are produced. The production of the remaining intermediate products, fluid whey and buttermilk, is strictly tied to the production of the respective final products for which these two intermediate products are by-products.

$$\left(\begin{array}{l} \sum_{ip \in BF} QMFUSE_{j,fp,ip} \\ + \sum_{j' \in US} \sum_{ip} \sum_{fp'} XIP_{j',j,ip,fp',fp} \\ + \sum_{j'=ROW} \sum_{ip} \sum_{ql} XIPM_{j',j,ip,fp,ql} \end{array} \right) \geq QFP_{j,fp} \quad \forall j \in US, fp \in \{FLU, ICM, YOG\} \tag{6}$$

Fluid milk, yogurt, and ice cream production [$PFPLT_{j,fp}$]: The yield of these products is quite straightforward and is simply based on volume. While the input mix may be different in each case, the production of the final product, *QFP*, is determined by the volume of the inputs processed at each of the plants. The available inputs include cream or skim milk separated and used at the plant, *QMFUSE*, shipments into the plant of intermediate products, *XIP*, or shipments into the plant of imported intermediate products, *XIPM*.

$$\left(\frac{\begin{array}{l} \sum_{ip \in BF} \sum_{c} \left(\theta^{IP}_{j,c,ip} \cdot QMFUSE_{j,fp,ip} \right) \\ + \sum_{j' \in US} \sum_{ip} \sum_{fp'} \sum_{c} \left(\theta^{IP}_{j',c,ip} \cdot XIP_{j',j,ip,fp',fp} \right) \\ + \sum_{j'=ROW} \sum_{ip} \sum_{c} \sum_{ql} \left(\theta^{IP}_{j',c,ip} \cdot XIPM_{j',j,ip,fp,ql} \right) \end{array}}{(1 - \theta^{H_2O}_{j,fp})} \right) \geq QFP_{j,fp} \quad \forall j \in US, fp = COT \tag{7}$$

Cottage cheese production [$PFPLT_{j,fp}$]: The output of cottage cheese, *QFP*, relates to the quantity of components used to produce the cottage cheese. Specifically, the quantity of components in the cream and skim milk, *QMFUSE*, plus the components in the interplant shipments or imported ingredients received, *XIP* and *XIPM*, respectively, all divided by one minus the moisture content of cottage cheese must be at least as great as the quantity of cottage cheese produced.

$$\left(\frac{\begin{array}{l} \sum_{ip \in BF} \sum_{c} \left(\psi_{j,c,fp} \cdot \theta^{IP}_{j,c,ip} \cdot QMFUSE_{j,fp,ip} \right) \\ + \sum_{j' \in US} \sum_{ip} \sum_{fp'} \sum_{c} \left(\psi_{j,c,fp} \cdot \theta^{IP}_{j',c,ip} \cdot XIP_{j',j,ip,fp',fp} \right) \\ + \sum_{j'=ROW} \sum_{ip} \sum_{c} \sum_{ql} \left(\psi_{j,c,fp} \cdot \theta^{IP}_{j',c,ip} \cdot XIPM_{j',j,ip,fp,ql} \right) \end{array}}{(1 - \theta^{H_2O}_{j,fp})} \right) \geq QFP_{j,fp} \quad \forall j \in US, fp \in CHS \tag{8}$$

Cheddar and other cheese production [$PFPLT_{j,fp}$]: The production functions for cheddar and other cheese are identical in all but one respect to the production structure just described for cottage cheese. The one difference is that not all of the milk components delivered to a cheese plant find their way into the final product. Hence, it is necessary to adjust the input composition parameters by a retention factor, ψ. In other words, only the components retained in the final cheese enter into the cheese yield calculation. All dairy components not retained are sent to a dry whey plant in the form of the intermediate product fluid whey.

$$\left(\frac{\begin{array}{l} \sum_{fp' \in \{CHS,CAS,MPC\}} \sum_{ip \in BF} \sum_{c} \left(\left(1-\psi_{j,c,fp'}\right) \theta^{IP}_{j,c,ip} \cdot QMFUSE_{j,fp',ip} \right) \\ + \sum_{j' \in US} \sum_{ip} \sum_{fp''} \sum_{fp' \in CHS} \sum_{c} \left(\left(1-\psi_{j,c,fp'}\right) \theta^{IP}_{j',c,ip} \cdot XIP_{j',j,ip,fp'',fp'} \right) \\ + \sum_{j'=ROW} \sum_{ip} \sum_{fp' \in CHS} \sum_{c} \sum_{ql} \left(\left(1-\psi_{j,c,fp'}\right) \theta^{IP}_{j',c,ip} \cdot XIPM_{j',j,ip,fp',ql} \right) \end{array}}{(1-\theta^{H_2O}_{j,fp})} \right) \tag{9}$$

$$\geq QFP_{j,fp} \quad \forall j \in US, fp = DWH$$

Production of dry whey products [$PFPLT_{j,fp}$]: The quantity of components not retained in cheese, casein, or MPC produced in the US divided by one minus the moisture content of dry whey products must be equal to or greater than the quantity of dry whey products produced. No casein or MPC is actually produced in the US in the base case scenario. Strictly speaking, unlike with cheese and casein, the production of MPC does not result in whey as a by-product. However, because the dry whey products category contains a mixture of different whey protein and lactose based products, we treat the lactose-rich permeate from MPC production as if it were fluid whey and direct it to the dry whey plants for further processing.

$$\left(\frac{\sum_{j' \in US} \sum_{ip=CRM} \sum_{fp'} \sum_{c=F} \left(\psi_{j,c,fp} \cdot \theta^{IP}_{j,c,ip} \cdot XIP_{j',j,ip,fp',fp} \right)}{(1-\theta^{H_2O}_{j,fp} - \theta^{SALT}_{j,fp}) \cdot \left(1 - \theta^{H_2O}_{j,fp} \left(\frac{\theta^{IP}_{j,c=SNF,ip=CRM}}{\theta^{H_2O}_{j,ip=CRM}} \right) \right)} \right) \geq QFP_{j,fp} \quad \forall j \in US, fp = BUT \tag{10}$$

Butter production [$PFPLT_{j,fp}$]: Butter plants in the model are unable to receive raw milk. Hence, the cream from which butter, and the buttermilk by-product, is produced must be shipped into the butter plant. In reality, butter plants are usually located next to powder plants, the main source of cream for butter making, and much of the cream is typically therefore received by pipeline rather than by road or rail shipments. Nevertheless, the quantity of butter produced is less than or equal to one minus the fat retained from the cream divided by one minus the water and salt content of the butter multiplied by an adjustment factor for the nonfat solids retained in the serum fraction of butter.

$$\begin{array}{l} \sum_{j' \in US} \sum_{ip'=CRM} \sum_{fp'} XIP_{j',j,ip',fp',fp} \geq \\ QFP_{j,fp} \cdot \left(1 - \theta^{SALT}_{j,fp}\right) + QIP_{j,ip=BMK,fp} \quad \forall j \in US, fp = BUT \end{array} \tag{11}$$

Buttermilk production [$PFPLT^{BMK}_{j,fp}$]: Buttermilk is produced as a by-product of the butter making process. The yield function for butter milk is volume based, and simply says that the volume of cream used to make butter less the amount of butter produced adjusted for its salt content yields the volume of buttermilk. Note that equation 11 and its complementary variable, $PFPLT_{j,fp}^{BMK}$, is a special case of the variable *PFPLT*, and applies only to the intermediate product buttermilk, which is produced at butter plants.

$$\left(\frac{\sum_{ip=SKM} \sum_{c} \left(\theta_{j,c,ip}^{IP} \cdot QMFUSE_{j,fp,ip} \right)}{(1-\theta_{j,fp}^{H_2O})} \right) \geq QFP_{j,fp} + QIP_{j,ip=NDM,fp} \quad \forall j \in US, fp = NDM \tag{12}$$

NDM production [$PFPLT_{j,fp}$]: The total quantity of NDM, as either a final product or an intermediate product, produced at an NDM plant is less than or equal to the components in the skim milk used at the plant divided by the moisture content of the NDM.

$$\left(\frac{\sum_{ip \in BF} \sum_{c} \left(\theta_{j,c,ip}^{IP} \cdot QMFUSE_{j,fp,ip} \right) + \sum_{j' \in US} \sum_{ip} \sum_{fp'} \sum_{c} \left(\theta_{j',c,ip}^{IP} \cdot XIP_{j',j,ip,fp',fp} \right)}{(1-\theta_{j,fp}^{H_2O})} \right) \geq QFP_{j,fp} \quad \forall j \in US, fp = ECD \tag{13}$$

Production of evaporated, condensed, and other dried products [$PFPLT_{j,fp}$]: The quantity of evaporated, condensed or dried products processed at a plant, *QFP*, can be no more than the quantity of components in the cream and skim milk used at the plant, plus the components in the interplant shipments received at the plant all divided by one minus the moisture content of the final product.

$$\left(\frac{\sum_{ip=SKM} \sum_{c} \left(\psi_{j,c,fp} \cdot \theta_{j,c,ip}^{IP} \cdot QMFUSE_{j,fp,ip} \right)}{(1-\theta_{j,fp}^{H_2O})} \right) \geq QFP_{j,fp} + QIP_{j,ip=MPC,fp} \quad \forall j \in US, fp \in \{CAS, MPC\} \tag{14}$$

Casein and MPC production [$PFPLT_{j,fp}$]: The quantity of components in the skim milk that are actually retained in the casein divided by one minus the moisture content of casein is greater than or equal the quantity of casein produced. The function for MPC production is the same as for casein except that the output includes both intermediate and final product forms.

$$\sum_{ip \in BF} \sum_{c} \left(\psi_{j,c,fp} \cdot \theta_{j,c,ip}^{IP} \cdot QMFUSE_{j,fp,ip} \right) +$$
$$\sum_{j' \in US} \sum_{ip} \sum_{fp'} \sum_{c} \left(\psi_{j,c,fp} \cdot \theta_{j',c,ip}^{IP} \cdot XIP_{j',j,ip,fp',fp} \right) +$$
$$\sum_{j'=ROW} \sum_{ip} \sum_{c} \sum_{ql} \left(\psi_{j,c,fp} \cdot \theta_{j',c,ip}^{IP} \cdot XIPM_{j',j,ip,fp,ql} \right) \geq \gamma_{j,fp,c} \cdot QFP_{j,fp}$$
$$\forall j \in US, fp \ni \gamma_{j,fp,c} > 0, c \in C \qquad (15)$$

Required minimum composition standards [$PMINREQ_{j,c,fp}$]: Minimum composition requirements for some components are imposed on the production process for certain products. For example, fluid milk in California must contain at least 12% total solids. The constraint only applies in cases were the required minimum proportion, γ, is defined to be greater than zero. It requires that for the particular component in question, the amount retained and used in the final product must be at least as much as the specified minimum.

$$QIP_{j,ip,fp} \geq \sum_{j'} \sum_{fp'} XIP_{j,j',ip,fp,fp'} \quad \forall j \in US, ip \in IP, fp \in FP \qquad (16)$$

Interplant shipment conservation of flows [$PIPFOB_{j,ip,fp}$]: The quantity of an intermediate product produced at a plant must be greater than or equal to the total amount of all shipments of that product to all other plants and regions.

$$QFP_{j,fp} \geq \sum_{k \in US} XFP_{j,k,fp} + \sum_{k=ROW} \sum_{xl} XFPX_{j,k,fp,xl} + XFPG_{j,fp} \quad \forall j \in US, fp \in FP \qquad (17)$$

Final product shipment conservation of flows [$PFPFOB_{j,fp}$]: The quantity of a final product produced at a plant must be greater than or equal to the total amount of all shipments to demand regions of that product.

$$QSM_{j,p} \geq \sum_{j' \in US} \sum_{fp} \sum_{ql} XIPM_{j,j',p,fp,ql} + \sum_{k \in US} \sum_{xl} XFPM_{j,k,p,ql} \quad \forall j = ROW, p \in P \qquad (18)$$

Supply of imported products balance [$PSM_{j,p}$]: The quantity of each product supplied to the US by the rest of the world, whether it be for intermediate or final uses, must be at least as great as the sum of the shipments of each product, regardless of which level, *ql*, of the import quota regime the imports came in under.

$$xvol_{fp,xl} \geq \sum_{j \in US} \sum_{k=ROW} XFPX_{j,k,fp,xl} \quad \forall fp \in FP, xl \in XL \qquad (19)$$

Quantitative restriction on subsidized US exports [$PEXS_{fp,xl}$]: Like many other countries, the US has made commitments to the WTO to limit the quantity of exports that it will assist with export subsidies. This constraint ensures that US dairy exports do not exceed those limits, *xvol*, in cases where such limits exist.

$$\sum_{j\in US} XFP_{j,k,fp} + \sum_{j=ROW}\sum_{ql} XFPM_{j,k,fp,ql} + \sum_{j\in US}\sum_{xl} XFPX_{j,k,fp,xl} \geq QD_{k,fp} \quad \forall k, fp \in FP \tag{20}$$

Final product shipments to demand [$PFPCIF_{k,fp}$]: The quantity of final product demanded at a demand location can be no more than the sum of all final product shipments to that demand location. The variable *XFPM* is only defined for shipments from the rest of the world to the US, while *XFPX* is only defined for shipments from US processors to rest of the world demand locations.

$$qlvl_{p,ql} \geq \sum_{j=ROW}\sum_{jj\in US}\sum_{fp} XIPM_{j,jj,p,fp,ql} + \sum_{j=ROW}\sum_{k\in US} XFPM_{j,k,p,ql} \quad \forall p \in P, ql \in QL \tag{21}$$

Import quota on all imported products [$PQR_{p,ql}$]: The sum of the quantities of imported intermediate and final products under import quota level *ql* (within- and over-quota) must be less than or equal to the quota amount, *qlvl*. The parameter *qlvl* is set arbitrarily high for products not subject to import quotas.

$$qlvl4_{ql} \geq \sum_{j=ROW}\sum_{j'\in US}\sum_{ip\in MPC}\sum_{fp} XIPM_{j,j',ip,fp,ql} + \sum_{j=ROW}\sum_{k\in US}\sum_{fp\in MPC} XFPM_{j,k,fp,ql} \quad \forall ql \in QL \tag{22}$$

Chapter 4 MPCs import quota [$PQR4_{ql}$]: While not effective in the base solution, this constraint enables an import quota, *qlvl4*, to be imposed on Chapter 4 MPC imports.

$$qlvl35_{ql} \geq \sum_{j=ROW}\sum_{j'\in US}\sum_{ip\in C35}\sum_{fp} XIPM_{j,j',ip,fp,ql} + \sum_{j=ROW}\sum_{k\in US}\sum_{fp\in C35} XFPM_{j,k,fp,ql} \quad \forall ql \in QL \tag{23}$$

Chapter 35 milk protein import quota [$PQR35_{ql}$]: This constraint enables an import quota to be applied to Chapter 35 milk proteins, *i.e.,* casein, caseinate, and MPCs. As with the preceding constraint, it is not effective in the base case.

