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Economic Implications of the Australia-U.S. Free Trade Agreement for U.S. Dairy Markets and Domestic Dairy Farm Programs

Selected Paper, AAEA Annual Meetings
Denver, Colorado, August 2-5, 2004,

Draft: May 15, 2004

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Short Abstract

We develop a simulation model to analyze the effects on U.S. milk markets of an Australia-U.S. free trade agreement. An important contribution to the literature is the derivation of explicit supply and demand relationships for milk components, which allows an analysis of long-term production, consumption, and trade patterns that is not tied to specific products. Simulations indicate that increased imports from Australia, resulting from bilateral trade liberalization, would result in modest reductions in U.S. milk prices and production.

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1. Issues and Approach

In February 2004, negotiators from Australia and the United States reached accord on a bilateral trade agreement between the two countries. Agricultural commodities, including dairy, sugar, and beef, were featured in negotiations building up to the accord, as Australians sought increased access to the U.S. market, and U.S. producers sought continued protection. The negotiated agreement resulted in very modest increases in Australian access to U.S. markets for these commodities. In the case of dairy, the United States agreed to expand Australian access gradually through a preferential tariff rate quota (TRQ). Under the agreement, the United States will increase Australia's low-tariff access to the U.S. market for those products already under TRQ. The agreement leaves unaltered the existing over-quota tariff rates for dairy products.

The purpose of this analysis was to develop a quantitative understanding of the implications for the U.S. dairy industry of the various policy scenarios that may have resulted from a bilateral free trade agreement between Australia and the United States (the AUS-FTA). We focused on the impacts of the AUS-FTA on the quantity of U.S. imports, the prices of milk components, the quantity of milk produced in the United States, and the farm-level price of U.S. milk. Also of interest were the impacts of the AUS-FTA on domestic dairy programs in the United States.

To evaluate the impacts of various policy alternatives we develop a simulation model of the global market for dairy products, focusing on Australia and the United States as elements of that market. We allow for the fact that much of the potential global dairy market is not open to market-driven trade, and significant trade (such as exports from the European Union) is largely insulated from market forces by government policy.

New Zealand enters the model as a primary competitor for Australia in the more open import markets, which are modeled in aggregate. This paper develops the simulation model in detail, and presents and interprets the quantitative findings. The implications for the dairy price support and direct payments are also discussed.

2. An Equilibrium Displacement Model of World Trade in Dairy Components

Our model represents the markets for both raw milk and dairy products in terms of the corresponding implicit markets for the fat and solids-not-fat (snf) components of milk and dairy products. The model specifies supply and demand equations for each component from four "regions": Australia (A), the United States (U), New Zealand (Z), and the market-based trade-exposed countries of the rest-of-the-world (R). Domestic and global market clearing is represented by treating the trade in dairy products in terms of the equivalent transactions in fat and snf components, under an assumption that the shadow values of these components are equated among products. Similar approaches have been used previously to analyze dairy trade (e.g., Chavas, Cox, and Jesse).

Global market-clearing conditions on quantities mean that the total amount of fat and snf in raw milk produced at the farm level, globally, is equal to the total amount of fat and snf in the dairy products sold at wholesale, globally. Within a country (or region), national market-clearing conditions on prices mean that the price of raw milk is determined by the implicit prices and quantities of the fat and snf components in the milk. Similarly, the prices of dairy products depend on the same implicit prices and the product-specific quantities of the fat and snf components, as well as other costs of production. The prices of dairy products (and thus the implicit prices of the components) are linked among countries by price transmission equations, reflecting trade barriers in some instances; and within the United States there are policy wedges associated with price supports and government purchases which, when they are binding, modify both the price and quantity market-clearing conditions. Consequently, the supply and demand of milk components are linked both within and among countries.

Raw milk production yields both fat and snf in ratios that vary by country, but are not readily responsive to fairly small changes in relative market prices of the components. Dairy products also contain fat and snf in differing proportions. The composition of individual products is not readily adjustable, however the proportions of products are flexible in response to relative prices. Hence the mixture of products produced and consumed in a market adjusts to respond to changes in the supply of fat and snf that may occur because of changes in the import or export mix.

The model shows how markets respond to specific adjustments in U.S. dairy import barriers. In our analysis, other U.S. policies remain in place when the import barriers facing Australia are relaxed to represent the implementation of the AUS-FTA or other trade agreements. In particular the U.S. price support policy remains in force.

U.S. Derived Supply of Fat and Non-Fat Components

The supply equation for U.S. raw milk (*M*) as a function of the all-milk price (*P*), can be represented in general form, and using a linear functional form, as follows:

(1) $$M = m(P) = b_0 + b_1 P .$$

Market clearing requires linking the prices of products to the price of raw milk, through the prices of their fat and snf components. The all-milk price is equal to the sum of the values, per hundredweight of milk, of the fat and snf components, given by the product of the shadow-value of fat (W_f) times the quantity of fat per hundredweight (*f*) plus the shadow-value of the non-fat component (W_n) times the quantity of snf components per hundredweight (n) in raw milk:

(2) $P = fW_f + nW_n$.

Substituting (2) into (1) and totally differentiating yields

(3) $dM = b_1 dP = b_1 f dW_f + b_1 n dW_n$.

The corresponding changes in total quantities of fat and snf components produced by the United States are given by

(4) $dF = f dM = b_1 f^2 dW_f + b_1 fn dW_n$, and

(5) $dN = n dM = b_1 nf dW_f + b_1 n^2 dW_n$.

To parameterize these equations we require information on the fat and snf component quantities in milk (i.e., f and n), and the slope of supply (b_1), which can be defined in terms of the elasticity of supply of milk (ε) as follows:

(6) $b_1 = \dfrac{\partial M}{\partial P} = \dfrac{M}{P}\varepsilon$.

Substituting equation (6) into equations (4) and (5) and rearranging terms yields:

(7) $\dfrac{dF}{F} = s_f \varepsilon \dfrac{dW_f}{W_f} + s_n \varepsilon \dfrac{dW_n}{W_n}$, and

(8) $\dfrac{dN}{N} = s_f \varepsilon \dfrac{dW_f}{W_f} + s_n \varepsilon \dfrac{dW_n}{W_n}$,

where $s_f = W_f F/PM$ is the value of milk fat as a share of the total value of raw milk, and $s_n = W_n N/PM$ is the value of snf as a share of the total value (and $s_n = 1 - s_f$). The supply equations for the two components ((7) and (8)) have the same structure as one another, and are identical to the corresponding proportional change form of the supply equation for raw milk, because the two components are produced in fixed proportions to one another and to the quantity of milk (i.e., $dF/F = dN/N = dM/M$).

U.S. Derived Demand for Fat and Non-Fat Components of Dairy Products

The quantity demanded for each milk product (X_j) depends on its own price and the prices of the other milk products, and we allow for a total of five products, namely: (a) fluid milk (including cream), (b) cheese, (c) butter (including butter oil), (d) skim milk powder, and (e) a residual "other" comprising products such as whole milk powder, yogurt, sour cream, ice cream, casein, and so on.

(9) $X_i = x_i(P_1, ..., P_J)$.

Competitive market clearing is imposed with an assumption that the price of each product, *i*, the price is equal to its costs of production or "make allowance" (g_i) plus the costs of its fat and snf components, which depend on the product-specific quantities of those components (f_i and n_i) and their market-wide shadow values (W_f and W_n):

(10) $P_i = g_i + W_f f_i + W_n n_i$.

The total amount of fat consumed is equal to the sum across the products of the product-specific fat per unit times the number of units consumed; similarly for snf:

(11) $F = \sum_{j=1}^{J} f_j X_j$, and

(12) $N = \sum_{j=1}^{J} n_j X_j$.