DUAL OR FIRST-ORDER INEQUALITIES

$$\alpha_i \cdot QS_i^{\varepsilon_i} \geq \frac{\sum_{j \in US} \sum_{fp \in REC} \sum_{cl} \left(BLACT_j + DP_j \right) XRM_{i,j,fp,cl}}{\sum_{j \in US} \sum_{fp \in REC} \sum_{cl} XRM_{i,j,fp,cl}} \quad \forall i \in US \tag{24}$$

Inverse raw milk supply function [QS_i]: The blend price at actual test, including over-order premiums, plus direct payments (under MILC) in region *j* weighted by all milk shipments from the region determine the quantity of raw milk supplied in region *i*.

$$\kappa_{j,p} \cdot QSM_{j,p}^{\lambda_{j,p}} \geq PSM_{j,p} \quad \forall j = ROW, p \in P \tag{25}$$

Inverse import supply for dairy products imported by the US [$QSM_{j,p}$]: The price in the rest of the world of the imported supply of product *p* must be less than or equal to the value of the inverse supply function for the quantity of the imported product supplied by the rest of the world.

$$PCLASSA_{j,cl} + tcas_{i,j,fp} \geq \sum_{ip \in BF} \left(\rho_{j,ip} \cdot PMFS_{j,fp,ip} \right) \qquad \forall i, j \in US, fp \in REC, cl \in CL \tag{26}$$

Zero profit condition on raw milk shipments [$XRM_{i,j,fp,cl}$]: The delivered milk cost (minimum classified price at actual test for class *cl* plus over-order premiums plus raw milk assembly costs) from supply region *i* to plant type *fp* in processing region *j* must be greater than or equal to the (internal) value of cream and skim separated from the raw milk received.

$$PMFS_{j,fp,ip} \geq PMFU_{j,fp,ip} \quad \forall j \in US, fp \in REC, ip \in BF \tag{27}$$

Zero profit condition on milk separation [$QMFSEP_{j,fp,ip}$]: The internal value of cream and skim separated at plant type *fp* is greater than or equal to the internal value of cream and skim used at that plant.

Equations 27 through 34 are the zero profit conditions on the use of milk fractions where in each case the complementary variable is $QMFUSE_{j,fp,ip}$. While the structure of the yield function varies by product type, in essence these conditions state that the internal value of cream and skim used at plant type *fp* must be greater than or equal to the internal unit value of the product at that plant times the amount of product produced.

$$PMFU_{j,fp,ip} \geq PFPLT_{j,fp} + \sum_{c} \left(PMINREQ_{j,fp,c} \cdot \psi_{j,c,fp} \cdot \theta_{j,c,ip}^{IP} \right) \qquad \forall j \in US, fp \in \{FLU, YOG\}, ip \in BF \tag{28}$$

$$PMFU_{j,fp,ip} \geq$$

$$PFPLT_{j,fp}\left(\frac{\sum_{c}\theta^{IP}_{j,c,ip}}{\left(1-\theta^{H_2O}_{j,fp}\right)}\right)+\sum_{c}\left(PMINREQ_{j,fp,c}\cdot\psi_{j,c,fp}\cdot\theta^{IP}_{j,c,ip}\right) \quad (29)$$

$$\forall j \in US, fp \in \{COT, NDM, ECD\}, ip \in BF$$

$$PMFU_{j,fp,ip} \geq$$

$$PFPLT_{j,fp}\left(\frac{\sum_{c}\left(\psi_{j,c,fp}\cdot\theta^{IP}_{j,c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp}\right)}\right)+\sum_{c}\left(PMINREQ_{j,fp,c}\cdot\psi_{j,c,fp}\cdot\theta^{IP}_{j,c,ip}\right) \quad (30)$$

$$\forall j \in US, fp \in \{CHS, CAS, MPC\}, ip \in BF$$

$$PMFU_{j,fp,ip} \geq$$

$$PFPLT_{j,fp'=DWH}\left(\frac{\sum_{c}\left(\left(1-\psi_{j,c,fp}\right)\theta^{IP}_{j,c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp'=DWH}\right)}\right)+\sum_{c}\left(PMINREQ_{j,fp,c}\cdot\psi_{j,c,fp}\cdot\theta^{IP}_{j,c,ip}\right) \quad (31)$$

$$\forall j \in US, fp \in \{CHS, CAS, MPC\}, ip \in BF$$

$$PMFU_{j,fp,ip} \geq PMIXSPEC_{j,fp,ip} + PMIXUSE^{CRM}_{j,ip=MIX,fp} +$$
$$PMIXUSE^{SKM}_{j,ip=MIX,fp}\left(\frac{\left(1-\theta^{H_2O}_{j,ip=SKM}\right)}{\theta^{CS}_{j}}\right) \quad \forall j \in US, fp = NDM, ip \in BF \quad (32)$$

Zero profit condition on manufacturing of ice cream mix at NDM plants [$QUSEMIX_{j,fp,ip}$]: The internal value of cream and skim milk used in ice cream mix must be greater than or equal to the value of the minimum component content constraint for ice cream mix plus the value of cream used in ice cream mix plus the value of concentrated skim used in ice cream mix.

$$PMFU_{j,fp,ip\in BF} + \delta_{j,ip'\in BF}\cdot PMIXSPEC_{j,fp=NDM,ip'\in BF} + pcip_{j,ip} - psub_{j,ip} +$$
$$PMIXUSE_{j,ip=MIX,fp=NDM} + PFPLT_{j,fp\in\{NDM,MPC\}} + \quad (33)$$
$$PFPLT^{BMK}_{j,fp=BUT} \geq PIPFOB_{j,ip,fp} \quad \forall j, ip, fp \in IPFR$$

Zero profit condition on processing of intermediate products [$QIP_{j,ip,fp}$]: The internal value of the milk fractions cream and skim milk used at plant type *fp* plus the processing costs and less production subsidies must be greater than or equal to value of the product at the plant.

$$PFPLT_{j,fp} + PFPLT^{BMK}_{j,fp=BUT}\left(1-\theta^{SALT}_{j,fp=BUT}\right) + pcfp_{j,fp} - psub_{j,fp} + \sum_c \left(\psi_{j,fp,c} \cdot PMINREQ_{j,fp,c}\right) \geq PFPFOB_{j,fp} \quad \forall j \in US, fp \in FP \tag{34}$$

Zero profit condition on processing of final products [$QFP_{j,fp}$]: The internal value of the product at plant type *fp* plus the value attributed to the minimum component composition requirement plus the unit processing cost less production subsidies must be greater than or equal to the fob price of product *fp* at that plant.

$$\begin{aligned}
& PIPFOB_{j',ip,fp} + tcip_{j',j,ip,fp',fp} \geq \\
& PFPLT_{j,fp=\{FLU,ICM,YOG\}} + PFPLT^{BMK}_{j,fp=BUT} + \\
& \frac{PFPLT_{j,fp=\{COT,ECD\}} \cdot \sum_c \theta^{IP}_{j',c,ip}}{\left(1-\theta^{H_2O}_{j,fp=\{COT,ECD\}}\right)} + \\
& \frac{PFPLT_{j,fp=CHS} \cdot \sum_c \left(\psi_{j,c,fp=CHS} \cdot \theta^{IP}_{j',c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp=CHS}\right)} + \\
& \frac{PFPLT_{j,fp=DWH} \cdot \sum_c \left(\left(1-\psi_{j,c,fp=CHS}\right)\theta^{IP}_{j',c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp=DWH}\right)} + \\
& \frac{PFPLT_{j,fp=BUT} \cdot \sum_c \left(\psi_{j,c=F,fp=BUT} \cdot \theta^{IP}_{j',c=F,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp=BUT} - \theta^{SALT}_{j,fp=BUT}\right)\left(1-\theta^{H_2O}_{j,fp=BUT} \cdot \theta_{j,c=SNF,ip=CRM} \big/ \theta^{H_2O}_{j,ip=CRM}\right)} + \\
& \sum_c \left(\psi_{j,fp,c} \cdot PMINREQ_{j,fp,c} \cdot \theta^{IP}_{j',c,ip}\right) \qquad \forall j', j, ip, fp', fp \in IPX
\end{aligned} \tag{35}$$

Zero profit condition on the shipment of intermediate products between plants [$XIP_{j,j',ip,fp,fp'}$]: The value of an intermediate product at its plant of origin plus transportation costs must be greater than or equal to the internal unit value of the product processed that makes use of the intermediate product at the receiving plant, times the yield of the product, plus the value of constraint on the composition of the product.

$$
\begin{aligned}
& PSM_{j',p}\left(1+\tau_{p,ql}\right)+PQR_{p,ql}+PQR4_{ql}+PQR35_{ql}+tar_{p,ql} \geq \\
& PFPLT_{j,fp=\{FLU,ICM,YOG\}} + \\
& \frac{PFPLT_{j,fp=COT}\cdot\sum_{c}\theta^{IP}_{j',c,ip}}{\left(1-\theta^{H_2O}_{j,fp=COT}\right)} + \\
& \frac{PFPLT_{j,fp=CHS}\cdot\sum_{c}\left(\psi_{j,c,fp=CHS}\cdot\theta^{IP}_{j',c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp=CHS}\right)} + \\
& \frac{PFPLT_{j,fp=DWH}\cdot\sum_{c}\left(\left(1-\psi_{j,c,fp=CHS}\right)\theta^{IP}_{j',c,ip}\right)}{\left(1-\theta^{H_2O}_{j,fp=DWH}\right)} \\
& \sum_{c}\left(\psi_{j,fp,c}\cdot PMINREQ_{j,fp,c}\right) \quad \forall j'=ROW, j\in US, p\in IP, fp\in FP, ql\in QL
\end{aligned} \tag{36}
$$

Zero profit condition for the shipment of intermediate product imports to the US [$XIPM_{j,j',p,fp,ql}$]: The price of an imported intermediate product at its location of origin times the *ad valorem* tariff rate plus the value of quota rents plus any specific tariffs must be greater than or equal to the internal unit value of the product processed that makes use of the intermediate product at the receiving plant times the yield of the product, plus the value of constraint on the composition of the composition of the product.

$$
PFPFOB_{j,fp}+tcfp_{j,k,fp} \geq PFPCIF_{k,fp} \quad \forall j,k\in US, fp\in FP \tag{37}
$$

Zero profit condition on shipments of final products [$XFP_{j,fp}$]: The ex-plant price of product *fp* in region *j* plus distribution costs to demand region *k* must be greater than or equal to the demand price of the product at demand region *k*.

$$
\begin{aligned}
& PSM_{j,p}\left(1+\tau_{p,ql}\right)+PQR_{p,ql}+PQR4_{ql}+PQR35_{ql}+tar_{p,ql} \geq \\
& PFPCIF_{k,p} \quad \forall j=ROW, k\in US, p\in FP
\end{aligned} \tag{38}
$$

Zero profit condition of final product imports into the US [$XFPM_{j,k,p}$]: The price of an imported final product at its location of origin times the *ad valorem* tariff rate plus the value of quota rents plus any specific tariffs must be greater than or equal to the landed price of the product at demand region *k*.

$$
\begin{aligned}
& PFPFOB_{j,fp}-xsub_{fp,xl}+PEXS_{fp,xl} \geq PFPCIF_{k,fp} \\
& \qquad \forall j\in US, k=ROW, fp\in FP
\end{aligned} \tag{39}
$$

Zero profit condition on exports from the US [$XFPX_{j,k,fp}$]: The ex-plant price of a final product to be exported less the per unit export subsidy plus the value of the quantitative constraint on subsidized exports, if one exists, must be greater than or equal to the demand price of the product in the ROW.

$$PFPCIF_{k,fp} \geq \begin{cases} \beta_{k,fp} \cdot QD_{k,fp}^{\eta_{k,fp}}; & \forall k \in K, fp \in FP \neq \{NDM, MPC\ 42\} \\ \beta_{k,fp} \left(QD_{k,fp} \cdot PFPCIF_{k,fp'}^{-\sigma_k^{NM}} \right)^{\eta_{k,fp}}; & \\ & \forall k \in K, fp \neq fp' \in \{NDM, MPC\ 42\} \end{cases} \quad (40)$$

Inverse demand function [$QD_{k,fp}$]: The demand price of final product *fp* in region *k* must be greater than or equal to the inverse demand relationship, where *QD* is the quantity demanded. Note that all demands are functions of own price, except for NDM and MPC 42 which include cross price terms in addition to the own price response.

CONSTRAINTS ON PRICE VARIABLES

$$PFPFOB_{j,fp} \geq cccpp_{fp} \quad \forall j \in US, fp \in FP \quad (41)$$

CCC purchasing constraint [$XFPG_{j,fp}$]: For butter, NDM and cheddar cheese, the ex-plant price must be at least as much as the price at which the CCC will purchase, *i.e., cccpp*.