To derive equations for the demands for components as functions of the prices of the components, we replace the product quantities in equations (11) and (12) with the corresponding demand equations from equation (9), and use equation (10) to replace the product prices with the prices of the components. Before making the substitutions, it is helpful to express the equations in differential form, as follows:

(13) $$dX_i = \sum_{j=1}^{J} \frac{\partial X_i}{\partial P_j} dP_j = \sum_{j=1}^{J} a_{ij} dP_j ,$$

(14) $$dP_j = f_j dW_f + n_j dW_n ,$$

(15) $$dF = \sum_{j=1}^{J} f_j dX_j \text{ , and}$$

(16) $$dN = \sum_{j=1}^{J} n_j dX_j \text{ .}$$

Substituting (14) into (13),

(17) $$dX_i = \sum_{j=1}^{J} a_{ij} (f_j dW_f + n_j dW_n) .$$

Next, substituting (17) into (15) and (16) yields equations for the quantities of fat and non-fat components as functions of their prices:

(18) $$dF = \sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} (f_i f_j dW_f + f_i n_j dW_n) = \left(\sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} f_i f_j \right) dW_f + \left(\sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} f_i n_j \right) dW_n ,$$

(19) $$dN = \sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} (n_i f_j dW_f + n_i n_j dW_n) = \left(\sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} n_i f_j \right) dW_f + \left(\sum_{i=1}^{I} \sum_{j=1}^{J} a_{ij} n_i n_j \right) dW_n .$$

To parameterize these equations we require information on the fat and non-fat component quantities for each of the products (i.e., f_i and n_i), and the matrix of demand coefficients, which can be defined in terms of the own- and cross-price elasticities of demand ($\eta_{ij} = d\ln X_i / d\ln P_j$) as follows:

(20) $$a_{ij} = \frac{\partial X_i}{\partial P_j} = \frac{X_i}{P_j} \eta_{ij} .$$

Substituting equation (20) into equations (18) and (19) yields

(21) $$dF = \left(\sum_{i=1}^{I} \sum_{j=1}^{J} f_i f_j \eta_{ij} \tfrac{X_i}{P_j} \right) dW_f + \left(\sum_{i=1}^{I} \sum_{j=1}^{J} f_i n_j \eta_{ij} \tfrac{X_i}{P_j} \right) dW_n \text{ , and}$$

(22) $$dN = \left(\sum_{i=1}^{I} \sum_{j=1}^{J} n_i f_j \eta_{ij} \tfrac{X_i}{P_j} \right) dW_f + \left(\sum_{i=1}^{I} \sum_{j=1}^{J} n_i n_j \eta_{ij} \tfrac{X_i}{P_j} \right) dW_n .$$

These equations show changes in demand for fat and non-fat components as linear functions of changes in the prices of fat and non-fat components, where the coefficients are defined in terms of own- and cross-price elasticities of demand for products, the content of those products in terms of fractions of fat and snf, and the quantities and prices of the products. In practice, we assume that the cross-price elasticities among our five broad categories of dairy products are zero (such that $\eta_{ij} = 0$ for $i \neq j$), as is consistent with most of the estimates in the literature and is intuitively reasonable, and hence the coefficients in the U.S. demand equations for fat and snf are simplified as follows:

(23) $$dF = \left(\sum_{i=1}^{5} f_i^2 \eta_{ii} \tfrac{X_i}{P_i} \right) dW_f + \left(\sum_{i=1}^{5} f_i n_i \eta_{ii} \tfrac{X_i}{P_i} \right) dW_n \text{, and}$$

(24) $$dN = \left(\sum_{i=1}^{5} n_i f_i \eta_{ii} \tfrac{X_i}{P_i} \right) dW_f + \left(\sum_{i=1}^{5} n_i^2 \eta_{ii} \tfrac{X_i}{P_i} \right) dW_n .$$

Elasticities of Demand for Fat and Non-Fat Components

To express these equations in terms of elasticities of demand for fat and snf we transform the equations into proportional change form as follows:

(25) $$\frac{dF}{F} = \left(\sum_{i=1}^{5} f_i^2 \eta_{ii} \tfrac{W_f}{F} \tfrac{X_i}{P_i} \right) \frac{dW_f}{W_f} + \left(\sum_{i=1}^{5} f_i n_i \eta_{ii} \tfrac{W_n}{F} \tfrac{X_i}{P_i} \right) \frac{dW_n}{W_n} \text{, and}$$

(26) $$\frac{dN}{N} = \left(\sum_{i=1}^{5} f_i n_i \eta_{ii} \tfrac{W_f}{N} \tfrac{X_i}{P_i} \right) \frac{dW_f}{W_f} + \left(\sum_{i=1}^{5} n_i^2 \eta_{ii} \tfrac{W_n}{N} \tfrac{X_i}{P_i} \right) \frac{dW_n}{W_n} .$$

Then, rearranging terms yields:

(27) $$\frac{dF}{F} = \left(\sum_{i=1}^{5} \eta_{ii} \tfrac{W_f F_i}{P_i X_i} \tfrac{F_i}{F} \right) \frac{dW_f}{W_f} + \left(\sum_{i=1}^{5} \eta_{ii} \tfrac{W_n N_i}{P_i X_i} \tfrac{F_i}{F} \right) \frac{dW_n}{W_n} = \eta_{ff} \frac{dW_f}{W_f} + \eta_{fn} \frac{dW_n}{W_n} \text{, and}$$

(28) $$\frac{dN}{N} = \left(\sum_{i=1}^{5} \eta_{ii} \tfrac{W_f F_i}{P_i X_i} \tfrac{N_i}{N} \right) \frac{dW_f}{W_f} + \left(\sum_{i=1}^{5} \eta_{ii} \tfrac{W_n N_i}{P_i X_i} \tfrac{N_i}{N} \right) \frac{dW_n}{W_n} = \eta_{nf} \frac{dW_f}{W_f} + \eta_{nn} \frac{dW_n}{W_n} .$$

Each of the elasticities of demand for fat and snf components in these equations depends on the elasticities of demand for the final products (i.e., η_{ii} for $i = 1, \ldots, 5$) weighted by the value of the component whose price is changing as a share of the value of the product, times the importance of that product as a source of the component.

U.S. Supply and Demand for Fat and Non-Fat Components

Beginning with equations (23) and (24), which express the demands in differential form, we can write linear equations for demand for fat and snf components of milk and dairy products produced and consumed in the United States as follows (noting that we have introduced superscripts D and S to represent demand and supply, and U to denote the United States, anticipating the introduction of corresponding equations for the other regions in the model):

U.S. Demand

(29) $$F^{DU} = \left(F^{DU}\right)^{BASE} + \alpha_{ff}^{U} dW_f^U + \alpha_{fn}^{U} dW_n^U$$

(30) $$N^{DU} = \left(N^{DU}\right)^{BASE} + \alpha_{nf}^{U} dW_f^U + \alpha_{nn}^{U} dW_n^U$$

In these equations, current quantities demanded are equal to the quantities that would be demanded with prices at their base values, plus the changes in quantities that would result from changes in the prices of their components relative to their base values:

$$dW_f^U = W_f^U - \left(W_f^U\right)^{BASE},$$

where the base values for the quantities and prices are the values that would prevail in the scenario in question in the absence of the AUS-FTA.

The parameters (own- and cross-price slopes) of the demand equations are defined in terms of the U.S. elasticities of demand for components, and the base vales of market prices and quantities, as follows:

$$(31)\qquad \begin{pmatrix} \alpha_{ff}^U & \alpha_{fn}^U \\ \alpha_{nf}^U & \alpha_{nn}^U \end{pmatrix} = \begin{pmatrix} \eta_{ff}^U \left(\dfrac{F^{DU}}{W_f^U} \right)^{BASE} & \eta_{fn}^U \left(\dfrac{F^{DU}}{W_n^U} \right)^{BASE} \\ \eta_{nf}^U \left(\dfrac{N^{DU}}{W_f^U} \right)^{BASE} & \eta_{nn}^U \left(\dfrac{N^{DU}}{W_n^U} \right)^{BASE} \end{pmatrix},$$

and the superscript "BASE" denotes that the slopes of the demand equations will be revised when we revise the base values of the quantities and prices for the simulation. The elasticities of demand for components are defined using actual 2002 data for prices and quantities produced and consumed, and elasticities of demand for products, according to:

$$(32)\qquad \begin{pmatrix} \eta_{ff}^U & \eta_{fn}^U \\ \eta_{nf}^U & \eta_{nn}^U \end{pmatrix} = \begin{pmatrix} \sum_{i=1}^{5} \eta_{ii} \frac{W_f F_i}{P_i X_i} \frac{F_i}{F} & \sum_{i=1}^{5} \eta_{ii} \frac{W_n N_i}{P_i X_i} \frac{F_i}{F} \\ \sum_{i=1}^{5} \eta_{ii} \frac{W_f F_i}{P_i X_i} \frac{N_i}{N} & \sum_{i=1}^{5} \eta_{ii} \frac{W_n N_i}{P_i X_i} \frac{N_i}{N} \end{pmatrix},$$

and these elasticities are held constant across the alternative scenarios.

U.S. Supply

The supply equations, similarly, are based on the differential form, and parameterized in terms of base values of the prices and quantities of fat and snf components, and price slopes:

$$(33)\qquad F^{SU} = \left(F^{SU}\right)^{BASE} + \beta_{ff} dW_f^U + \beta_{fn} dW_n^U$$

$$(34)\qquad N^{SU} = \left(N^{SU}\right)^{BASE} + \beta_{nf} dW_f^U + \beta_{nn} dW_n^U$$

As for the demand equations, the parameters (own- and cross-price slopes) of the supply equations are defined in terms of the U.S. elasticities of supply for components, and their underlying determinants, as follows

$$\begin{pmatrix} \beta_{ff}^U & \beta_{fn}^U \\ \beta_{nf}^U & \beta_{nn}^U \end{pmatrix} = \begin{pmatrix} \varepsilon_{ff}^U \left(\frac{F^{SU}}{W_f^U} \right)^{BASE} & \varepsilon_{fn}^U \left(\frac{F^{SU}}{W_n^U} \right)^{BASE} \\ \varepsilon_{nf}^U \left(\frac{N^{SU}}{W_f^U} \right)^{BASE} & \varepsilon_{nn}^U \left(\frac{N^{SU}}{W_n^U} \right)^{BASE} \end{pmatrix}$$

(35)

$$= \begin{pmatrix} s_f^U \varepsilon^U \left(\frac{F^{SU}}{W_f^U} \right)^{BASE} & s_n^U \varepsilon^U \left(\frac{F^{SU}}{W_n^U} \right)^{BASE} \\ s_f^U \varepsilon^U \left(\frac{N^{SU}}{W_f^U} \right)^{BASE} & s_n^U \varepsilon^U \left(\frac{N^{SU}}{W_n^U} \right)^{BASE} \end{pmatrix}$$

and the superscript "BASE" once more denotes that the slopes of the supply equations will be revised when we revise the base values of the quantities and prices for the simulation (but using the same matrix of own- and cross-price elasticities of supply of components that was derived using the actual 2002 prices and quantities).

Supply and Demand for Fat and Non-Fat Components in Global "Regions"

As noted above, we represent the world with five regions, comprised of (a) the United States (U), (b) Australia (A), (c) other trade-exposed countries with complete price transmission – basically, New Zealand (Z), (d) somewhat trade-exposed countries (R), having partial but incomplete price transmission, and (e) other countries (O) with zero price transmission and essentially closed borders for market response to changes in world prices for dairy products.

For the purposes of the model we have to take account of the fact that some of the countries in the trade exposed group (A, U, Z, and R) have transactions with the non-trade-exposed countries (O), which we treat as fixed elements of managed trade for the analysis. These fixed quantities must be dealt with as an element of the quantity market-clearing conditions in the trade-exposed group, but the non-trade-exposed countries otherwise do not play any role in the model, since their internal prices and transactions with the trade-exposed countries are treated as fixed and exogenous for the analysis. Hence, the model includes supply and demand equations for fat and non-fat components of milk for each of four regions, and a set of market clearing conditions for prices and quantities which reflect (a) some fixed quantities traded between counties in region O and the trade-exposed countries (in regions A, U, Z and R), but zero price transmission and hence no changes in quantities traded between O and the other regions, (b) incomplete price transmission between Australia and the countries in region R characterized as having incomplete price transmission (R), and (c) complete price transmission between Australia (A) and the United States (U) and between Australia and New Zealand.

The supply and demand equations take the same form as their counterparts derived for the United States above, and are to be parameterized accordingly. The price slopes of the linear supply and demand equations are based on matrices of elasticities of domestic supply and demand for fat and snf components, combined with base values for prices and quantities of fat and snf components supplied and demanded. For different scenarios, the base values of prices and quantities may change, but the matrices of elasticities are to be based on some preliminary computations with contemporary data and held constant across scenarios. Results of a full range of sensitivity analysis across elasticity scenarios are available from the authors.

For any region, K (K = A, U, Z, or R) the equations for domestic supply and demand for fat and non-fat components of milk and dairy products are given by

Demand

(36) $$F^{DK} = \left(F^{DK}\right)^{BASE} + \alpha_{ff}^{K} dW_f^K + \alpha_{fn}^{K} dW_n^K$$

(37) $$N^{DK} = \left(N^{DK}\right)^{BASE} + \alpha_{nf}^{K} dW_f^K + \alpha_{nn}^{K} dW_n^K$$

Supply

(38) $F^{SK} = \left(F^{SK}\right)^{BASE} + \beta_{ff} dW_f^K + \beta_{fn} dW_n^K$

(39) $N^{SK} = \left(N^{SK}\right)^{BASE} + \beta_{nf} dW_f^K + \beta_{nn} dW_n^K$

The parameters (own- and cross-price slopes) of the demand equations are defined in terms of the elasticities of demand for components in region K, as follows

(40) $$\begin{pmatrix} \alpha_{ff}^K & \alpha_{fn}^K \\ \alpha_{nf}^K & \alpha_{nn}^K \end{pmatrix} = \begin{pmatrix} \eta_{ff}^K \left(\dfrac{F^{DK}}{W_f^K}\right)^{BASE} & \eta_{fn}^K \left(\dfrac{F^{DK}}{W_n^K}\right)^{BASE} \\ \eta_{nf}^K \left(\dfrac{N^{DK}}{W_f^K}\right)^{BASE} & \eta_{nn}^K \left(\dfrac{N^{DK}}{W_n^K}\right)^{BASE} \end{pmatrix}$$

The U.S. elasticities of demand for components are defined using 2002 data for prices and quantities produced and consumed, and elasticities of demand for products, according to:

(41) $$\begin{pmatrix} \eta_{ff}^U & \eta_{fn}^U \\ \eta_{nf}^U & \eta_{nn}^U \end{pmatrix} = \begin{pmatrix} \sum_{i=1}^{5} \eta_{ii} \frac{W_f F_i}{P_i X_i} \frac{F_i}{F} & \sum_{i=1}^{5} \eta_{ii} \frac{W_n N_i}{P_i X_i} \frac{F_i}{F} \\ \sum_{i=1}^{5} \eta_{ii} \frac{W_f F_i}{P_i X_i} \frac{N_i}{N} & \sum_{i=1}^{5} \eta_{ii} \frac{W_n N_i}{P_i X_i} \frac{N_i}{N} \end{pmatrix}$$

It is assumed that the corresponding elasticities for the other regions will be similar, and the same values are applied throughout for every region in every time period.