CLASSIFIED PRICING RULES

Conditions specific to the Other US region, i.e., FMMO formulas:

$$PRFAT = \frac{1}{0.82} \left(\left(\frac{\sum_{j \in US} \sum_{fp=BUT} \left(PFPFOB_{j,fp} \cdot QFP_{j,fp} \right)}{\sum_{j \in US} \sum_{fp=BUT} QFP_{j,fp}} \right) - 11.5 \right) \quad (42)$$

The butterfat price is equal to the weighted average wholesale price of butter less a make allowance divided by a yield factor.

$$PRSNF = \frac{1}{1.02} \left(\left(\frac{\sum_{j \in US} \sum_{fp=NDM} \left(PFPFOB_{j,fp} \cdot QFP_{j,fp} \right)}{\sum_{j \in US} \sum_{fp=NDM} QFP_{j,fp}} \right) - 14.0 \right) \quad (43)$$

The SNF price is equal to the weighted average wholesale price of nonfat dry milk less a make allowance divided by a yield factor.

$$PRPROT = 1.405\left(\left(\frac{\sum_{j\in US}\sum_{fp=CHE}\left(PFPFOB_{j,fp}\cdot QFP_{j,fp}\right)}{\sum_{j\in US}\sum_{fp=CHE} QFP_{j,fp}}\right)-16.5\right)$$
$$+1.28\left(1.582\left(\left(\frac{\sum_{j\in US}\sum_{fp=CHE}\left(PFPFOB_{j,fp}\cdot QFP_{j,fp}\right)}{\sum_{j\in US}\sum_{fp=CHE} QFP_{j,fp}}\right)-16.5\right)-PRFAT\right) \quad (44)$$

The protein price is a function of the weighted average wholesale price of cheddar cheese adjusted by the value of butterfat, and taking into account the make allowance and a yield factor.

$$PROS = \frac{1}{0.968}\left(\left(\frac{\sum_{j\in US}\sum_{fp=DWH}\left(PFPFOB_{j,fp}\cdot QFP_{j,fp}\right)}{\sum_{j\in US}\sum_{fp=DWH} QFP_{j,fp}}\right)-14.0\right) \quad (45)$$

The other solids (*i.e.,* nonfat and non-protein) price is equal to the weighted average wholesale price of dry whey less a make allowance and divided by a yield factor.

$$PRFATCL_{j,cl} = PRFAT + cldiff_{j,cl} \quad \forall j = OTH, cl \in CL \quad (46)$$

This equation specifies how the price of fat for each class is determined.

$$PRSKMCL_{j,cl} = \begin{cases} MAX\left[PRSKMCL_{j,cl=III}, PRSKMCL_{j,cl=IV}\right] + cldiff_{j,cl}; \\ \qquad\qquad\qquad\qquad \forall j = OTH, cl = I \\ PRSKMCL_{j,cl=IV} + cldiff_{j,cl}; \quad \forall j = OTH, cl = II \\ 0.01\left(3.1\cdot PRPROT + 5.9\cdot PROS\right); \quad \forall j = OTH, cl = III \\ 0.09\cdot PRSNF; \quad \forall j = OTH, cl = IV \end{cases} \quad (47)$$

This equation specifies the price of skim milk by class under the FMMO pricing formulas.

$$PRSNFCL_{j,cl} = 0.09\cdot PRSKMCL_{j,cl} \quad \forall j = OTH, cl = II \quad (48)$$

This equation specifies how the Class II price of SNF is determined.

$$PRCLA_{j,cl} = PRSKMCL_{j,cl}\left(\frac{\sum_{i=US}\sum_{fp\in FP}\left(\left(1-\theta^{RM}_{i,c=F}\right)XRM_{i,j,fp,cl}\right)}{\sum_{i=US}\sum_{fp\in FP}XRM_{i,j,fp,cl}}\right)+ PRFATCL_{j,cl}\left(\frac{\sum_{i=US}\sum_{fp\in FP}\left(\theta^{RM}_{i,c=F}\cdot XRM_{i,j,fp,cl}\right)}{\sum_{i=US}\sum_{fp\in FP}XRM_{i,j,fp,cl}}\right)\quad \forall j=OTH, cl\in CL \tag{49}$$

This equation determines the minimum class prices at actual test to be the weighted average class prices of skim milk and fat.

$$PRCLS_{j,cl} = 0.035\cdot PRFATCL_{j,cl} + 0.965\cdot PRSKMCL_{j,cl}\quad \forall j=OTH, cl\in CL \tag{50}$$

This equation determines the minimum class prices at standard test.

Conditions specific to California:

$$CRPCH_j = 9.8\left(\frac{\sum_{j'\in US}\sum_{fp=CHE}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=CHE}QFP_{j',fp}}\right)+ 0.27\left(\frac{\sum_{j'\in US}\sum_{fp=BUT}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=BUT}QFP_{j',fp}}-0.01\right)\quad \forall j=CAL \tag{51}$$

The California Class 1 cheese commodity reference price is a function of the national weighted average wholesale cheese and butter prices adjusted by make allowances and yield factors.

$$CRPBP_j = 1.2\left(3.5\right)\left(\frac{\sum_{j'\in US}\sum_{fp=BUT}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=BUT}QFP_{j',fp}}\right)+ 0.99\left(8.7\right)\left(\frac{\sum_{j'=CAL}\sum_{fp=NDM}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'=CAL}\sum_{fp=NDM}QFP_{j',fp}}\right)\quad \forall j=CAL \tag{52}$$

The California Class 1 butter/powder commodity reference price is a function of the national weighted average wholesale butter and NDM prices adjusted by make allowances and yield factors.

$$CRP_j = MAX\left[CRPCH_j, CRPBP_j\right]\quad \forall j=CAL \tag{53}$$

The California Class 1 commodity reference price is the maximum of the cheese commodity reference price and the butter/powder commodity reference price.

$$PVCL4B_j = 10\left(\frac{\sum_{j'\in US}\sum_{fp=CHE}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=CHE} QFP_{j',fp}} - 0.179\right) + 0.27\left(\frac{\sum_{j'\in US}\sum_{fp=BUT}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=BUT} QFP_{j',fp}} - 0.197\right) \quad \forall j = CAL \tag{54}$$

The Class 4B product value in California is a function of the weighted average national wholesale cheese and butter prices less make allowances times yield factors.

$$PCL1CAR_j = \frac{0.24}{87.8}\left(CRP_j + 0.464 - 3.5\left(PRFATCL_{j,cl=1}\right)\right) \quad \forall j = CAL \tag{55}$$

The California Class 1 fluid carrier price is a function of the commodity reference price and the Class 1 butterfat price.

Equations 56 through 58 determine the price of fat by class in California.

$$PRFATCL_{j=CAL,cl=1} = 1.2\left(\left(\frac{\sum_{j'\in US}\sum_{fp=BUT}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=BUT} QFP_{j',fp}}\right) - 0.1\right) \tag{56}$$

$$PRFATCL_{j,cl} = \begin{cases} PRFATCL_{j,cl=4} + 0.03815; & \forall j = CAL, cl = 2/3 \\ PRFATCL_{j,cl=4}; & \forall j = CAL, cl = 4B \end{cases} \tag{57}$$

$$PRFATCL_{j=CAL,cl=4A} = 1.2\left(\left(\frac{\sum_{j'\in US}\sum_{fp=BUT}\left(0.01\cdot PFPFOB_{j',fp}\cdot QFP_{j',fp}\right)}{\sum_{j'\in US}\sum_{fp=BUT} QFP_{j',fp}}\right) - 0.142\right) \tag{58}$$

Equations 59 and 60 determine the price of SNF by class in California.

$$PRSNFCL_{j,cl} = \begin{cases} \frac{0.76}{8.7}\left(CRP_j + 0.464 - 3.5\cdot PRFATCL_{j,cl}\right); & \forall j = CAL, cl = 1 \\ PRSNFCL_{j,cl=4A} + 0.071; & \forall j = CAL, cl = 2/3 \\ \frac{1}{8.78}\left(PVCL4B_j - 3.65\cdot PRFATCL_{j,cl}\right); & \forall j = CAL, cl = 4B \end{cases} \tag{59}$$

$$PRSNFCL_{j=CAL,cl=4A} = 0.99\left(\left(\frac{\sum_{j}\sum_{fp=NDM}\left(0.01\cdot PFPFOB_{j,fp}\cdot QFP_{j,fp}\right)}{\sum_{j}\sum_{fp=NDM} QFP_{j,fp}}\right) - 0.14\right) \quad (60)$$

$$PRCLA_{j,cl} = \begin{cases} 100\left(\theta^{RM}_{i,c=F}\cdot PRFATCL_{j,cl} + \left(\theta^{RM}_{i,c=P} + \theta^{RM}_{i,c=S}\right) PRSNFCL_{j,cl}\right) \\ \qquad + \left(1 - \sum_{c}\theta^{RM}_{i,c}\right) PCL1CAR_{j}; \qquad \forall i, j = CAL, cl = 1 \\ 100\left(\theta^{RM}_{i,c=F}\cdot PRFATCL_{j,cl} + \left(\theta^{RM}_{i,c=P} + \theta^{RM}_{i,c=S}\right) PRSNFCL_{j,cl}\right); \\ \qquad \forall i, j = CAL, cl \neq 1 \end{cases} \quad (61)$$

Determine the class price of raw milk at actual test.

$$PRCLS_{j,cl} = \begin{cases} 3.5\left(PRFATCL_{j,cl}\right) + 8.7\left(PRSNFCL_{j,cl}\right) + \\ \qquad 87.8\left(PCL1CAR_{j}\right); \quad \forall j = CAL, cl = 1 \\ 3.5\left(PRFATCL_{j,cl}\right) + 8.7\left(PRSNFCL_{j,cl}\right); \quad \forall j = CAL, cl \neq 1 \end{cases} \quad (62)$$

Determine the class price of raw milk at standard test.

Conditions applicable to both regions:

$$OOPD_{j} = \frac{\sum_{i\in US}\sum_{fp=CHE}\sum_{cl=III/4B}\left(PS_{i} + tcas_{i,j,fp} - PRCLA_{j,cl}\right) XRM_{i,j,fp,cl}}{\sum_{i\in US}\sum_{fp=CHE}\sum_{cl=III/4B} XRM_{i,j,fp,cl}} \quad \forall j \in US \quad (63)$$

The over-order premium (or deduct) equals the weighted average marginal milk value at supply region *i* plus the cost of assembling raw milk at cheese plants less the cheese milk price at average test.

$$TOTUTIL_{j} = \sum_{ip\in BF}\sum_{fp\in FP} QMFUSE_{j,fp,ip} + \sum_{j'\in US}\sum_{ip\in IP}\sum_{fp'\in FP}\sum_{fp\in FP} XIP_{j',j,ip,fp',fp} \quad \forall j \in US \quad (64)$$

Compute total utilization by region.

$$CLASSUTIL_{j,cl} = \frac{\sum_{ip\in BF}\sum_{fp\in FP} QMFUSE_{j,fp,ip} + \sum_{j'\in US}\sum_{ip\in IP}\sum_{fp'\in FP}\sum_{fp\in FP} XIP_{j',j,ip,fp',fp}}{TOTUTIL_{j}} \quad (65)$$

$$\forall j \in US, cl \in CL$$

Compute class utilization by region.

$$PCLASSA_{j,cl} = PRCLA_{j,cl} + OOPD_j \quad \forall j \in US, cl \in CL \tag{66}$$

The actual price of milk by class is equal to the price at test plus any deducts or premiums.

$$PCLASSS_{j,cl} = PRCLS_{j,cl} + OOPD_j \quad \forall j \in US, cl \in CL \tag{67}$$

The class price of milk is equal to the price at standard test plus any deducts or premiums.

$$PBLENDA_j = \sum_{cl} \left(PRCLA_{j,cl} \cdot CLASSUTIL_{j,cl} \right) \quad \forall j \in US \tag{68}$$

The blend price in region *j* at actual test, excluding deducts and premiums, is the weighted average class price at actual test.

$$PBLENDS_j = \sum_{cl} \left(PRCLS_{j,cl} \cdot CLASSUTIL_{j,cl} \right) \quad \forall j \in US \tag{69}$$

The blend price in region *j* at standard test, excluding deducts and premiums, is the weighted average class price at standard test.

$$BLACT_j = PBLENDA_j + OOPD_j \quad \forall j \in US \tag{70}$$

The blend price at actual test inclusive of over-order premiums and deductions.

$$PEM_j = propem_j \left({qs0_{i=j}} \big/ {QS_{i=j}} \right) \quad \forall j \in US \tag{71}$$

The proportion of milk in processing region *j* that is eligible for direct payments equals an estimated proportion of eligible milk adjusted by the ratio of the reference quantity of raw milk to the simulated quantity of raw milk.

$$DP_j = PEM_j \cdot MAX\left[0, \left(0.45 \left(16.94 - PCLASSS_{j'=OTH,cl=I} - OOPD_{j'=OTH} - 3.25 - 2.69 \right) \right) \right] \quad \forall j \in US \tag{72}$$

Direct payments ($/cwt) in processing region *j* are equal to 45% of the difference between $16.94/cwt and the FMMO Class I price at Boston, times the proportion of milk eligible for direct payments, if this difference is positive. The term (3.25 - 2.69) adjusts the Boston Class I differential to the FMMO average Class I differential to ensure the model's Class I price is comparable to the Boston Class I price.

SUMMARY OF CLASSIFIED PRICING ARRANGEMENTS

This appendix concludes with a summary description of the manner in which the classified pricing rules operate. Specifically, we discuss how observed product prices influence milk component prices and therefore the minimum class prices that processors must pay for raw milk. While this can be seen in the relevant equations in the above algebraic description of the model, it is necessary to have a clear understanding of these processes in order to interpret the model's results. The process is explained separately for each of the two regions in the model. For the sake of clarity and brevity, a slightly different labeling nomenclature is adopted here than was the case with the algebraic description of the model. We also ignore the constant terms and parameters in the classified pricing formulas in order to focus solely on the variable elements that influence prices.

OTHER US REGION

Although the Other US region includes areas not covered by FMMO regulations, by far and away the majority of the raw milk in this region is in fact priced under FMMO rules. Hence, we adopt the FMMO classified pricing regulations for the Other US region.

- Observe product prices in national markets and compute component prices:

$P_{FAT} = f\left(P_{BUT}\right)$. The price of fat is a function of the price of butter.

$P_{SNF} = f\left(P_{NDM}\right)$. The price of SNF is a function of the price of NDM.

$P_{PRT} = f\left(P_{CHE}, -P_{BUT}\right)$. The price of protein is a function of the price of cheddar cheese and butter. The sign on the butter price is negative.

$P_{OS} = f\left(P_{DWH}\right)$. The price of other solids, *i.e.,* non-protein SNF, is a function of the price of dry whey products.

- Calculate component prices by class:

$PFAT_{cl} = f\left(P_{FAT}, cldiff_{cl}\right)$. The price of fat by class is just the price of the fat component plus the class differential, which is equal to zero for Class III and IV.

$PSNF_{cl=II} = f\left(PSKM_{cl}\right)$. The price of SNF is a function of the skim milk price (only relevant for Class II).

$PSKM_{cl=I} = f\left(\max\left[PSKM_{cl=III}, PSKM_{cl=IV}\right], cldiff_{cl=I}\right)$. The price of skim milk for Class I is the maximum of the Class III and IV skim price, plus the Class I differential.

$PSKM_{cl=II} = f\left(PSKM_{cl=II}, cldiff_{cl=II}\right)$. The price of skim milk for Class II is the Class II skim price, plus the Class II differential.

$PSKM_{cl=III} = f\left(P_{PRT}, P_{OS}\right)$. The price of skim milk for Class III is a function of the price of protein and other solids, *i.e.,* cheddar cheese, butter, and dry whey products.

$PSKM_{cl=IV} = f\left(P_{SNF}\right)$. The price of skim milk in Class IV is a function of the price of SNF.

- Calculate minimum raw milk prices by class, at standard test:

$P_{cl}^{RM} = f\left(PFAT_{cl}, PSKM_{cl}\right)$. The minimum price of milk by class, at standard test, is a function of the class prices of fat and skim milk, respectively. The functional relationship remains the same at actual test, only the weight assigned to each component price differs.

CALIFORNIA

- Observe product prices in national markets, except in the case of NDM which is based on the observed California price, and compute commodity reference prices:

$CRP = \max\left[f\left(P_{CHE}, P_{BUT}\right), f\left(P_{NDM}, P_{BUT}\right)\right]$. The commodity reference price is the maximum of a function of the national price of cheddar cheese and butter, and a function of the California price of NDM and the national price of butter.

$PV_{4B} = f\left(P_{CHE}, P_{BUT}\right)$. The Class 4B product value is a function of the national price of cheddar cheese and butter.

$PCAR_{cl=1} = f\left(CRP, -PFAT_{cl=1}\right)$. The Class 1 carrier price is a function of the CRP and the negative of the Class 1 price of fat in California.

- Calculate component prices by class:

$PFAT_{cl} = f\left(P_{BUT}\right)$. While the parameters in the formulas vary for each class, the price of fat in California is determined to be a function of the national price of butter.

$PSNF_{cl=1} = f\left(CRP, -PFAT_{cl=4A}\right)$. The Class 1 price of SNF in California is a function of the commodity reference price and is influenced negatively by the Class 4A price of fat, in essence the national butter price.

$PSNF_{cl=2/3} = f\left(PSNF_{cl=4A}\right)$. The Class 2/3 price of SNF is a function of the Class 4A price of SNF.

$PSNF_{cl=4B} = f\left(PV_{cl=4B}, -PFAT_{cl=4B}\right)$. The Class 4B price of SNF is a function of the Class 4B product value and the negative of the Class 4B fat price. In other words, it is influenced by the national price of cheese and butter. But the price of butter enters the formula in two places, each with a different sign. The price of butter positively influences the Class 4B product value and while that positively affects the Class 4B price of SNF, the 4B price of fat in turn directly and negatively enters the SNF price formula.

$PSNF_{cl=4A} = f\left(P_{NDM}\right)$. The Class 4A price of SNF is a function of the California price of NDM.

- Calculate minimum raw milk prices by class, at standard test.

$P_{cl=1}^{RM} = f\left(PFAT_{cl=1}, PSNF_{cl=1}, PCAR_{cl=1}\right)$. The Class 1 price of raw milk in California is a function of the price of fat, SNF, and the Class 1 carrier price.

$P_{cl\neq1}^{RM} = f\left(PFAT_{cl\neq1}, PSNF_{cl\neq1}\right)$. All other minimum raw milk class prices in California are a function of the price of fat and SNF.

Finally, in both regions, the blend price is the class utilization weighted price of the individual minimum class prices (either at standard or actual test). It is the blend price at actual test, plus any over-order premiums or deductions, which the model assumes producers respond to.

APPENDIX B: DETAILS OF MODEL DATA

DATA SOURCES

The quantity-based data for the model include milk production and component composition, dairy product demand and minimum component composition, component retention factors, supply and demand elasticities, and US trade policy parameters (TRQ levels, ad valorem tariffs, unit tariffs, unit export subsidies, and limits on export subsidies). Value-based data include estimated costs of dairy product processing and distribution, milk prices, domestic dairy product prices, and imported dairy product prices. These data come from government agencies (Federal Milk Marketing Orders, NASS, California Department of Food and Agriculture), previous research (for elasticity values and processing and distribution costs), and internal model calibration runs.

Table B1. Dairy Product Designations in the Model

Product Description	Product Type in Model			
	Inter-mediate	Final	Import	Export
Fluid milk		Y		
Ice cream		Y	Y	Y
Yogurt		Y		
Cottage cheese		Y		
Cheddar cheese		Y	Y	Y
Other cheese		Y	Y	Y
Dry whey products		Y	Y	Y
Butter		Y	Y	Y
Nonfat dry milk	Y	Y	Y	Y
Evaporated, condensed and dry products		Y	Y	Y
Casein		Y	Y	
Caseinate		Y	Y	
MPC>90		Y	Y	
MPC 42 (low protein)	Y	Y	Y	
MPC 56 (medium protein)	Y	Y	Y	
MPC 70 (high protein)	Y	Y	Y	
40% fat cream	Y			
Skim milk	Y			
Ice cream mix	Y			
Fluid whey	Y			
Buttermilk	Y			

RAW MILK SECTOR

Table B2. Raw Milk Reference Data, 2001

Region	Milk Supplied[1] (mil. lbs)	Own-price Elasticity[2]	All-milk price ($/cwt)[3]	Composition[4]			
				% Fat	% SNF	% Protein	% Other Solids
Other US[5]	132,085	0.312	15.23	3.67	8.72	3.11	5.61
California	33,251	0.433	13.72	3.59	8.63	3.08	5.55
Total	165,336		14.93				

[1] Milk production from *Milk Production*, February 2002.

[2] Raw milk elasticities adapted from FAPRI, as reported in US GAO (2001).

[3] All-milk price for California from January through December 2001 issues of A*gricultural Prices*, USDA/NASS. All-milk price for Other US regions calculated using the California all-milk price, the US all-milk price from *Agricultural Prices* and milk production data for the two regions.

[4] Fat composition for both regions from unpublished FMMO and CDFA data. SNF for FMMO region from relationship used in Pratt *et al.* (1997) based on data from four marketing orders. The protein percentage is estimated using standard milk composition (3.1/8.7) times actual SNF content. The other solids content is determined by difference. For California, SNF, protein and other solids are from unpublished CDFA data.

[5] Includes both areas regulated by FMMO and state-regulated or unregulated areas.

PRODUCTION OF AND DEMAND FOR MANUFACTURED DAIRY PRODUCTS

Reference final demand data is built up using production, imports, exports, and dairy use. A summary of the final demand data as used in the model follows.

Table B3. Summary of Final Product Demand, Imports, and Exports; 2001

Product	Final Demand, mil lbs[1]		Exports, million lbs	Imports, million lbs
	Other US	California		
Fluid products	49,679.7	6,424.9	0.0	0.0
Ice cream	5,572.8	773.9	93.5	14.5
Yogurt	1,731.0	240.4	5.3	5.9
Cottage cheese	1,222.0	169.7	0.0	0.0
Cheddar cheese	3,359.9	574.2	51.2	70.0
Other cheese	3,868.3	530.9	39.2	143.8
Dry whey products[2]	4,274.0	757.0	530.7	57.1
Butter	1,142.0	195.5	3.7	45.5
NDM	330.1	36.2	212.0	7.4
Evap., cond. & dried	704.2	102.3	125.1	37.2
Casein	119.2	16.6	0.0	135.8
Caseinates	74.0	10.3	0.0	84.3
MPC>90%	13.4	1.9	0.0	15.3
MPC 42 (low protein)[3]	12.9	1.8	0.0	20.9
MPC 56 (medium protein)	18.4	2.6	0.0	20.9
MPC 70 (high protein)	18.4	2.6	0.0	20.9

[1] Demand for fluid milk based on FMMO and CDFA data on fluid milk sales. Demand estimates for ice cream, yogurt, and cottage cheese are based on production data from *Dairy Products*. For other domestically produced products, data on production, change in stocks, imports, exports and dairy industry (intermediate product) use were used to develop initial demand estimates. In order to ensure component balance in the base model scenario, assumptions regarding the percentage of production covered in NASS *Dairy Product* surveys and intermediate product use were modified through iteration of the model structure. Demand for casein, caseinates and MPCs is based on import data. Aggregate US data for products other than fluid milk was allocated to regions based on adjusted per capita consumption (for methods, see Pratt *et al.*, 1997) and regional population. Intermediate demands are endogenous to the model. They are not specified as explicit demand relationships, and therefore are not reported herein.

[2] Final demand for whey products assumes all fluid whey is processed into dry product, which is not in fact the case. This assumption is necessary because the model does not explicitly model the costs of alternative whey disposal (other than drying). Use of actual estimated whey final product demand would result in a dry whey price of zero.

[3] All demand for casein, caseinates, and MPCs in 2001 is met from imports. It is assumed that the total Chapter 4 MPC imports are evenly distributed across the three protein levels. Furthermore, it is assumed that 30% of the MPC 42 is used in the dairy industry, *i.e.,* it does not enter final demand.

Note that the summary table above has demand values inclusive of their calibration adjustments, *i.e.*, it is the numbers used in the model to actually generate the base solution and do the analysis.

PRODUCT COMPOSITION

The model assumes that the composition of raw milk is known (see Table B). We also assume that the protein content of raw milk is (3.1/8.7) times the SNF content, and the other solids content is therefore (5.6/8.6) times the SNF content. Assuming that skim milk contains 0.075% fat, it is a simple matter of arithmetic to then compute the SNF content of skim milk, and therefore the protein and other solids content as well:

$$\theta^{IP}_{j,c=SNF,ip=SKM} = \theta^{RM}_{j,c=SNF} \Big/ \left(1-\theta^{RM}_{j,c=F}\right)$$

$$\theta^{IP}_{j,c=P,ip=SKM} = \left(3.1 \big/ 8.7\right) \theta^{IP}_{j,c=SNF,ip=SKM}$$

$$\theta^{IP}_{j,c=S,ip=SKM} = \left(5.6 \big/ 8.7\right) \theta^{IP}_{j,c=SNF,ip=SKM}$$

However, this logic only follows if raw milk from multiple supply locations, each with a different composition, is not allowed to be co-mingled at processing plants.

It has previously been noted that a number of parameters were computed using an independent system of simultaneous equations. In essence, the parameters in question were specified as variables when the conceptual model was initially developed. However, because of the level of spatial aggregation adopted for this study, and therefore the absence of the possibility for raw milk from multiple sources to be co-mingled at processing plants, these variables can be parameterized. The process used to compute these parameters is now described.

System to determine quantity of cream and skim milk, *i.e.,* given raw milk of known composition and assuming cream of 40% fat and skim milk of 0.075% fat, then solve:

$$\theta^{IP}_{j,c=F,ip=CRM} \cdot QCRM_j + \theta^{IP}_{j,c=F,ip=SKM} \cdot QSKM_j = \theta^{RM}_{j,c=F} \qquad \forall j$$

$$SNFCRM \cdot QCRM_j + \theta^{IP}_{j,c=SNF,ip=SKM} \cdot QSKM_j = \theta^{RM}_{j,c=SNF} \quad \forall j$$

$$QCRM_j + QSKM_j = 1 \qquad \forall j$$

where *QCRM* is the quantity of cream yielded, *QSKM* is the quantity of skim milk, and *SNFCRM* is the SNF content of cream. This can then be apportioned into protein and other solids assuming that these components appear in the serum portion of cream in the same ratio as they appear in the raw milk serum.

The parameterized variables include the following: the SNF content of cream and skim milk; the composition of NDM; the respective volume shares of cream and skim milk to be separated from a unit of raw milk; and the shares of cream and concentrated skim milk required to be combined to make ice cream mix.

In principle, the component composition of both intermediate and products is endogenous, that is, it depends on the composition of the raw milk separated and recombined to make the intermediate products. In a model with limited spatial disaggregation such as this one, it is possible to calculate the composition of the intermediate products *ex ante*, given the composition of the milk in each region and the assumption that raw milk is not shipped between the two US regions in the model (Table B4). For final products, the composition is endogenously determined by the model based on the raw milk and intermediate products used in their manufacture. Unlike models that assume a fixed proportions production technology with minimum proportional component content, our model uses product yield functions and minimum component contents. The compositions of FP based on the yield functions and minimum component requirements are reported in Appendix C (Table C8).