The region-specific parameters (own- and cross-price slopes) of the supply equations are defined in terms of the elasticities of supply for components, and their underlying determinants, as follows

(42) $$\begin{pmatrix} \beta_{ff}^K & \beta_{fn}^K \\ \beta_{nf}^K & \beta_{nn}^K \end{pmatrix} = \begin{pmatrix} s_f^K \varepsilon^K \left(\dfrac{F^{SK}}{W_f^K}\right)^{BASE} & s_n^K \varepsilon^K \left(\dfrac{F^{SK}}{W_n^K}\right)^{BASE} \\ s_f^K \varepsilon^K \left(\dfrac{N^{SK}}{W_f^K}\right)^{BASE} & s_n^K \varepsilon^K \left(\dfrac{N^{SK}}{W_n^K}\right)^{BASE} \end{pmatrix}$$

where the superscript "BASE" once more denotes that the slopes of the supply equations will be revised when we revise the base values of the quantities and prices for the simulation (but using the matrix of elasticities derived using 2002 prices and quantities).

Market-Clearing Conditions

Quantity market clearing conditions require that total production of fat equals total consumption of fat, globally, and similarly, total production of snf equals total consumption of snf. The structure of the supply side of the model assures that this restriction on the markets for the components means that the total supply of raw milk also equals the total demand for raw milk. Algebraically, this means that:

(43) $F^{SA} + F^{SU} + F^{SZ} + F^{SR} - F^{DA} - F^{DU} - F^{DZ} - F^{DR} = \bar{F}^{O}$, and

(44) $N^{SA} + N^{SU} + N^{SZ} + N^{SR} - N^{DA} - N^{DU} - N^{DZ} - N^{DR} = \bar{N}^{O}$,

where $\bar{F}^{O}$ and $\bar{N}^{O}$ are the net imports of fat and non-fat solids by region O from the countries included in the other regions of the model.

The market-clearing conditions on prices entail linkages in terms of both the initial prices and how they differ among countries, and in terms of the changes in prices and how they are transmitted between pairs of countries. Our basic premise is that initially the internal U.S. price is higher than that for the comparable Australian product at the U.S. border, for both fat and snf. Initially we have the following conditions for prices among the different markets:

(45) $W_f^U = W_f^A + T_f^U; \quad W_f^Z = W_f^A; \quad W_f^R = (1-\lambda_f^R)W_f^A + T_f^R$, and

(46) $W_n^U = W_n^A + T_n^U; \quad W_n^Z = W_n^A; \quad W_n^R = (1-\lambda_n^R)W_n^A + T_n^R$,

where T^K is the size of the price wedge between region K and world-trading prices, at the U.S. border, for the relevant milk component. We assume price equality between

Australia and New Zealand, reflecting their bilateral free-trade agreement and the fact that they compete directly in third countries (though there may still be rents from particular markets, which we might reasonably treat as being outside the model – that is we do not identify who receives the rents created by price distortions and managed trade). We allow that prices in Australia and New Zealand may differ from those in the other countries in region R, both in absolute terms and as a proportion of the price, as a device to capture both price wedges and partial but incomplete price transmission.

Free trade between the United States and Australia is modeled by eliminating the wedge between the United States and Australian prices but not eliminating the other wedges. Hence the final conditions for market clearing include the following:

(47) $W_f^U = W_f^A; \quad W_f^Z = W_f^A; \quad W_f^R = (1-\lambda_f^R)W_f^A + T_f^R,$

(48) $W_n^U = W_n^A; \quad W_n^Z = W_n^A; \quad W_n^R = (1-\lambda_n^R)W_n^A + T_n^R.$

Once we choose a value for the price transmission parameter, say λ_n^R, the value of the corresponding price wedge parameter, T_n^R, is determined, given our observations of the prices, W_n^R and W_n^A. A larger value of λ_n^R implies a smaller degree of price transmission and a correspondingly large value of the absolute price wedge, T_n^R for a given pair of prices; when λ_n^R takes a value of 1, price transmission is non-existent.

Having parameterized the model using the initial prices, given by equations (45) and (46), and the quantities embodied in the quantity clearing conditions given by equations (43) and (44), we can then solve for the new values of prices and quantities implied by the same quantity clearing conditions (equations (43) and (44)) and the alternative price conditions, from equations (47) and (48).

3. Trade Scenarios, Simulation Results, and Interpretations

We use this model to simulate the impact of the United States opening its borders to imports from Australia, while retaining existing trade barriers against imports from other countries. In practice, however, we do not model bilateral flows, and the model results could imply bilateral quantity flows that are consistent with more-general liberalization since we have free bilateral arbitrage between Australia and the United States and between Australia and countries in region (Z), in particular New Zealand. Consequently, we imposed an additional constraint, such that, compared with the relevant baseline, as a response to the AUS-FTA, total U.S. imports from all sources cannot increase by more than Australia's total exports to all destinations. The equilibrium trade flows were such that this constraint was not even close to binding in any case.

Baseline Scenarios

We have referred in several places to alternative baselines for the simulation, and the use of "base" values of quantities and prices to parameterize the slopes of the supply and demand equations, where the "base" values may vary among time periods and scenarios studied. Our model examines the effect of the AUS-FTA in 2009 and 2014. Thus we require projections of prices and quantities for milk fat and snf in these two years for each region in the model. Projected baseline price data for 2009 and 2014 are presented in Table 1 and Table 2; quantity data for 2009 and 2014 are documented in Table 3 and Table 4. The baseline projections are discussed in detail in Alston et al.

Results for Various Policy Scenarios

Table 6 shows the results for the simulated effects of the AUS-FTA in 2009 under various assumptions. The results in Table 6 show that in all cases analyzed – in terms of combinations of scenarios and parameter values – the AUS-FTA would cause an increase in U.S. imports of both milk fat and snf, and a consequent lowering of U.S. prices of both fat and snf as well as U.S. production of fat and snf.

The first column in Table 6 shows the results for the base case, with a moderate pace of liberalization that would achieve complete bilateral free trade by 2009. The results indicate a modest impact of the AUS-FTA on U.S. production of milk (and fat and snf, which are produced in fixed proportions in milk), a decrease of 2.0 percent. This is associated with a 2.0 percent decrease in the price of raw milk – the percentage changes in price and quantity are equal given the U.S. supply elasticity of 1.0. Both fat and snf imports would increase (by 3.0 and 2.6 percent as a share of U.S. consumption), with corresponding reductions in prices of 5.7 percent for fat and 0.1 percent for snf, with these differences primarily reflecting the relatively large initial price wedge for fat.

The next three columns show the corresponding results when we allow for a lower or higher degree of trade exposure of countries in the rest of the world, and when we allow for a more elastic supply of milk in Australia and New Zealand. Across the scenarios, the results vary in the expected fashion. Reducing the extent to which the ROW markets are trade exposed reduces the price and quantity impacts in the United States, and increasing the extent of ROW trade exposure has the converse effect. (Reducing the trade exposure of the ROW reduces the extent to which Australia can transmit higher prices into ROW markets and divert supply from the ROW to the United States, thus reducing the effective elasticity of supply from Australia to the United States). Increasing the elasticity of supply in Australia and New Zealand is another way of making the effective elasticity of supply from Australia to the United States greater and this also makes the price and quantity effects in the United States greater.

Our base case allows for implementation of the AUS-FTA by 2009. When we allow for a slower rate of elimination of U.S. barriers to imports from Australia under the AUS-FTA (free trade by 2014), we have only partial liberalization by 2009, and the fifth column of numbers in Table 6 shows the results for this case. Here the effects of the AUS-FTA by 2009 are generally in the same direction but much smaller than (on the order of one-tenth of) the effects of a complete liberalization of bilateral trade in dairy products in the same year. The effects on the relative prices of fat and snf in the United States are qualitatively different when the liberalization consists of allocation of expanded U.S., import quotas to Australia, reflecting the specific content of those product quotas. Hence, while our results indicate that the price of fat would fall by 3 percent (compared with 7.5 percent with complete liberalization), the price of snf would rise by 1.6 percent (compared with a 0.1 percent fall under complete liberalization), and as a result the raw milk price would fall by only 0.3 percent. The rise in the price of snf may seem counterintuitive. It comes about because fat and snf are produced jointly. A reduction in U.S. production of milk implies reductions in both fat and snf production, of which, under the partial liberalization scenario, the fat is more-than fully replaced with imports while the snf is less-than fully replaced with imports.

Under the assumption of a slow pace of liberalization, complete free trade would not be achieved in 2009, but it would be achieved by 2014. The second-last column in Table 6 shows the results in the base case, which are quite similar to those in the first column of numbers representing complete bilateral liberalization in 2009. This reflects the fact that the simulations were based on the same extrapolated price wedges, modest differences in baseline quantities and prices between 2009 and 2014, and relatively small changes in response to the AUS-FTA.

AUS-FTA with Doha WTO Agreement

The final column of Table 6 shows our results for the implementation of the AUS-FTA in 2014 after having implemented a new WTO agreement (the WTO agreement would not have any impacts on the 2009 analysis of the AUS-FTA). The anticipated WTO agreement is expected to bring about significant adjustments in world markets for dairy products, in particular some lowering of U.S. internal prices as a reflection of expanded import quantities, but more importantly an increase in world market prices reflecting a general opening of some import markets and a reduction in the use of export subsidies. Together these changes will substantially reduce the price wedge between Australia and the United States, greatly reducing the work remaining to be done in response to the AUS-FTA. These expectations are reflected plainly in the results in the last two columns of Table 6. The results for the "with-WTO" scenario are an order of magnitude smaller than those for the "without-WTO" scenario. Across the various cases considered, the AUS-FTA implies only very small changes in U.S. prices and quantities – generally in the range of half of one percent or less – if a WTO agreement has already been implemented.

Implications of the AUS-FTA for U.S. Government Budget Costs and Removals

The United States uses a variety of government programs to provide income and price support to the U.S. dairy industry. The Milk Income Loss Contract (MILC) payment program that was initiated in 2002 pays farmers when the price of milk falls below a trigger level. The payment is available to all commercial dairy farmers, but only on the first 2.4 million pounds of milk production for any given farm each year. The government offsets 45 percent of the shortfall in a specific trigger price. The MILC payment rate per hundredweight in any month is equal to

0.45($16.94 – Boston Class minimum wholesale fluid milk price),

if the Boston Class minimum wholesale fluid milk price is less than $16.94; otherwise the MILC payment is zero.

Though the law specifies the Boston price, the payments are tied to national prices for manufactured milk products because the federal milk marketing order system sets the Boston Class 1 price to be equal to a base price, which depends directly on movements in manufactured milk product prices, the Class 1 mover, plus $3.25 per hundredweight. Since the projected Boston Class 1 prices are below the $16.94 specified in the MILC program, if it is still in force the program will offset some of the revenue loss from a lower milk price caused by the AUS-FTA. Given growth in the size of dairy farms over the next decade, and hence the shift in the distribution of production, the 2.4 million pound limit implies that the revenue loss resulting from the AUS-FTA will be about 20 percent less than that implied by the shifts in the all-milk price alone. This additional revenue would come directly from additional government budget costs of the MILC program. MILC program costs would therefore rise by a few percentage points.

Under the price support and the government purchase program for butter, skim milk powder (smp), and cheese, the government purchases manufactured milk products at stated purchase prices, which then become the approximate floor prices for those commodities. (We use the term approximate because, with transaction costs, quality differences, and other product specifications, some commercial manufactured products may trade at prices below the government purchase prices.) Currently the purchase prices are at $0.80 for smp, $1.27 for cheese and $1.10 for butter. These prices are used to support the farm price of raw milk at the legislated rate of $9.90. This government support price has declined substantially over the past two decades and has been periodically scheduled for elimination. Comparing the government purchase prices to the product prices in the tables, prices remain above the support prices in all our scenarios, such that the price support and purchase program is not triggered in either 2009 or 2014.

4. Conclusion

The U.S. import quantity changes implied by an AUS-FTA are derived from three sources: (a) modest production growth in Australia in response to increases in the price of milk facing Australian producers, (b) small reductions in consumption in Australia in response to these price increases, and (c) diversion of exported dairy products from other export markets when the U.S. market opens. The increase in U.S. imports in the base case of Table 6 imply that about one-third of the additional shipments to the United States derive from additional Australian exports (mostly new production) and about two-thirds derive from exports diverted from other markets. With an AUS-FTA in place, new exports to the United States comprise about one-third of all Australian exports and about one-fifth of Australian production. The U.S. market would become important for Australia, but exports to other markets would still be important as well.

The results for U.S. prices and quantities of milk indicate small effects from an AUS-FTA on the U.S. market (about 2 percent changes in both price and quantity of milk for the base case). These results also show a relatively small range of impacts given large changes in underlying parameters. For all these cases, including those from the scenario with the large price wedge, the impacts on the U.S. dairy industry are best characterized as modest compared with other price and policy changes in the United States. For example from 1981 to 1991 the support price for milk in the United States fell by 25 percent in nominal terms, and by more in real terms. The price support is now about $3.00 per hundred pounds of milk below where it was two decades ago, and still the United States government has been acquiring products under the price support program. Over the past four years, U.S. milk prices have been moved up and down by 25 percent or morefrom year to year. The 2 percent milk price change associated with an AUS-FTA is very small in comparison with milk price changes of these magnitudes. Furthermore, the MILC program has recently compensated producers with direct payments of more than $1.50 per hundredweight; much larger than the price changes contemplated under an AUS-FTA. And, of course, an AUS-FTA will be phased in over a 5 to 10 year period giving time for full adjustment to the anticipated changes. Over this time scale, productivity growth, regional adjustments, and other changes are likely to continue to transform the U.S. dairy industry in ways that are far more important than any contemplated changes under the AUS-FTA.