Table B4. Composition of Intermediate Products from US Plants

Product	Region	Composition[1]			
		% Fat	% SNF	% Protein	% Other Solids
Cream	Other US	40.00	5.36	1.91	3.45
	California	40.00	5.30	1.89	3.41
Skim milk	Other US	0.08	9.05	3.23	5.83
	California	0.08	8.95	3.19	5.76
Ice cream mix	Other US	9.17	9.74	3.47	6.27
	California	9.17	9.74	3.47	6.27
Fluid whey[2]	Other US	0.41	7.04	0.91	6.13
	California	0.34	7.13	0.92	6.21
Buttermilk	Other US	0.77	9.10	3.24	5.85
	California	0.77	8.99	3.20	5.79
NDM	Other US	0.79	95.21	33.93	61.29
	California	0.80	95.20	33.92	61.28
MPC 42	Other US	1.00	95.00	42.00	53.00
	California	1.00	95.00	42.00	53.00
MPC 56	Other US	1.20	94.80	56.00	38.80
	California	1.20	94.80	56.00	38.80
MPC 70	Other US	1.40	94.60	70.00	24.60
	California	1.40	94.60	70.00	24.60

[1] Fat and SNF values calculated based on raw milk composition and assumptions about the fat content of cream and skim. Due to the level of spatial aggregation in the model, raw milk supplies from each region are not co-mingled. Hence, the values of these intermediate products can be determined exogenously. Protein values for products determined based on protein:SNF ratio in raw milk. Other solids composition equals SNF less protein.

[2] The composition of fluid whey is determined endogenously and depends on the mix of products entering the cheese vat, and their respective composition.

Table B5. Composition of Selected Imported Products

Product	Composition[1]			
	% Fat	% SNF	% Protein	% Other Solids
Casein	1.0	93.0	92.0	1.0
Caseinates	1.0	95.0	94.0	1.0
MPC>90%	1.8	95.0	90.0	5.0

Source: Compositions based on information in *Dairy Proteins*, Wisconsin Center for Dairy Research (2001).

[1] Protein content of imported Chapter 4 MPC 40% is assumed to be the same as that reported for intermediate products in Table B.

Table B6. Minimum Component Specifications for Final Products

Product	Region	Composition		
		% Fat	% SNF	% Protein
Fluid milk	Other US	2.65		
	California	2.36	9.64	
Yogurt	Other US	1.55	13.5	
	California	1.55	13.5	
Cottage cheese	Other US	15.41	15.40	
	California	15.41	15.40	
Cheddar cheese	Other US	33.00		25.50
	California	33.00		25.50
Other cheese	Other US	24.60		22.50
	California	24.60		22.50

Source: Minimum fat content for fluid milk is actual average fat content of fluid milk sales from FMMO and CDFA data. Minimum solids content for fluid milk in California is based on regulations specifying a minimum total solids content. Other measures are based on USDA (1979).

Table B7. Component Retention Factors Used to Determine the Yield of Selected Products at US Plants

Product	Region	% Retention		
		Fat	Protein	Other Solids
Cheddar cheese	Other US	93.00	74.90	5.00
	California	93.00	74.90	5.00
Other cheese	Other US	85.00	74.90	8.00
	California	85.00	74.90	8.00
Butter	Other US	99.00		
	California	99.00		
Casein	Other US		74.90	3.00
	California		74.90	3.00
MPC 42	Other US	99.93	98.25	73.40
	California		98.25	73.40
MPC 56	Other US	99.97	96.04	39.66
	California		96.04	39.66
MPC 70	Other US	99.96	94.77	20.16
	California		94.77	20.16

Source: Papadatous *et al.*, 2002; and David Barbano, Department of Food Science, Cornell University, *personal communication*,

DEMAND ELASTICITIES

Note that final demand elasticities are assumed to be the same in both regions. Demand for US exports simply assumed to be 3 times the domestic demand elasticities. The protein products are all set at 0.5, same as for NDM.

TableB8. Elasticities, Final Demand, Exports, and Imports

Product	Elasticity for:		
	Final Demand[1]	Demand for US Exports[2]	Import Supply (to the US)
Fluid products	-0.25		
Ice cream	-0.50	-1.50	2.5
Yogurt	-0.50	-1.50	2.5
Cottage cheese	-0.50		
Cheddar cheese	-0.50	-1.50	10.0
Other cheese	-0.25	-0.75	10.0
Dry whey products	-0.30	-0.90	5.0
Butter	-0.25	-0.75	10.0
NDM	-0.50	-1.50	10.0
Evap., cond. & dried	-0.30	-0.90	2.5
Casein	-0.50		5.0
Caseinates	-0.50		5.0
MPC>90%	-0.50		5.0
MPC 42 (low protein)	-0.50		5.0
MPC 56 (medium protein)	-0.50		5.0
MPC 70 (high protein)	-0.50		5.0

[1] Demand elasticities adapted from US GAO (2001).

[2] Equal to three times the domestic demand elasticity.

PROCESSING COSTS

The model uses fixed, exogenously determined costs to account for the expense of the processing activity. Processing costs are generally based on best practice operations in plants of medium to large capacity, by US standards, and take account of both fixed and variable cost components. Costs enter the model on a per unit of product manufactured basis, as opposed to charging costs according to the throughput of the raw product inputs. All costs for both intermediate and final products are shown in Tables B9 and B10, respectively.

Table B9. Processing Costs for Intermediate Products

Product	Processing[1] ($/100 lbs)		Overhead, Storage, Profit, etc.[2] ($/100 lbs)	
	Other US	California	Other US	California
Cream	2.8	2.8	0.0	0.0
Skim milk	2.8	2.8	0.0	0.0
Ice cream mix	2.8	2.8	0.0	0.0
Fluid whey	0.0	0.0	0.0	0.0
Buttermilk	2.8	2.8	0.0	0.0
NDM	8.2	8.2	2.5	0.0
MPC 42[3]	28.7	28.7	0.0	0.0
MPC 56[3]	37.0	37.0	10.0	10.0
MPC 70[3]	104.2	104.2	0.0	0.0

[1] Estimates based on fixed and variable costs for medium sized processing operations (large cheese operations in California) from Pratt *et al.* (1997), p. 74, and (unpublished) mean predicted processing volumes from the US Dairy Sector Simulator Pratt *et al.* (1997) using 2001 supply and demand data.

[2] Based on industry sources, professional judgment, and the model calibration process. Note that the overhead, etc is added to arrive at total processing costs, *e.g.*, total NDM cost in Other US is 8.2 + 2.5 = 10.7.

[3] Based on costs applicable in 2001; the base case year. Lower costs were used in counterfactual scenarios. See text for details.

Table B10. Processing Costs for Final Products

Product	Processing[1] ($/100 lbs)		Overhead, storage, profit, etc.[2] ($/100 lbs)	
	Other US	California	Other US	California
Fluid products	2.8	2.8	0.0	0.0
Soft products[3]	5.3	5.3	0.0	0.0
Cheddar cheese	11.0	9.5	2.4	3.2
Other cheese	11.0	9.5	24.2	26.2
Dry whey	3.5	3.5	2.6	5.1
Butter	4.2	4.2	5.2	10.8
NDM	8.2	8.2	2.5	0.0
Evap., cond. & dried	8.2	8.2	-6.5	-5.6
Casein	13.0	13.0	0.0	0.0
MPC 42[4]	28.7	28.7	0.0	0.0
MPC 56[4]	37.0	37.0	10.0	10.0
MPC 70[4]	104.2	104.2	0.0	0.0

[1] Estimates based on fixed and variable costs for medium sized processing operations (large cheese operations in California) from Pratt *et al.* (1997), p. 74, and (unpublished) mean predicted processing volumes from the US Dairy Sector Simulator Pratt *et al.* (1997) using 2001 supply and demand data.

[2] Based on industry sources, professional judgment, and the model calibration process.

[3] Includes ice cream, yogurt, and cottage cheese.

[4] Based on costs applicable in 2001; the base case year. Lower costs were used in counterfactual scenarios. See text for details. Based on MPC yields from ultra-filtered milk--and diafiltration processes for the high protein MPCs—(David Barbano, *personal communication*) and costs estimated from a survey of current US ultra-filtered milk processors, assuming 0.5 million lbs milk processed per plant per day (Mark Stephenson, Cornell Program on Dairy Markets and Policy, Cornell University, personal communication). Because UF processing costs decrease in a nonlinear manner with increasing volumes, these reported costs will overstate unit processing costs for MPCs compared to plant volumes that could be observed as more US-based UF processing facilities were established.

Reductions in processing costs as volumes processed increase for MPCs made with ultrafiltration are from Mark Stephenson, Cornell University (personal communication) based on a small survey of processing costs in UF plants (Figure B1) and assumptions about the costs of drying UF milk.

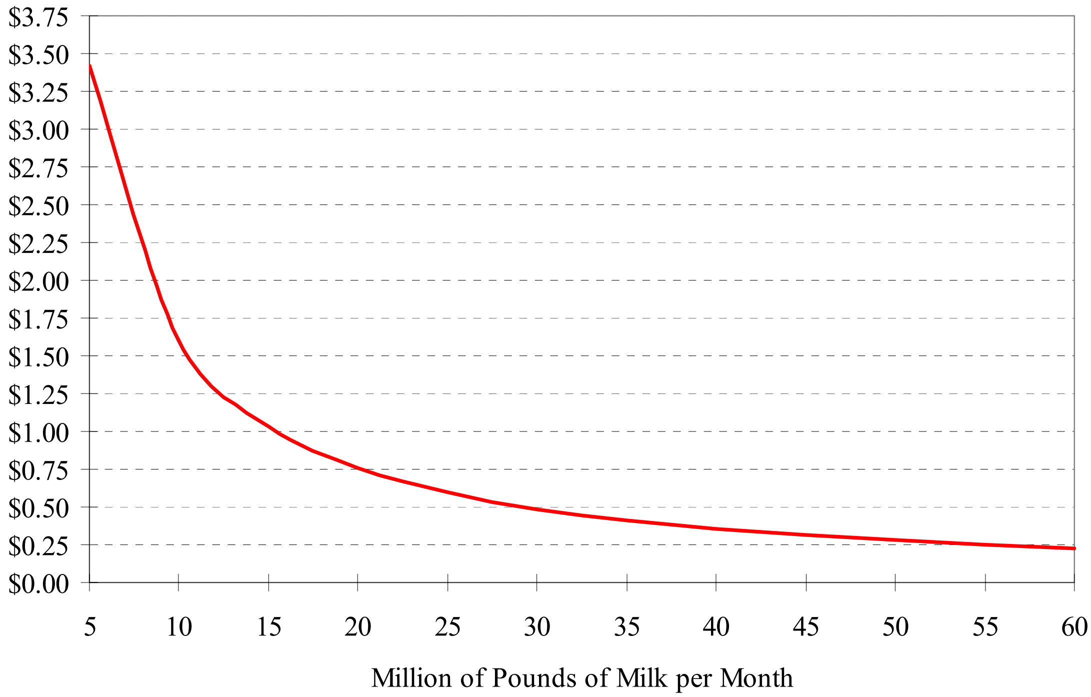

Figure B1. Ultrafiltration Cost by Plant Size, $/cwt

TRANSPORTATION COSTS

There are three sets of transport costs required in the model; assembling raw milk at plants, moving intermediate products between plants, and the distribution of final products to demand locations. All such costs are determined as in Pratt *et al.* (1997) and are based on the distance traveled between locations. However, the level of spatial aggregation adopted for this study means that the notion of point-to-point distances has much less significance than in a spatially detailed model such as that described by Pratt *et al.*

Spatial aggregation not withstanding, the US Dairy Sector Simulator of Pratt *et al.* was run using 2001 data and the mean predicted distances within and between the two regions used in the current model were determined for each product type and for raw milk. These distances, which are reported in Nicholson and Bishop (2004), were used to compute the transportation costs.

Table B11. Transportation Costs for Raw Milk Assembly

Product	Distance, miles		Cost, $/cwt	
	US to US	CA to CA	US to US	CA to CA
Fluid products	200	250	0.80	1.00
Yogurt	50	50	0.20	0.20
Cottage cheese	50	50	0.20	0.20
Cheddar cheese	50	25	0.20	0.10
Other cheese	25	25	0.10	0.10
NDM	50	50	0.20	0.20
Evap., cond. & dried	80	80	0.32	0.32
Casein	50	50	0.20	0.20
MPC	50	50	0.20	0.20

Source: Estimates based on mean predicted distances and formulas from the US Dairy Sector Simulator, Pratt *et al.* (1997).

Note: Distances and costs only specified for the plant types permitted to receive raw milk.

Table B12. Distances for Computing Final Product Distribution Costs, Miles

Product	US to US	US to CA	CA to US	CA to CA
Fluid products	25	2,120	2,120	25
Ice cream	75	2,120	2,120	75
Yogurt	75	2,120	2,120	75
Cottage cheese	75	2,120	2,120	75
Cheddar cheese	300	2,120	2,120	200
Other cheese	300	2,120	2,120	200
Dry whey products	300	2,120	2,120	200
Butter	350	2,120	2,120	200
NDM	350	2,120	2,120	200
Evap., cond. & dried	250	2,120	2,120	200
Casein	350	2,120	2,120	200
MPCs	350	2,120	2,120	200

Source: Estimates based on mean predicted distances and formulas from the US Dairy Sector Simulator, Pratt *et al.* (1997).

Note: Distances and costs only specified for the plant types permitted to receive raw milk.

Table B13. Transportation Costs for Final Product Distribution, $/100 lbs

Product	US to US	US to CA	CA to US	CA to CA
Fluid products[1]	13.02	n.a.	n.a.	14.58
Ice cream[2]	114.65	122.01	120.65	116.02
Yogurt[3]	107.94	114.04	113.94	108.05
Cottage cheese[4]	87.32	94.91	93.32	88.91
Cheddar cheese	1.58	6.57	6.57	1.17
Other cheese	1.58	6.57	6.57	1.17
Dry whey products	1.41	5.90	5.90	1.05
Butter	1.76	6.57	6.57	1.17
NDM	1.58	5.90	5.90	1.05
Evap., cond. & dried	1.24	5.90	5.90	1.05
Casein	1.58	5.90	5.90	1.05
MPCs	1.58	5.90	5.90	1.05

Source: Estimates based on formulas in Pratt *et al.* (1997) and predicted mean distances reported in Table B12.

Note: "n.a." denotes that the model is not configured to permit such shipments.

[1] A retail margin of $12.77/100 lbs in the Other US and $14.32 in California is added to the value to allow comparisons with reported retail prices.

[2] A retail margin of $114.08/100 lbs in the Other US and $115.44 in California is added to the value to allow comparisons with reported retail prices.

[3] A retail margin of $107.37/100 lbs in the Other US and $107.47 in California is added to the value to allow comparisons with reported retail prices.

[4] A retail margin of $86.75/100 lbs in the Other US and $88.34 in California is added to the value to allow comparisons with reported retail prices.

Table B14. Distances for Computing Intermediate Product Transport Costs, Miles

Product	Origin plant	Receiving plant	US to US	US to CA	CA to US	CA to CA
Cream	Fluid	Cottage cheese	25	2,120	2,120	25
		Butter; evap., cond. & dried	50	2,120	2,120	50
	Yogurt	Butter	10	n.a.	n.a.	10
	Cottage cheese	Butter	50	n.a.	n.a.	50
	Other cheese	Butter	50	n.a.	n.a.	50
	NDM; casein: MPCs	Cottage cheese; butter; evap., cond. & dried	50	2,120	2,120	50
Skim milk	NDM, casein: MPCs	Cheese – cottage, cheddar, and other; evap., cond. & dried	75	2,120	2,120	75
Ice cream mix	NDM	Ice cream	75	2,120	2,120	75
Fluid whey	Cheese – cheddar and other; casein; MPCs	Dry whey products	0	2,120	2,120	0
Buttermilk	Butter	Evap., cond. & dried	50	n.a.	n.a.	50
NDM	NDM	Cheddar; other cheese	50	2,120	2,120	50
		Cottage cheese; fluid (high solids only)	100	2,120	2,120	100
MPCs	MPCs	Cheddar; other cheese	50	2,120	2,120	50
		Cottage cheese	100	2,120	2,120	100

Source: Estimates based on mean predicted distances from the US Dairy Sector Simulator (Pratt *et al.*, 1997).

Note: n.a. denotes that the model is not configured to permit such shipments.

Table B15. Transportation Costs for Intermediate Products, $/100 lbs

Product	Origin plant	Receiving plant	US to US	US to CA	CA to US	CA to CA
Cream	Fluid	Cottage cheese	0.10	8.48	8.48	0.10
		Butter; evap., cond. & dried	0.20	8.48	8.48	0.20
	Yogurt	Butter	0.04	n.a.	n.a.	0.04
	Cottage cheese	Butter	0.20	n.a.	n.a.	0.20
	Other cheese	Butter	0.20	n.a.	n.a.	0.20
	NDM; casein: MPCs	Cottage cheese; butter; evap., cond. & dried	0.20	8.48	8.48	0.20
Skim milk	NDM, casein, MPCs	Cheese – cottage, cheddar, and other; evap., cond. & dried	0.30	8.48	8.48	0.30
Ice cream mix	NDM	Ice cream	0.30	8.48	8.48	0.30
Fluid whey	Cheese – cheddar and other; casein; MPCs	Dry whey products	0.00	8.48	8.48	0.00
Buttermilk	Butter	Evap., cond. & dried	0.20	n.a.	n.a.	0.20
NDM	NDM	Cheddar; other cheese	0.38	5.90	5.90	0.38
		Cottage cheese; fluid (high solids only)	0.63	5.90	5.90	0.63
MPC	MPC	Cheddar; other cheese	0.38	5.90	5.90	0.38
		Cottage cheese	0.63	5.90	5.90	0.63

Source: Estimates based on formulas in Pratt *et al.* (1997) and predicted mean distances reported in Table B.

Note: n.a. denotes that the model is not configured to permit such shipments.

POLICIES

Table B16. US Import TRQ Details: Quota Levels, Ad Valorem Tariffs, and Specific Tariffs

Product	Quota, mil lbs	Ad valorem tariff, %		Unit tariff, $/100 lbs	
		Within	Over	Within	Over
Fluid products	No limit	0.0	0.0	0.00	0.00
Ice cream	14.5	20.0	17.0	0.00	22.77
Yogurt	No limit	0.0	0.0	0.00	0.00
Cheddar cheese	37.0	11.6	0.0	0.00	48.18
Other cheese	251.7	9.6	0.0	0.00	98.39
Dry whey products	No limit	7.7	0.0	0.00	0.00
Butter	15.4	0.0	0.0	5.58	69.90
NDM	11.6	0.0	0.0	1.50	39.24
Evap., cond. & dried	22.4	0.0	0.0	1.25	7.61
Casein	No limit	0.0	0.0	0.00	0.00
Caseinates	No limit	0.0	0.0	0.17	0.00
MPC (Chapter 35)	No limit	0.0	0.0	0.17	0.00
MPC (Chapter 4)	No limit	0.0	0.0	0.17	0.00

Source: Values for TRQs and tariffs adapted from Harmonized Tariff Schedule of the United States (2001) (Rev. 1) as appropriate for model product categories.

Table B17. US Export Subsidy Details: Unit Subsidies and Quantity Restrictions

Product	Unit Subsidy $/100 lbs	Quantity Restriction Mil lbs
Cheddar cheese	54.43	6.7
Butter	81.47	46.5
NDM	54.85	212.0

Source: Export subsidy information from Foreign Agricultural Service, USDA.

APPENDIX C: MODEL CALIBRATION AND VALIDATION

Having formulated the model and compiled the necessary data, we now turn to assessing the appropriateness of the model for its stated purposes. Measuring how well the reference data are replicated is part of the model validation procedure. The process of refining model parameters to ensure that the reference data can be replicated is referred to as model calibration. Calibration is a task made necessary by the fact that it is simply not feasible for statistical agencies to observe, let alone measure with complete accuracy, all of the data required in a model such as the one used for this study.

THE CALIBRATION PROCESS

The goal of the calibration process is to have the model-generated prices in the base solution come as close as possible to replicating the observed (*i.e.,* actual or reference) market prices for the 2001 base year. Reference data are compiled, as described in Appendix B, as best as can reasonably be done. Then the model is run to generate an *initial* base case solution. Based upon a comparison with the reference data, certain parameters are then adjusted and the model is re-run to generate a *calibrated* base case solution. Three sets of parameters are the focus of our calibration efforts: processing costs, final product distribution costs, and final demand quantities. Uncertainty as to the actual value is the criteria used to select which parameters to adjust. For example, we know there is some degree of unreliability associated with the NASS estimates of cheese production due to the voluntary response of dairy companies to NASS surveys. On the other hand, we can be relatively sure of production estimates for fluid products as these data are compiled from the audited statistics used to administer the various classified pricing systems.

The approach to making the necessary parameter adjustments involves working from the initial solution to the Mixed Complementarity Problem, *i.e.,* the model, and modifying each of the constraints that holds as a strict equality to include a new variable. This new variable represents the adjustment to processing and final product distribution costs that is required in order for the model-generated product prices to equal the reference product prices. We focus on aligning product prices because they contribute directly (but non-linearly) to raw milk class prices via the product price formulas.

Solving for the values of the new variables that result in the model replicating the reference values for milk supplies and dairy product demands implies that the values for these variables, *i.e.,* milk supplies and dairy product demands, must be held fixed at their actual levels. Hence it is not possible to simply add the new variable directly into the MCP model because for any variable that is held fixed in an MCP model, its complementary equation will automatically be excluded from the model. This follows from complementary slackness. Thus, an alternative approach was implemented.

Under this approach, the initial MCP is solved and all of the non-zero variables (*i.e.,* the solution to the model) and their complementary equations are converted into a system of (strict) equations. This system is then modified, as noted above, to include the new variables. Specifically, when the MCP is converted to a system of equations, the new variable is added to equations (33) and (34). The milk supply (QS_i) and product demand ($QD_{k,fp}$) variables are then fixed at their reference levels and the system is solved to yield the necessary adjustment values for processing and final distribution costs. The processing and final distribution cost parameters are thus updated, and the MCP version of the model is then solved iteratively to yield the revised reference demand quantities. At each iteration, the reference demand quantity for selected manufactured products is updated so that it equals the model-predicted demand quantity. The process is continued until the required adjustment is less than a predetermined threshold.

The adjustments made to processing costs as a result of the calibration process are shown in Table C1. Specifically, the column entitled "Difference" is in fact the value of the new variable added to the system of equations. We assign this value to "Overhead, storage, and profit" element of processing costs (see Table B9).

Table C1. Adjustments to Processing Costs due to Calibration, $/100 lbs

Product, Region	Initial	Post-calibration	Difference
Cheddar cheese			
Other US	11.0	13.4	2.4
California	9.5	12.7	3.2
Other cheese			
Other US	11.0	35.2	24.2
California	9.5	35.7	26.2
Dry whey products			
Other US	3.5	6.1	2.6
California	3.5	8.6	5.1
Butter			
Other US	4.2	9.4	5.2
California	4.2	15.0	10.8
NDM			
Other US	8.2	10.7	2.5
California	8.2	8.2	0.0
Evap., cond. & dried			
Other US	8.2	1.7	-6.5
California	8.2	2.6	-5.6

Note: There was no change due to calibration for products not listed in table.

Similarly, Table C2 shows the adjustment made to the retail margin component of final product distribution costs as a result of model calibration (see Table B10).

Table C2. Adjustments to Retail Margins due to Calibration, $/100 lbs

Product, Region	Initial	Post-calibration	Difference
Fluid products			
Other US	16.0	12.8	-3.2
California	16.0	14.3	-1.7
Ice Cream			
Other US	107.0	114.1	7.1
California	107.0	115.4	8.4
Yogurt			
Other US	107.0	107.4	0.4
California	107.0	107.5	0.5
Cottage cheese			
Other US	107.0	86.8	-20.2
California	107.0	88.3	-18.7

Note: Retail margins are an element of final product distribution costs. There was no change due to calibration for products not listed in table.

Adjustments made to the reference demand data are as shown in Table C3.

Table C3. Adjustments to Final Demand due to Calibration, Million Pounds

Product, Region	Initial	Post-calibration	Difference
Cheddar cheese			
Other US	3,745.8	3,359.9	-385.9
California	520.2	574.2	54.0
Rest of world	69.3	51.2	-18.1
Other cheese			
Other US	4,221.9	3,868.3	-353.6
California	586.4	530.9	-55.4
Rest of world	45.5	39.2	-6.3
Dry whey products			
Other US	4,629.0	4,274.0	-355.0
California	762.0	757.0	-5.0
Rest of world	656.3	530.7	-125.6
Butter			
Other US	1,083.3	1,142.0	58.7
California	150.4	195.5	45.1
NDM			
Other US	387.5	330.1	-57.4
California	53.8	36.2	-17.6
Evap., cond. & dried			
Other US	728.3	704.2	-24.1
California	101.1	102.3	1.2

Note: There was no change due to calibration for products not listed in table.

STATISTICAL ANALYSIS OF THE BASE SOLUTION COMPARED WITH ACTUAL OUTCOMES

Model calibration efforts were focused on alignment of final product prices. Prior to reporting the results regarding this alignment, a brief digression to discuss measures of association is appropriate. As Hazell and Norton (1986) note in their now-classic text, there is no definitive consensus on the measures most appropriate to evaluate model predictions, nor what value of a particular measure should be deemed unacceptable. In most instances, a combination of measures provides a better assessment than a single measure, and subjectivity is difficult to avoid in assessment of model adequacy. Four commonly-used statistical measures are used to gauge the validity of the base case scenario: mean absolute deviation, percentage absolute deviation, Theil's coefficient and correlation coefficients.

Letting x^P denote model-predicted values, x^A the actual observed outcomes, and N the number of observations, we can define the following:

Mean absolute deviation: $MAD = \frac{1}{N}\sum_{i=1}^{N}\left|x_i^P - x_i^A\right|$

The MAD measures the average absolute difference between model-predicted and observed values for a set of N outcomes of interest.

Percentage absolute deviation: $PAD = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|x_i^P - x_i^A\right|}{\left|x_i^A\right|}$

The PAD is similar to the MAD, but measures the average percentage difference between model-predicted and observed values for a set of N outcomes of interest.

Theil's coefficient: $T = \frac{\left[\frac{1}{N}\sum_{i=1}^{N}\left(x_i^P - x_i^A\right)^2\right]^{\frac{1}{2}}}{\left[\frac{1}{N}\sum_{i=1}^{N}\left(x_i^P\right)^2\right]^{\frac{1}{2}} + \left[\frac{1}{N}\sum_{i=1}^{N}\left(x_i^A\right)^2\right]^{\frac{1}{2}}}$

The Theil's coefficient is less straightforward to interpret. The value of this indicator equals zero when predicted an actual values are equal for all N outcomes of interest. The closer the coefficient is to zero, the better the correspondence between the model-predicted and actual values.

The correlation coefficient: $r = \frac{\sum_{i=1}^{N}\left(x_i^P - \overline{x}_i^P\right)\left(x_i^A - \overline{x}_i^A\right)}{\left[\sum_{i=1}^{N}\left(x_i^P - \overline{x}_i^P\right)^2 \cdot \sum_{i=1}^{N}\left(x_i^A - \overline{x}_i^A\right)^2\right]^{\frac{1}{2}}}$

The product-moment correlation coefficient is sometimes used to measure association between predicted and observed values. Although correlation coefficients can equal one for very high levels of MAD or PAD (because they capture whether patterns, not levels, are consistent between actual and predicted outcomes) the correlation coefficient provides additional information that other measures do not.