Table 1: *Product and Component Prices and Price Wedges, 2009*[1]

	Most Plausible Price Projections			Price Projections Based on FAPRI, 2003		
	U.S.	Australia[2]	Wedge	U.S.	Australia[2]	Wedge
			($/lb)			
Butter	1.16	0.88	0.24	1.39	0.80	0.59
Smp	0.84	0.84	0.00	0.81	0.80	0.00
Cheese	1.30	1.20	0.10	1.31	1.05	0.26
Fat[3]	1.30	1.00	0.30	1.53	0.76	0.72
Snf[3]	0.71	0.71	0.00	0.68	0.68	0.00

Table 2: *Product and Component Prices and Price Wedges, 2014*[1]

	Most Plausible Price Projections			Price Projections Based on FAPRI, 2003		
	U.S.	Australia[2]	Wedge	U.S.	Australia[2]	Wedge
			($/lb)			
Butter	1.20	0.97	0.23	1.46	0.83	0.63
Smp	0.97	0.84	0.00	0.81	0.80	0.00
Cheese	1.34	1.24	0.10	1.33	1.04	0.29
Fat[3]	1.36	1.06	0.30	1.61	0.82	0.79
Snf[3]	0.71	0.71	0.00	0.68	0.68	0.00

[1]For the "Projections Based on FAPRI, 2003" U.S. prices are for grade AA butter, grade A NFDM (smp), and 40 pound block cheddar, and projections are available from FAPRI (2003) in their baseline publication. Australian prices are from Dairy Australia and reflect four-year average export prices (1999-2002) in order to smooth exchange rate and other market fluctuations. These base prices are increased or decreased by the FAPRI percentage growth rates for Australian prices applied to each product from 2002 to 2014. The "Most Plausible Price Projections" adjust FAPRI 2003 projections for considerations such as U.S. trends in farm productivity, scale, and regional shifts and adjust Australian prices for the unusually low exchange rates observed in the 2001 to 2002 period.

[2]Whenever the U.S. price is above the Australian price, we add $0.05 per pound cost of transport to reflect cost of moving product from Australia to the United States, so that the prices are the opportunity cost of product in the U.S. market. This is reflected in the Australian prices of butter, cheese and fat shown in the table.

[3]Based on 0.8 lbs of fat per 1 lb of butter, and 0.99 lbs of snf per 1 lb of SMP using the equations in the text.

Table 3: *Base Production and Consumption Projections Used to Calibrate the Model, 2009*

	Trading Region			
	Australia (A)	United States (U)	New Zealand (Z)	ROW (R)[1]
Milk fat	(million pounds)			
Production	1,297	6,660	1,567	8,818
Consumption	527	6,899	164	9,788
Net Exports	770	(239)	1,403	(970)
Milk snf				
Production	2,714	15,660	3,279	19,841
Consumption	1,171	15,265	365	22,421
Net Exports	1,543	395	2,914	(2,580)

Table 4: *Base Production and Consumption Projections Used to Calibrate the Model, 2014*

	Trading Region			
	Australia (A)	United States (U)	New Zealand (Z)	ROW (R)[1]
Milk fat	(million pounds)			
Production	1,385	6,982	1,647	8,818
Consumption	534	7,190	172	9,788
Net Exports	842	(208)	1,475	(970)
Milk snf				
Production	2,900	16,417	3,446	19,841
Consumption	1,206	15,920	381	22,421
Net Exports	1,694	497	3,065	(2580)

[1]The region, R, does not include those countries for which price transmission from Australia and New Zealand would be negligible, which includes some important net importers. Consequently, net export totals do not sum to zero across regions.

Table 5: *Base Data Used to Calibrate the Model with WTO, 2014*

	Trading Region			
	Australia (A)	United States (U)	New Zealand (Z)	ROW (R)[1]
Milk fat	(million pounds)			
Production	1,855	6,915	2,267	8,818
Consumption	438	7,223	146	9,788
Net Exports	1,417	(308)	2,121	(970)
Milk snf				
Production	3,882	16,260	4,745	19,841
Consumption	1,079	15,963	359	22,421
Net Exports	2,803	297	4,386	(2580)
Prices	(cents per lb)			
Fat	1.530	1.570	1.530	1.545
Snf	0.840	0.840	0.840	0.840

[1]The region, R, does not include those countries for which price transmission from Australia and New Zealand would be negligible, which includes some important net importers. Consequently, net export totals do not sum to zero across regions.

Table 6: *Effects of the AUS-FTA on U.S. Dairy Prices and Quantities*

	Simulation						
	2009 Values					2014 Values	
		ROW Trade Exposure					
	Base Case	Low	High	Elastic Aust/NZ Supply	Australian Quota Expansion	Base Case without Doha Agreement	Base Case with Doha Agreement
Changes in U.S. fat production (mil lb)	-135	-117	-166	-168	-17	-160	-18.3
Percentage of base production (%)	*-2.0*	*-1.8*	*-2.5*	*-2.5*	*-0.3*	*-2.3*	*-0.3*
Changes in U.S. snf production (mil lb)	-318	-275	-391	-394	-40	-376	-42.9
Percentage of base production (%)	*-2.0*	*-1.8*	*-2.5*	*-2.5*	*-0.3*	*-2.3*	*-0.3*
Changes in U.S. fat imports (mil lb)	210	181	259	257	43	248	28.0
Percentage of base consumption (%)	*3.0*	*2.6*	*3.8*	*3.7*	*0.6*	*3.4*	*0.4*
Changes in U.S. snf imports (mil lb)	394	342	483	494	23	466	53.9
Percentage of base consumption (%)	*2.6*	*2.2*	*3.2*	*3.2*	*0.2*	*2.9*	*0.3*
Changes in U.S. price of fat (cents/lb)	-7.4	-6.3	-9.3	-8.6	-5.0	-8.8	-1.1
Percentage of base price (%)	*-5.7*	*-4.9*	*-7.1*	*-6.7*	*-3.0*	*-6.5*	*-0.7*
Changes in U.S. price of snf (cents/lb)	0.0	0.0	0.1	-0.2	1.3	0.1	-0.03
Percentage of base price (%)	*0.1*	*0.0*	*0.2*	*-0.2*	*1.6*	*0.1*	*-0.03*
Changes in U.S. quantity of milk (bil lb)	-3.7	-3.2	-4.5	-4.5	-0.46	-4.3	-0.50
Percentage of base production (%)	*-2.0*	*-1.8*	*-2.5*	*-2.5*	*-0.3*	*-2.3*	*-0.3*
Changes in U.S. price of milk ($/cwt)	-0.24	-0.21	-0.30	-0.30	-0.03	-0.28	-0.04
Percentage of base price (%)	*-2.0*	*-1.8*	*-2.5*	*-2.5*	*-0.3*	*-2.3*	*-0.3*

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Appendix. Specification of Parameters and Implementation of the Model

The parameters of the supply and demand equation for the four regions being explicitly modeled are defined by underlying elasticities of demand for dairy products, the elasticity of supply of raw milk, factors that define the quantities of the fat and snf components in raw milk and each of the individual dairy products, and the relevant set of "base" values of the prices and quantities of the dairy products and milk for the scenario in question.

Elasticities of Supply and Demand for Milk and Dairy Products

The literature includes a large number and considerable variety of estimates of elasticities of supply of milk and demand for dairy products, both in reports of econometric studies of supply and demand, and in reports of models used to quantify policy impacts. Some of the variation among the elasticity estimates reflects differences in the context to which they are meant to apply (i.e., different places, different products at different market levels, or different times) or the concept they are meant to represent (i.e., different lengths of run or different things being held constant), and some of it represents measurement error resulting from various sources.

In general it is surprisingly difficult to estimate meaningful elasticities of supply or demand for agricultural products, and the precision and robustness of the estimates is often low. The signal-to-noise ratio is low in the typically available time-series data, where changes in production or consumption attributable to prices are confounded with effects of other variables, and where the econometric identification of supply and demand factors is tricky. This is especially important for commodities for which prices are regulated and managed in ways such that relative price variation is constrained (e.g., among various dairy products when policies specify price differentials, and reflecting their use of a common input, milk). In addition, policy might play other roles in conditioning the data in ways that mean that the observations reflect both economizing responses of producers and consumers and the behavior of policymakers, such that the estimated relationships cannot be used to evaluate policy change (the Lucas critique; see Sumner and McDonald 2003). The estimation difficulties are more pronounced on the supply side, particularly because of dynamic responses which imply lags between observed price changes and their realized impacts, and the requirement to model decision-making under uncertainty and the formation of expectations; aspects which are particularly important for livestock products, where the production cycle is multi-year, and the dynamics are long-term.