The results of the calibration exercise indicate the model predicts outcomes observed in 2001 with a degree of accuracy appropriate for its use in assessing alternative policy scenarios. Model predictions of milk production, milk prices, and class prices are all quite similar to observed values (Table C4). Class utilization in the two regions is less well predicted, but still simulates the general pattern of larger utilization for butter-powder in California. Wholesale and retail prices are also well-predicted, with larger prediction errors for relatively minor product groupings such as dry whey products and evaporated, condensed and dry milk (Table C5).

Production of products is well predicted in most cases (Table C6). However, production of cheddar cheese, dry whey, NDM and evaporated, condensed and dried products is less well predicted. In the case of cheddar cheese, this is largely due to differences related to changes in final demand in the calibration process. For dry whey, this difference is due to assuming a higher whey demand to account for whey components disposed of in a manner other than dry whey production. Thus, for these two products, the larger discrepancy between the actual and observed outcomes is explained by other model assumptions. The differences between model predictions and observed values for NDM and evaporated, condensed and dried products indicate that the model is not capturing some intermediate product use. For both products, the model predictions are significantly below the observed values, which may in part be due to the level of spatial and temporal aggregation employed in our model. Although it is important to capture the role that intermediate products play in dairy market outcomes, it is unlikely that the larger differences in production values for these products has a significant impact on the predictions with regard to the key research questions. Model predictions of quantities demanded are quite good (Table C7), with PAD's ranging from 0.01% to 4.88%.

Table C4. Statistical Analysis of Model's Predictive Ability, Raw Milk Sector

Variable	Actual[1]	Model Predicted[2]	MAD[3]	PAD[4]	T[5]	r[6]
Raw milk supply						
Other US	132.09	132.16	0.08	0.06%		
California	33.25	33.33	0.08	0.23%		
Total	165.34	165.49	0.15	0.09%	0.000	1.0000
All-milk price						
Other US	15.23	15.26	0.03	0.18%		
California	13.72	13.79	0.07	0.52%		
Total	14.93	14.96	0.04	0.25%	0.002	1.000
Class utilization						
Other US						
I	38.17	37.52	0.65	1.71%		
II	9.82	7.90	1.92	19.58%		
III	44.19	45.81	1.62	3.66%		
IV	7.82	8.78	0.96	12.25%		
California					0.085	0.968
1	18.56	19.04	0.48	2.59%		
2&3	9.48	4.61	4.87	51.41%		
4b	43.41	54.68	11.27	25.96%		
4a	28.55	21.67	6.88	24.08%		
Class prices, $/cwt						
I	16.23	16.28	0.05	0.29%		
II	13.93	13.93	0.00	0.00%		
III	13.54	13.59	0.05	0.35%		
IV	13.23	13.23	0.00	0.00%		
California					0.001	0.999
1	15.36	15.36	0.00	0.02%		
2&3	13.84	13.84	0.00	0.01%		
4b	12.95	12.99	0.04	0.32%		
4a	13.09	13.09	0.00	0.01%		
Component Prices						
Fat	185.04	185.01	0.03	0.02%		
SNF	77.77	77.78	0.01	0.01%		
Protein	210.83	211.65	0.82	0.39%	0.002	1.000
Other SNF solids	13.40	13.70	0.30	2.20%		

[1] Observed or reference values.

[2] Calibrated base solution values.

[3] Mean Absolute Deviation.

[4] Percentage Absolute Deviation.

[5] Theil's coefficient.

[6] Correlation coefficient.

Table C5. Statistical Analysis of Model's Predictive Ability, Wholesale and Retail Prices

Product	Actual[1]	Model Predicted[2]	MAD[3]	PAD[4]	T[5]	r[6]
Fluid products						
Other US	2.75	2.75	0.01	0.25%		
California	2.84	2.84	0.00	0.11%		
Ice cream						
Other US	1.48	1.48	0.00	0.00%		
California	1.48	1.48	0.00	0.20%		
Yogurt						
Other US	1.29	1.29	0.00	0.23%		
California	1.29	1.29	0.00	0.00%		
Cottage cheese	1.35	1.35	0.00	0.30%		
Other US	1.35	1.35	0.00	0.30%		
California	1.35	1.35	0.00	0.30%		
All retail prices					0.001	1.000
Cheddar cheese	1.49	1.49	0.00	1.13%		
Other US	1.49	1.49	0.00	1.13%		
California	1.45	1.44	0.01	1.03%		
Other cheese	1.49	1.48	0.01	0.40%		
Other US	1.49	1.48	0.01	0.40%		
California	1.45	1.46	0.00	0.28%		
Dry whey products	0.29	0.28	0.00	1.75%		
Other US	0.29	0.28	0.00	1.75%		
California	0.26	0.25	0.01	3.14%		
Butter	1.64	1.65	0.01	0.37%		
Other US	1.64	1.65	0.01	0.37%		
California	1.62	1.60	0.02	1.36%		
NDM	0.95	0.93	0.01	1.27%		
Other US	0.95	0.93	0.01	1.27%		
California	0.92	0.93	0.01	1.19%		
Evap/cond/dried	0.40	0.39	0.01	2.50%		
Other US	0.40	0.39	0.01	2.50%		
California	0.40	0.39	0.01	2.50%		
All wholesale prices					0.005	0.999

Note: Fluid, ice cream, yogurt, and cottage cheese are retail prices; all others are wholesale.

[1] Observed or reference values, $/lb.

[2] Calibrated base solution values, $/lb.

[3] Mean Absolute Deviation, $/lb.

[4] Percentage Absolute Deviation.

[5] Theil's coefficient.

[6] Correlation coefficient.

Table C6. Statistical Analysis of Model's Predictive Ability, Production

Product	Actual[1]	Model Predicted[2]	MAD[3]	PAD[4]	T[5]	r[6]
Fluid products	56,104.6	56,136.0	31.36	0.06%		
Ice cream	6425.8	6,442.4	16.61	0.26%		
Yogurt	1,970.9	1,983.7	12.76	0.65%		
Cottage cheese	1,391.7	1,389.7	2.04	0.15%		
Cheddar cheese	3,551.8	3,922.0	370.16	10.42%		
Other cheese	4,014.4	4,175.9	161.47	4.02%		
Dry whey products	2,428.1	5,522.7	3,094.6	127.45%		
Butter	1,223.9	1,303.1	79.19	6.47%		
NDM	1,440.0	844.0	596.00	41.39%		
Evap/cond/dried	2,051.9	858.1	1,193.8	58.18%		
All Production					0.033	0.997

[1] Observed or reference values, million lbs.

[2] Calibrated base solution values, million lbs.

[3] Mean Absolute Deviation, $/lb.

[4] Percentage Absolute Deviation.

[5] Theil's coefficient.

[6] Correlation coefficient.

Table C7. Statistical Analysis of Model's Predictive Ability, Final Demand

Product	Actual[1]	Model Predicted[2]	MAD[3]	PAD[4]	T[5]	r[6]
Fluid products	56,104.6	56,136.0	31.36	0.06%		
Ice cream	6,346.7	6,345.9	0.76	0.01%		
Yogurt	1,971.4	1,973.1	1.67	0.08%		
Cottage cheese	1,391.7	1,389.7	2.04	0.15%		
Cheddar cheese	3,934.1	3,915.0	19.07	0.48%		
Other cheese	4,399.2	4,391.6	7.62	0.17%		
Dry whey products	5,031.0	4,986.9	44.14	0.88%		
Butter	1,337.4	1,333.7	3.72	0.28%		
NDM	366.2	384.1	17.88	4.88%		
Evap., cond. & dried	806.5	805.2	1.29	0.16%		
Casein	135.8	135.8	0.00	0.0%		
Caseinates	84.3	84.3	0.03	0.03%		
MPC>90%	15.3	15.3	0.01	0.04%		
MPC 42	14.7	14.0	0.68	4.63%		
MPC 56	20.9	20.9	0.01	0.05%		
MPC 70	20.9	20.9	0.01	0.04%		
All final demand					0.001	1.000

[1] Observed or reference values, million lbs.

[2] Calibrated base solution values, million lbs.

[3] Mean Absolute Deviation, \$/lb.

[4] Percentage Absolute Deviation.

[5] Theil's coefficient.

[6] Correlation coefficient.

Note that actual CCC purchases of NDM equaled 259.9 million lbs, model prediction equaled 259.5 million lbs, which implies that MAD = 0.43 and PAD = 0.16%.

Although not statistically compared with known reference values, we conclude this appendix by presenting the composition of final products in the base case scenario. Final product composition is determined endogenously and is a function of the composition of various inputs that were combined in order to produce each of the final products. It is yet another measure of the validity of the base case scenario that the values shown in Table C8 correspond with what we understand the actual composition of the final product (aggregates) to be.

Table C8. Composition of Final Products from US Plants

Product	Region	Composition			
		% Fat	% SNF	% Protein	% Other Solids
Fluid products	Other US	2.65	8.81	3.14	5.67
	California	2.36	9.64	3.43	6.21
Ice cream	Other US	9.17	9.74	3.47	6.27
	California	9.17	9.74	3.47	6.27
Yogurt	Other US	1.55	13.55	4.81	8.69
	California	1.55	13.55	4.81	8.69
Cottage cheese	Other US	15.41	15.40	5.49	9.91
	California	15.41	15.40	5.49	9.91
Cheddar cheese	Other US	33.42	28.58	25.50	3.08
	California	33.44	28.56	25.50	3.06
Other cheese	Other US	24.60	26.84	22.50	4.34
	California	24.60	26.84	22.50	4.34
Dry whey products	Other US	5.31	90.69	11.75	78.93
	California	4.41	91.59	11.81	79.78
Butter	Other US	81.70	1.30	0.46	0.84
	California	81.71	1.29	0.46	0.83
NDM	Other US	0.79	95.21	33.93	61.29
	California	0.80	95.20	33.92	61.28
Evap., cond. & dried	Other US	6.69	25.81	9.20	16.61
	California	2.56	29.94	10.67	19.27

APPENDIX D. ADDITIONAL RESULTS

Table D1. Raw Milk Supply by Scenario, Million Pounds

Scenario	Other US	California
Base	132,162	33,327
No Chapter 4 MPC imports	132,413	33,372
TRQ without compensation	132,637	33,491
TRQ with compensation	131,812	33,163
MPC and Casein subsidy	133,061	34,032
Tilt	131,521	32,940

Table D2. Raw Milk Shipments to Plants by Scenario, Million Pounds

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Other US						
Fluid products	51,108	50,966	50,639	50,928	50,172	51,228
Yogurt	2,816	2,818	2,823	2,820	2,828	2,808
Cottage cheese	1,977	1,988	2,022	2,006	2,066	1,977
Cheddar cheese	25,750	25,287	22,580	22,893	19,690	25,389
Other cheese	35,291	28,194	27,957	26,891	27,692	35,440
NDM	14,079	14,118	14,246	14,186	14,403	14,050
Evap., cond. & dried	1,141	1,138	1,141	1,108	1,176	59
Casein	–	–	3,700	3,709	5,519	–
MPC 42	–	6,952	6,894	6,638	9,251	–
MPC 56	–	427	374	374	186	300
MPC 70	–	525	260	259	80	270
California						
Fluid products	6,568	6,556	6,516	6,552	6,462	6,594
Yogurt	392	392	393	393	393	413
Cottage cheese	278	279	284	282	289	278
Cheddar cheese	12,857	13,016	15,020	15,117	17,134	13,596
Other cheese	5,580	5,550	4,468	4,509	4,423	5,605
NDM	7,652	7,555	6,774	6,260	2,832	6,171
Evap., cond. & dried	–	–	36	50	30	284
MPC 42	–	24	–	–	2,468	–
MPC 56	–	-	–	–	-	–
MPC 70	–	-	–	–	-	–

Table D3. Production of Intermediate Products by Scenario, Million Pounds

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Other US						
NDM	286.63	281.49	251.36	254.84	–	275.02
MPC 42	0.00	483.34	479.28	460.99	646.98	–
Cream	2,212.25	2,294.46	2,585.24	2,570.63	2,915.58	2,268.91
Skim milk	–	–	–	–	–	1,176.05
Ice cream mix	5,572.74	5,588.22	5,639.04	5,615.22	5,701.03	5,561.44
Fluid whey	54,455.05	55,202.31	55,474.96	54,584.48	56,004.74	54,742.95
Buttermilk	1,000.51	1,042.49	1,191.17	1,184.74	1,359.64	1,029.99
California						
NDM	166.86	194.45	275.35	277.53	65.71	166.86
MPC 42	–	–	–	–	174.40	–
Cream	805.27	796.46	627.93	586.23	490.07	805.27
Ice cream mix	869.67	876.28	899.27	888.74	927.62	869.67
Fluid whey	16,593.73	16,757.88	17,636.72	17,761.81	21,720.00	16,593.73
Buttermilk	397.91	393.23	305.19	283.66	233.08	397.91