Increasingly in agricultural policy models, the recognition of the limitations of econometric estimation has led to a greater emphasis on introspection and calibration approaches rather than placing reliance on the direct use of econometrically estimated elasticities. This is particularly so for analysis that proposes to evaluate policy changes of the types that would imply changes in markets outside the range of historical experience (i.e., of the types that would not be well reflected in an extrapolative approach), or where we want to measure long-run responses, and we recognize that the typical elasticity estimates are most likely at best to reflect only short- or intermediate-run responses. These observations are especially pertinent for the present context. We have in mind to simulate responses, over a comparatively long period of time, to policy changes that can be regarded as fully anticipated and permanent in nature. For this kind of policy change, we require long-run elasticities of the type that generally cannot be estimated directly, especially for livestock products. In addition, we have in mind to simulate policy change that goes outside the range of past policy change.

On the demand side, the literature includes estimates of elasticities of final consumer demand, or demand at the wholesale market level for individual dairy products – such as our product categories of fluid milk, cheese, butter, skim milk powder, and "other" – applicable to various countries and time periods. Such elasticities are sometimes estimated directly using either time-series data (e.g., Wohlgenant 1989) or using cross-sectional data (e.g., Heien and Wessells 1988), and sometimes are the result of calibration. The literature also includes estimated elasticities of aggregate demand for dairy products, or of the corresponding derived demand for milk used to produce them, both directly estimated or calibrated, and it includes elasticities of export as well as domestic demand in cases where the products are traded. While there are a great many estimates of the elasticity of demand for particular products in particular places (e.g., the elasticity of demand for fluid milk in New York state has been estimated many times, mostly in the context of studies of demand response to advertising), only a few studies have reported a mutually consistent and complete set of estimates of own- and cross-price elasticities of demand for the full set of dairy products. Huang (1985, 1993) provided two sets of estimates of elasticities of consumer demand for dairy products, within the context of a comprehensive set of elasticities of demand for all foods, which have been used in various policy models (e.g., Chavas, Cox, and Jesse 1998, Cox and Chavas 2001). However, Huang's elasticities, especially the more recent estimates, are not favored for the present purpose. In particular, the elasticity of demand for fluid milk seems implausibly low (at –0.04), and the other elasticities are also at the low end of the range.

Both Wohlgenant (1989) and Heien and Wessells (1988) obtained estimates of elasticities of demand for fluid milk closer to –0.6, amidst generally larger elasticities compared with Huang's, and we have more confidence in their elasticities.

Balagtas and Sumner (2003) reviewed the estimates of U.S. elasticities of supply and demand for milk and dairy products in the agricultural economics literature. They reported that estimates of the long-run elasticity of farm-level demand for fluid class milk range from –0.34 (Ippolito and Masson 1978) to –0.076, almost zero (Helmberger and Chen 1994), and that estimates of elasticities of farm-level demand for manufacturing milk range from –0.35 (Dahlgran 1980; Helmberger and Chen 1994) to –0.20 (Ippolito and Masson 1978). Heien and Wessells (1988) estimated own-price elasticities of retail demand of –0.63 for milk, –0.52 for cheese, and –0.73 for butter, somewhat larger than Huang's (1985) corresponding elasticities. Balagtas and Sumner (2003) opted for a value of –0.2 to represent the elasticity of national demand for manufacturing milk at the farm level, and they also used –0.2 to represent the corresponding elasticity of demand for milk for fluid use. They noted that these elasticities fall within the range of estimates in the literature, and suggested they would be appropriate for an intermediate time-horizon of 3-6 years.

The demand for dairy products is expected to be more elastic than the demand for milk, and we have in mind an even longer-run context than Balagtas and Sumner (2003) were using. We use a value of –0.5 to represent the most likely value of the own-price elasticity of demand for each of our product categories at wholesale, in-between the Heien and Wessells (1988) values of about –0.6 for retail elasticities, and the Balagtas and Sumner (2003) values of –0.2 for farm-level elasticities. As noted before, the cross-price elasticities are all assumed to be zero, which is in keeping with the literature although some studies identified some cross-price effects for some product categories (when products are more disaggregated this becomes more likely).

On the supply side there is less information available, and it is probably less directly useful. Balagtas and Sumner (2003) reported a range of supply elasticities for U.S. raw milk production relevant to an intermediate time horizon of 3-6 years in which to allow for adjustment of milk production through managed changes in herd size in response to an expected, permanent change in the relative price of milk. This concept of supply response is relevant for the present analysis although we would have in mind a longer run of 5-10 years rather than 3-6 years, and hence would have in mind a larger supply response elasticity. Balagtas and Sumner (2003) settled on a supply elasticity of 1.0, which was intermediate among the relevant estimates in the literature (Chavas and Klemme, 1986, 0.22 to 1.17; Cox and Chavas, 2001, 0.37; Ippolito and Masson, 1978, 0.4 to 0.9; Helmberger and Chen, 1994, 0.583; Chen, Courtney, and Schmitz, 1972, 2.53). In the analysis below, like Balagtas and Sumner (2003), we use 1.0 as our base estimate of the elasticity of supply of raw milk in the United States and region R. For Australia and New Zealand, where dairy is a larger share of total agriculture in the relevant regions, and is pasture-based and therefore land-constrained, our base elasticity is 0.6. We also try a value of 1.0 to reflect the higher end of the range for these countries.

Derived Elasticities of Supply and Demand for Fat and Nonfat Components

The own-price elasticity of domestic demand at wholesale is assumed to be –0.5 for each of the five categories of U.S. dairy products. Combining these elasticities of demand for products with the relevant information on composition of the products (in terms of their fat and nonfat components) and the 2002 data on U.S. consumption and prices of these components (discussed below), we derived the corresponding estimates of the elasticities of demand for components using equation (41):

$$(49) \quad \begin{pmatrix} \eta_{ff}^{U} & \eta_{fn}^{U} \\ \eta_{nf}^{U} & \eta_{nn}^{U} \end{pmatrix} = \begin{pmatrix} -0.19 & -0.12 \\ -0.09 & -0.24 \end{pmatrix}.$$

Similarly, on the supply side, using a supply elasticity of raw milk of 1.0, the U.S. component proportions of 3.7 percent butterfat and 8.7 percent solids not fat, and 2002 data on U.S. production and prices of fat and snf components of raw milk (discussed below), the matrix of U.S. component supply elasticities is given by

$$(50) \quad \begin{pmatrix} \varepsilon_{ff}^{U} & \varepsilon_{fn}^{U} \\ \varepsilon_{nf}^{U} & \varepsilon_{nn}^{U} \end{pmatrix} = \begin{pmatrix} 0.36 & 0.52 \\ 0.36 & 0.52 \end{pmatrix}.$$

The elasticities of supply and demand for components are approximately proportional to the underlying elasticities of supply of raw milk (1.0) and demand for dairy products (-0.5 in each case), so it is straightforward to examine the implications of alternative underlying elasticity assumptions. In the absence of complete, specific data on other regions needed to replicate these steps taken with the U.S. data, we assume the elasticities of demand for components for every region will be similar to those for the United States and we hold these values constant across the various simulations. On the supply side, however, we allow supply elasticities of milk and components to vary among regions, depending on the underlying elasticity of supply of milk. Specifically, in Australia and New Zealand we assume as our base case that the elasticity of supply of milk is less elastic, at 0.6, while it is 1.0 in the United States and the rest-of-the-world. A milk supply elasticity of 0.6 implies scaling down all the values in equation (50) by a factor of 0.6. Thus, for K = Z or A, we use as base values:

(51) $$\begin{pmatrix} \varepsilon_{ff}^{K} & \varepsilon_{fn}^{K} \\ \varepsilon_{nf}^{K} & \varepsilon_{nn}^{K} \end{pmatrix} = \begin{pmatrix} 0.22 & 0.31 \\ 0.22 & 0.31 \end{pmatrix}.$$

We also simulate the AUS-FTA using a less likely assumption that the supply elasticities are all equal at 1.0, for comparison.