Table D4. Production of Final Products by Scenario, Million Pounds

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Other US						
Fluid products	49,712.63	49,574.15	49,256.48	49,537.26	48,801.89	49,829.10
Ice cream	5,572.74	5,588.22	5,639.04	5,615.22	5,701.03	5,561.44
Yogurt	1,743.28	1,744.17	1,747.28	1,745.58	1,750.30	1,738.38
Cottage cheese	1,220.18	1,226.54	1,247.44	1,237.92	1,274.64	1,220.17
Cheddar cheese	2,635.64	2,588.34	2,311.26	2,343.27	2,009.47	2,598.54
Other cheese	3,610.41	3,591.97	3,561.82	3,425.92	3,528.00	3,625.66
Dry whey products	4,232.17	4,224.71	4,217.42	4,153.76	4,071.91	4,236.47
Butter	932.41	971.53	1,110.08	1,104.09	1,267.08	959.87
NDM	432.72	439.87	476.56	470.00	735.92	331.06
Evap., cond. & dried	738.64	750.14	796.47	781.81	860.90	665.26
Casein	–	–	95.48	95.72	142.41	–
MPC42	–	12.23	12.21	12.20	12.50	–
MPC56	–	22.21	19.45	19.45	9.66	15.57
MPC70	–	21.42	10.60	10.59	3.25	11.02
California						
Fluid products	6,423.33	6,410.97	6,372.50	6,407.22	6,319.31	6,448.75
Ice cream	869.67	876.28	899.27	888.74	927.62	881.22
Yogurt	240.38	240.51	240.90	240.73	241.31	252.98
Cottage cheese	169.48	170.37	173.27	171.98	176.45	169.74
Cheddar cheese	1,286.32	1,302.96	1,503.60	1,513.27	1,710.58	1,360.98
Other cheese	565.46	562.43	556.58	561.75	551.04	567.97
Dry whey products	1,290.49	1,305.59	1,440.66	1,451.01	1,584.97	1,350.78
Butter	370.68	366.32	284.31	264.25	217.13	307.45
NDM	411.28	374.79	224.87	179.59	94.00	249.57
Evap., cond. & dried	119.50	118.09	105.11	104.10	81.41	205.79
MPC 42	–	1.70	–	–	–	–

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
MPC 56	–	-	–	–	–	–
MPC 70	–	-	–	–	–	–

Table D5. Prices (At Plants) of Final Products, by Scenario, $/lb

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Other US						
Fluid products	1.63	1.66	1.73	1.66	1.84	1.60
Ice cream	0.33	0.33	0.30	0.31	0.27	0.34
Yogurt	0.21	0.21	0.20	0.21	0.20	0.20
Cottage cheese	0.48	0.47	0.42	0.44	0.37	0.48
Cheddar cheese	1.49	1.51	1.57	1.51	1.65	1.46
Other cheese	1.48	1.51	1.56	1.51	1.62	1.46
Dry whey products	0.28	0.28	0.27	0.27	0.27	0.28
Butter	1.65	1.57	1.34	1.44	1.05	1.70
NDM	0.93	0.93	0.93	0.93	0.93	0.86
Evap., cond. & dried	0.39	0.38	0.35	0.37	0.32	0.38
Casein	–	–	2.44	2.43	1.49	–
MPC 42	–	1.09	1.10	1.10	1.05	–
MPC 56	–	1.40	1.41	1.41	1.43	1.29
MPC 70	–	1.89	1.91	1.91	1.93	1.75
California						
Fluid products	1.59	1.61	1.68	1.62	1.78	1.54
Ice cream	0.32	0.31	0.29	0.30	0.26	0.32
Yogurt	0.21	0.21	0.20	0.21	0.20	0.20
Cottage cheese	0.46	0.45	0.41	0.43	0.36	0.46
Cheddar cheese	1.44	1.46	1.52	1.46	1.60	1.41
Other cheese	1.46	1.49	1.54	1.49	1.60	1.44
Dry whey products	0.25	0.24	0.22	0.23	0.22	0.23
Butter	1.60	1.52	1.29	1.39	1.05	1.65
NDM	0.93	0.93	0.93	0.93	0.93	0.84
Evap., cond. & dried	0.39	0.38	0.36	0.37	0.33	0.38
MPC 42	–	1.13	–	–	–	–

Region, Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
MPC 56	–	-	–	–	–	–
MPC 70	–	-	–	–	–	–

Table D6. Demand of Final Products in Other US Region by Scenario, Million Pounds

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Fluid products	49,712.63	49,574.15	49,256.48	49,537.26	48,801.89	49,829.10
Ice cream	5,572.74	5,588.22	5,639.04	5,615.22	5,701.03	5,570.65
Yogurt	1,732.69	1,733.49	1,736.28	1,734.75	1,738.96	1,738.38
Cottage cheese	1,220.18	1,226.54	1,247.44	1,237.92	1,274.64	1,220.17
Cheddar cheese	3,340.11	3,314.98	3,252.21	3,317.68	3,176.61	3,370.89
Other cheese	3,862.11	3,843.67	3,813.52	3,844.26	3,779.70	3,877.36
Dry whey products	4,232.33	4,224.89	4,290.60	4,259.85	4,289.91	4,249.69
Butter	1,137.91	1,150.84	1,197.05	1,175.68	1,271.58	1,128.95
NDM	346.49	347.00	347.60	347.93	339.44	342.66
Evap., cond. & dried	702.98	707.50	722.98	715.60	743.38	707.94
Casein	119.20	119.20	112.40	112.54	143.56	119.20
Caseinate	73.98	73.98	64.40	64.46	73.98	73.98
MPC>90%	13.40	13.40	11.58	11.59	13.40	13.40
MPC 42	12.25	12.23	12.21	12.20	12.50	12.38
MPC 56	18.36	19.52	19.45	19.45	19.34	20.32
MPC 70	18.36	18.82	18.73	18.74	18.64	19.54

Table D7. Demand of Final Products in California by Scenario, Million Pounds

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Fluid products	6,423.33	6,410.97	6,372.50	6,407.22	6,319.31	6,448.75
Ice cream	773.20	775.40	782.46	779.34	790.00	774.00
Yogurt	240.38	240.51	240.90	240.73	241.31	241.53
Cottage cheese	169.48	170.37	173.27	171.98	176.45	169.74
Cheddar cheese	574.88	570.39	559.21	570.87	545.77	580.37
Other cheese	529.49	526.98	522.11	526.41	517.48	531.57
Dry whey products	754.54	759.21	777.91	771.19	777.76	768.98
Butter	195.79	198.09	206.35	202.52	217.13	194.20
NDM	37.64	38.20	38.03	38.01	37.09	37.57
Evap., cond. & dried	102.25	102.91	105.11	104.10	107.68	103.44
Casein	16.60	16.60	15.65	15.67	19.99	16.60
Caseinate	10.30	10.30	8.96	8.97	10.30	10.30
MPC>90%	1.90	1.90	1.64	1.64	1.90	1.90
MPC 42	1.73	1.70	1.71	1.71	1.75	1.73
MPC 56	2.57	2.69	2.68	2.69	2.70	2.84
MPC 70	2.57	2.60	2.62	2.62	2.60	2.73

Table D8. Demand Prices of Final Products in Other US Region by Scenario, $/lb

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Fluid products[1]	2.75	2.78	2.85	2.78	2.96	2.72
Ice cream	1.48	1.47	1.45	1.46	1.41	1.48
Yogurt	1.29	1.29	1.28	1.28	1.28	1.28
Cottage cheese	1.35	1.34	1.30	1.32	1.24	1.35
Cheddar cheese	1.51	1.53	1.59	1.53	1.66	1.48
Other cheese	1.50	1.53	1.57	1.53	1.63	1.47
Dry whey products	0.29	0.30	0.28	0.29	0.28	0.29
Butter	1.66	1.59	1.36	1.46	1.07	1.72
NDM	0.95	0.95	0.95	0.95	0.95	0.87
Evap., cond. & dried	0.40	0.39	0.37	0.38	0.33	0.39
Casein	2.18	2.18	2.45	2.45	1.50	2.18
Caseinate	2.34	2.34	3.09	3.08	2.34	2.34
MPC>90%	2.21	2.21	2.96	2.96	2.21	2.21
MPC 42	1.11	1.11	1.11	1.12	1.06	0.99
MPC 56	1.60	1.42	1.43	1.43	1.44	1.31
MPC 70	2.00	1.91	1.92	1.92	1.94	1.77

[1] Price for fluid products is $/gallon

Table D9. Demand Prices of Final Products in California by Scenario, $/lb

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Fluid products[1]	2.84	2.86	2.93	2.87	3.03	2.80
Ice cream	1.48	1.47	1.45	1.46	1.42	1.48
Yogurt	1.29	1.29	1.29	1.29	1.28	1.28
Cottage cheese	1.35	1.34	1.30	1.31	1.25	1.35
Cheddar cheese	1.45	1.47	1.53	1.47	1.61	1.42
Other cheese	1.47	1.50	1.56	1.50	1.61	1.45
Dry whey products	0.26	0.25	0.23	0.24	0.23	0.24
Butter	1.61	1.54	1.30	1.41	1.06	1.66
NDM	0.94	0.94	0.94	0.94	0.94	0.85
Evap., cond. & dried	0.40	0.39	0.37	0.38	0.34	0.39
Casein	2.18	2.18	2.45	2.45	1.50	2.18
Caseinate	2.34	2.34	3.09	3.08	2.34	2.34
MPC>90%	2.21	2.21	2.96	2.96	2.21	2.21
MPC 42	1.11	1.14	1.13	1.13	1.08	0.99
MPC 56	1.60	1.46	1.46	1.46	1.44	1.31
MPC 70	2.00	1.95	1.92	1.92	1.94	1.77

[1] Price for fluid products is $/gallon

Table D10. Total Imports by Scenario, Million Pounds

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Ice cream	9.23	9.10	8.70	8.88	8.29	9.21
Cheddar cheese	37.00	37.00	37.00	75.06	39.91	37.00
Other cheese	251.70	251.70	251.70	418.35	251.70	251.70
Dry whey products	0.17	0.17	0.13	0.15	0.13	0.15
Butter	35.01	15.84	15.40	15.40	15.40	60.03
NDM	11.60	11.60	11.60	11.60	11.60	11.60
Evap., cond. & dried	45.89	42.96	34.28	38.17	26.27	42.68
Casein	135.80	135.80	32.57	32.50	21.15	135.80
Caseinate	84.27	84.27	73.37	73.43	84.27	84.27
MPC>90%	15.29	15.29	13.22	13.23	15.29	15.29
MPC 42	34.52	–	16.95	16.98	29.82	20.09
MPC 56	20.92	–	7.17	7.12	12.39	7.58
MPC 70	20.93	–	10.75	10.77	17.99	11.25

Table D11. Import Supply Prices (at Point of Origin) by Scenario, $/lb

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Ice cream	1.24	1.23	1.21	1.22	1.18	1.23
Cheddar cheese	1.17	1.17	1.17	1.26	1.18	1.17
Other cheese	1.32	1.32	1.32	1.39	1.32	1.32
Dry whey products	0.27	0.28	0.26	0.27	0.26	0.27
Butter	0.96	0.89	0.89	0.89	0.89	1.02
NDM	0.58	0.58	0.58	0.58	0.58	0.58
Evap., cond. & dried	0.33	0.32	0.29	0.30	0.26	0.32
Casein	2.18	2.18	1.64	1.64	1.50	2.18
Caseinate	2.34	2.34	2.28	2.28	2.34	2.34
MPC>90%	2.21	2.21	2.15	2.15	2.21	2.21
MPC 42	1.11	0.00	0.96	0.96	1.07	0.99
MPC 56	1.60	0.00	1.29	1.29	1.44	1.31
MPC 70	2.00	0.00	1.75	1.75	1.94	1.77

Table D12. Destination of Imports by Use and Scenario, Million Pounds

Product	Destination	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Intermediate Use							
MPC 42	Other US	–	–	–	–	–	5.97
	California	20.55	–	15.24	15.27	28.07	–
MPC 56	California	–	–	4.49	4.43	–	–
Final Use							
Ice cream	Other US	–	–	–	–	–	9.21
	California	9.23	9.10	8.70	8.88	8.29	–
Cheddar cheese	Other US	37.00	37.00	37.00	75.06	39.91	37.00
Other cheese	Other US	251.70	251.70	251.70	418.35	251.70	251.70
Dry whey products	Other US	0.17	0.17	0.13	0.15	0.13	0.15
Butter	Other US	35.01	15.84	15.40	15.40	15.40	60.03
NDM	Other US	11.60	11.60	11.60	11.60	11.60	11.60
Evap., cond. & dried	Other US	45.89	42.96	34.28	38.17	–	42.68
	California					26.27	
Casein	Other US	119.20	119.20	16.92	16.83	1.16	119.20
	California	16.60	16.60	15.65	15.67	19.99	16.60
Caseinate	Other US	73.98	73.98	64.40	64.46	73.98	73.98
	California	10.30	10.30	8.96	8.97	10.30	10.30
MPC>90%	Other US	13.40	13.40	11.58	11.59	13.40	13.40
	California	1.90	1.90	1.64	1.64	1.90	1.90
MPC 42	Other US	12.25	–	–	–	–	12.38
	California	1.73	–	1.71	1.71	1.75	1.73
MPC 56	Other US	18.36	–	–	–	9.69	4.74
	California	2.57	–	2.68	2.69	2.70	2.84
MPC 70	Other US	18.36	–	8.13	8.15	15.39	8.52
	California	2.57	–	2.62	2.62	2.60	2.73

Table D13. US Export Quantities and Prices by Scenario

Product	Base	No Chapter 4 MPC Imports	TRQ Without Compensation	TRQ with Compensation	Subsidy	Tilt
Exports	(million lbs)					
Ice cream	105.70	109.98	125.51	118.27	145.92	107.22
Cheddar cheese	43.97	42.94	40.44	43.05	37.57	45.25
Other cheese	35.97	35.45	34.47	35.34	33.56	36.40
Dry whey products	535.95	546.38	589.70	573.87	589.35	568.73
Butter	4.41	4.75	6.39	5.53	10.90	4.20
NDM	212.00	212.00	212.00	212.00	212.00	212.00
Evap., cond. & dried	98.79	100.77	107.77	104.39	117.51	102.35
Prices	($/lb)					
Ice cream	0.32	0.31	0.29	0.30	0.26	0.32
Cheddar cheese	1.44	1.46	1.52	1.46	1.60	1.41
Other cheese	1.46	1.49	1.54	1.49	1.60	1.44
Dry whey products	0.25	0.24	0.22	0.23	0.22	0.23
Butter	0.78	0.71	0.48	0.58	0.23	0.84
NDM	0.55	0.55	0.55	0.55	0.55	0.55
Evap., cond. & dried	0.39	0.38	0.35	0.37	0.32	0.38