Baseline Quantities: The Size of Region R

In addition to elasticities of supply and demand, as discussed and defined above, to parameterize our simulation model we require projected baseline values for prices, production, and consumption of fat and snf for each of the four trading regions, for each year we model (2009 and 2014), as well as the actual values for 2002, which we use to define the elasticities of supply and demand for fat and snf.

Quantity data on production, consumption, and trade of dairy products are available for the year 2002, and as projections for 2009 and 2014, for Australia, the United States, and New Zealand. These can be used to deduce the corresponding quantities of fat and snf given knowledge of the content of the products. Such data are not available for all of the other countries of the world, but for the purposes of the model we only need to know the quantities that are produced, consumed, and traded in aggregate by region R, which has restricted trade and is partially flexible in its relations with Australia and New Zealand. We do not require specifics on production and consumption in the other region, O, whose prices are fully insulated from world trading prices; but, to close the model, we do require information on net trade between each region in the model and region O.

We use data from United Nations, Food and Agricultural Organization FAO (2003), FAPRI (2003), and the USDA (2003) to calculate the production and consumption of dairy products in region R. The FAO presents data for production, consumption, and trade for raw milk and the four major dairy products. We begin with a region R defined to include all of Central America and the Caribbean, South America, and much of Asia, as well as half of Africa. China, India, Pakistan and Japan are excluded from region R because of their lack of price responsiveness or lack of connection to world dairy markets. Much of Africa outside South Africa, and a number of small markets that account for only about 10 million metric tons of milk production, are also left out of region R. According to the FAO database, region R then accounts for 100 million metric tons of raw milk production (almost 25 percent of total raw milk production in the world). The United States, Australia and New Zealand account for another 100 million tons and the rest is in region O and outside the market-driven part of world dairy trade.

Milk is about 4 percent fat and 9 percent snf in region R, and therefore region R produces about 4 million metric tons of fat and 9 million metric tons of snf. Converting to billions pounds of components yields production of 8.82 billion pounds of fat and 19.84 billion pounds of snf. We have no direct data on consumption in region R; however, we do have data showing that region R is a net importer. Net imports of fat in the form of butter, cheese, skim milk powder and whole milk powder are about 11 percent of production and net imports of snf are about 13 percent of production. Thus net imports are 0.97 billion pounds of fat and 2.58 pounds of snf, and consumption is about 9.79 billion pounds of fat and 22.42 billion pounds of snf.

Imputing Component Prices

While data on past prices and quantities of milk and dairy products are available for some countries, milk component prices are generally not directly observable, and are not typically reported in ERS or FAPRI projections and, therefore, must be imputed from the limited information that is available. We impute component prices in the four trading regions comprising our model using detailed U.S. information and evidence on international price wedges.

In the United States, federal and California milk marketing orders use formulae to calculate prices for fat and snf based on market prices for manufactured dairy products, product-specific costs of production, yield factors, and quantities of fat and snf (U.S. Department of Agriculture AMSc, 2003; California Department of Food and Agriculture, 2003b). To calculate the prices for fat and snf we use the federal marketing order formulae for Class IV (butter-powder) fat and snf. These are

(52) $W_f = 1.20(P_{butter} - 0.115),$ and

(53) $W_n = 0.99(P_{smp} - 0.140),$

where P_{butter} is the price of butter and P_{smp} is the price of skim milk powder (smp).[1] Using the FAPRI 2003 baseline data, the average U.S. prices in 2002 were $1.12 per pound for butter, and $0.94 per pound for smp. Using equations (52) and (53), the fat and snf prices associated with these product prices are $1.20 per pound for fat, and $0.79 per pound for snf. These are shown in Table 1.

Analogous calculations are not possible based on similar data on relationships for product and component prices for the other regions pertinent to our model. There are two

[1] Federal Class III (cheese) and California formulae would yield slightly different component prices; we use the federal Class IV formulae because they are relatively transparent. They also apply to a substantial amount of milk in the United States across many states.

ways to recover prices of fat and snf for these other regions. First, we may use available product prices and apply the same composition and manufacturing cost assumptions used for the United States to calculate the component prices implied by the product prices. Second, we may use the observed relationships between U.S. and world prices of dairy product prices, and the U.S. relationship between product prices and component prices. These methods yield equivalent results.

U.S. and Australian product prices differ by a per unit price wedge (τ_j for product j = butter, smp, cheese, etc.), as follows:

(54) $$P_j^U = P_j^A + \tau_j$$

The relationship between product prices and component prices in the United States is captured by equation (10) of our model, which is reproduced here and extended to apply also to Australia (i.e., with $k = U$ or A):

(55) $$P_j^k = g_j^k + f_j^k W_f^k + n_j^k W_n^k .$$

Substituting (54) into (55) yields:

(56) $$g_j^U + f_j^U W_f^U + n_j^U W_n^U = g_j^A + f_j^A W_f^A + n_j^A W_n^A + \tau_j .$$

Assuming make allowances and product-specific component quantities do not differ significantly across countries, equation (56) simplifies to

(57) $$f_j \left(W_f^U - W_f^A\right) + n_j \left(W_n^U - W_n^A\right) = \tau_j = P_j^U - P_j^A .$$

Since butter carries essentially no snf ($n_{butter} \approx 0$), and smp carries essentially no fat ($f_{smp} \approx 0$), the implied component wedges are:

(58) $$W_f^U - W_f^A = \frac{\tau_{butter}}{f_{butter}}$$

(59) $$W_n^U - W_n^A = \frac{\tau_{smp}}{n_{smp}}$$

Thus, based on U.S. component prices and the observed product prices or price wedges, we can recover Australian component prices.2 Based on Australian export data from Dairy Australia these component prices are as shown in Table A-1. In order to reduce the influence of extreme values of the exchange rate between the U.S. dollar and the Australian dollar, and given fluctuations in world dairy product prices, we have used a four-year average of Australian export prices to represent the Australian price over 1999-2002. However, this was a period of historically high values of the U.S. dollar and low values of the Australian dollar.

[2] Although we use only butter and smp to calculate component price wedges, the results are also reasonably consistent with the observed cheese price wedge in 2002. One pound of cheese contains approximately 0.31 pounds of fat, and 0.33 pounds of snf, so that the implied price wedge for cheese is $0.19 per pound (= 0.31 x 0.46 + 0.33 x 0.15). The difference between this imputed cheese price wedge and the observed wedge ($0.18 per pound) may be because of differences between U.S. and Australian make allowances, or differences between shipping costs of various products.

Table A-1: *Dairy Product and Component Prices, 2002*

	Wholesale U.S.[1]	Australian Export[2]
	($/lb)	
Butter	1.12	0.71
Smp	0.94	0.75
Cheese	1.20	1.02
Fat[3]	1.20	0.71
Snf[3]	0.79	0.60

[1]U.S. prices are for Grade AA Butter, Grade A NFDM, and 40# Block Cheddar contracts traded; available from FAPRI (2003) in their baseline publication.

[2]Australian export prices are from Dairy Australia and reflect four-year average export prices (1999-2002) in order to smooth exchange rate and other market fluctuations.

[3]Based on 0.8 lbs of fat per 1 lb of butter, and 0.99 lbs of snf per 1 lb of SMP using the equations in the text.